Department of **Employment, Economic Development and Innovation**
Agri-Science Queensland

The Wambiana grazing trial

Key learnings for sustainable and profitable management in a variable environment

1 November 2011

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MLA Meat & Livestock Australia | Queensland Government

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Acknowledgments

We are deeply grateful to the Lyons family of 'Wambiana' and the Grazier Advisory Committee for their continued interest, guidance and support in running the trial.

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1. A brief summary of the Wambiana trial

1.1 Purpose of trial

Rainfall variability is a major challenge to sustainable and profitable beef production in northern Australia. While grazing management strategies to cope with this variability do exist, they have not been widely adopted. This is partly because there is little data on how these strategies perform relative to existing management.

A major problem is the perception that recommended strategies are not profitable and that managers need to stock relatively heavily to be financially viable.

The Wambiana trial was established in December 1997 near Charters Towers to objectively test how a range of grazing strategies cope with climate variability. To ensure relevance to the grazing industry, the trial was run in close association with a grazier advisory committee. Trial paddocks contained a range of soil types to reflect conditions in large, commercial paddocks.

The different grazing strategies tested were:

1. Heavy stocking (HSR) stocked at twice the long-term carrying capacity (LTCC) of the site.
2. Moderate stocking (MSR) stocked at the LTCC.
3. Variable stocking (VAR) with stocking rates adjusted annually in May based on forage availability.
4. Southern Oscillation Index (SOI)—variable strategy with stocking rates adjusted annually in November according to forage availability and the SOI.
5. Rotational wet season spelling (R/Spell) coupled with moderate-heavy stocking.

Strategies were compared in terms of their effects on animal production, economic performance and land condition. Collaborative work with other agencies was also done to compare how these strategies affected biodiversity, soil health, soil carbon and grazing behaviour.

Rainfall varied sharply over the trial period from some of the wettest to some of the driest years on record. While several of the observed trends in animal production and pasture composition at the trial are expected, a number of unexpected results and novel interactions have been recorded as the long-term effects of the different treatments have emerged.

A summary of the key findings and principles from the trial covering the 13 years to date are presented overleaf. Further detail is provided in subsequent sections. The publication concludes with some key learnings and management guidelines for grazing in a variable climate.

1.2 Key learnings summary

- Heavy stocking (HSR) made the least profit and caused degradation to C- condition pastures. Although it made a profit in individual wet years, in drier years it was unprofitable. It also reduced marketing and pasture management options and incurred far greater costs, such as drought feeding and reduced stocking rates, than the other strategies.
- Moderate stocking (MSR) at or near LTCC generated far more profit in the longer term than the HSR and was as profitable as the more complicated VAR and R/Spell strategies. The MSR maintained pasture in B+ condition, despite severe drought, and together with the R/Spell strategy, resulted in the best pasture and land condition after 13 years.
- Variable stocking (VAR) made as much profit as the MSR, but was riskier and profit was more variable. After 13 years, pasture condition (B-) was also slightly poorer, relative to the MSR. This was a persistent effect of very heavy stocking rates in the VAR strategy preceding and going into the 2002–03 drought.
- Wet season spelling (R/Spell) in a 3-paddock system, with light to moderately heavy stocking, maintained pastures in B+ condition and was nearly as profitable as the MSR. The potential for wet season spelling to sustain higher utilisation rates and produce higher profits than moderate stocking on its own was not clarified in this trial.
- Monitoring and adaptive management are essential for managing grazing in an unpredictable and variable environment.

In conclusion all strategies tested in the trial had deficiencies. We suggest that an optimal strategy would be based on moderate stocking at or about long-term carrying capacity and include some flexibility in stocking rates, wet season spelling, control of area selective grazing and periodic fire to control woodland thickening.

1.3 Results summary

- Selective grazing of different land types and of patches within these land types occurred irrespective of the stocking rate applied.
- Rainfall largely drives year-to-year variation in pasture mass and ground cover, but management also played a significant role.
- Perennial grasses like desert bluegrass were far less sensitive to rainfall variation than annuals or the weaker perennial grasses like cotton panic. Maintaining a healthy perennial pasture is therefore essential for efficient production.
- Pasture condition, ground cover and pasture mass declined as average pasture utilisation rates increased. However, the timing of utilisation was also important, with heavy utilisation leading into drought having a persistently negative effect on pasture composition.
- Wet season spelling increased the abundance of important perennial grasses like desert bluegrass and maintained pastures in B+ condition. The effects of wet season spelling on pasture condition were negligible in dry years.
- Individual live weight gains (LWG) were greatest at lighter stocking rates. This, together with superior body condition, resulted in a higher carcass value at the meatworks.

- Heavy stocking generally gave the greatest animal production per unit area but this was only achieved through the use of drought feeding in dry years.
- Heavy stocking was only profitable in good rainfall years, but profitability decreased significantly in drier years, due to higher costs and reduced product value.
- Heavy stocking reduced ground cover, which directly increased the number and intensity of run-off events and the loss of sediment and nutrients.
- Fire had a big effect on woodland structure and caused a significant shift to smaller size classes but had little apparent effect on tree density. Carissa ovata cover was also reduced but this effect was relatively short lived (‹2 years).

2. The Wambiana trial

2.1 Introduction and rationale

Cattle production in northern Australia has many challenges, including the significant variation in rainfall and hence, pasture growth. This makes it difficult to consistently match stock numbers with available pasture, especially given that most production systems are not suited to having large variations in cattle numbers between years. In dry years, overgrazing occurs unless stock numbers are reduced. This can result in major economic losses due to the costs of survival feeding, forced sales and agistment. Low rainfall and overgrazing also leads to land degradation and increased erosion. Such changes can occur very rapidly, producing persistent, if not irreversible, decline in the land's capacity to grow useful perennial pasture and carry cattle.

Rainfall variability is a major challenge to the sustainable and profitable management of grazing lands in northern Australia.

Research from different locations in Queensland (Gillard 1979; Orr et al. 2010), as well as overseas research (Danckwerts et al. 1993), shows that stocking rate is the most important management factor affecting pasture condition and animal production. A number of grazing management strategies that focus on stocking rate are accordingly recommended to manage for rainfall variability. For example, moderate stocking at long-term carrying capacity reduces exposure to drought. Alternatively, variable stocking in line with available pasture should avoid overgrazing in dry years but allow the manager to take advantage of good rainfall years. Strategies involving wet season spelling are also recommended as are variable strategies that use seasonal climate forecasts such as the Southern Oscillation Index (SOI) to make stocking rate adjustments.

These recommendations are logical and are supported by case studies (Landsberg et al. 1998 and Mann 1993), and limited available research. For example, the Meat and Livestock Australia (MLA) EcoGraze project (Ash et al. 2011) near Charters Towers, clearly showed that light (25%) pasture utilisation rates or moderate (50%) utilisation rates with annual wet season spelling, maintained or improved pasture condition. In contrast, heavy (75%) utilisation rates or moderate utilisation rates without spelling, led to pasture degradation and a major loss of productive capacity.

There has been no objective comparison of the full financial and land condition impacts of the recommended management strategies relative to more widely applied systems, such as constant heavy stocking. Most research to date has been conducted in relatively small (<20 ha), uniform paddocks rather than in larger, more diverse paddocks which are more representative of commercial reality.

There is therefore a lack of data on the profitability and sustainability of these recommended strategies to manage for rainfall variability, particularly at a scale relevant to commercial conditions. This lack of data makes it difficult for producers to assess the performance of recommended strategies relative to current management and has directly hindered the adoption of better management strategies by the grazing community.

The Wambiana trial started in 1997 in response to this lack of data. Its basic intent was to directly compare different grazing strategies under the same rainfall and on the same soil types and to generate hard data upon which graziers could base their management.

Wambiana trial objective

Test the ability of different grazing strategies and how they cope with rainfall variability in terms of their effects on pasture condition, animal production, profitability and water quality.

2.2 How the trial was conducted

2.2.1 Site description

The trial is located 70 km south of Charters Towers on Wambiana, a commercial cattle property owned by the Lyons family. The site was in fair to good pasture condition (B condition) when the trial started. Average long-term annual rainfall for 'Trafalgar', 17 km north west of the site is 643 mm, but annual rainfall is highly variable ranging from 207 mm to 1409 mm.

The vegetation is savanna woodland (forest country) and contains a mixture of Reid River box (*Eucalyptus brownii*) on texture-contrast soils (sodosols), silver-leaf ironbark *(E. melanophloia)* on yellow-brown earths (kandosols) and brigalow (*Acacia harpophylla*) on heavy clays (vertosols and grey earths). The soils are relatively infertile and generally phosphorous (P) deficient with a range from approximately four to eight parts per million. A patchy understorey of currant bush (*Carissa ovata*) also occurs on the sodosols and heavy clays. The pasture is dominated by native grasses such as desert bluegrass (*Bothriochloa ewartiana*), golden beard grass (*Chrysopogon fallax*), wiregrass (*Aristida*), black speargrass (*Heteropogon contortus*), Queensland bluegrass (*Dicanthium sericeum*) and silky browntop (*Eulalia aurea*), as well as a range of annuals, weaker perennial grasses and forbs.

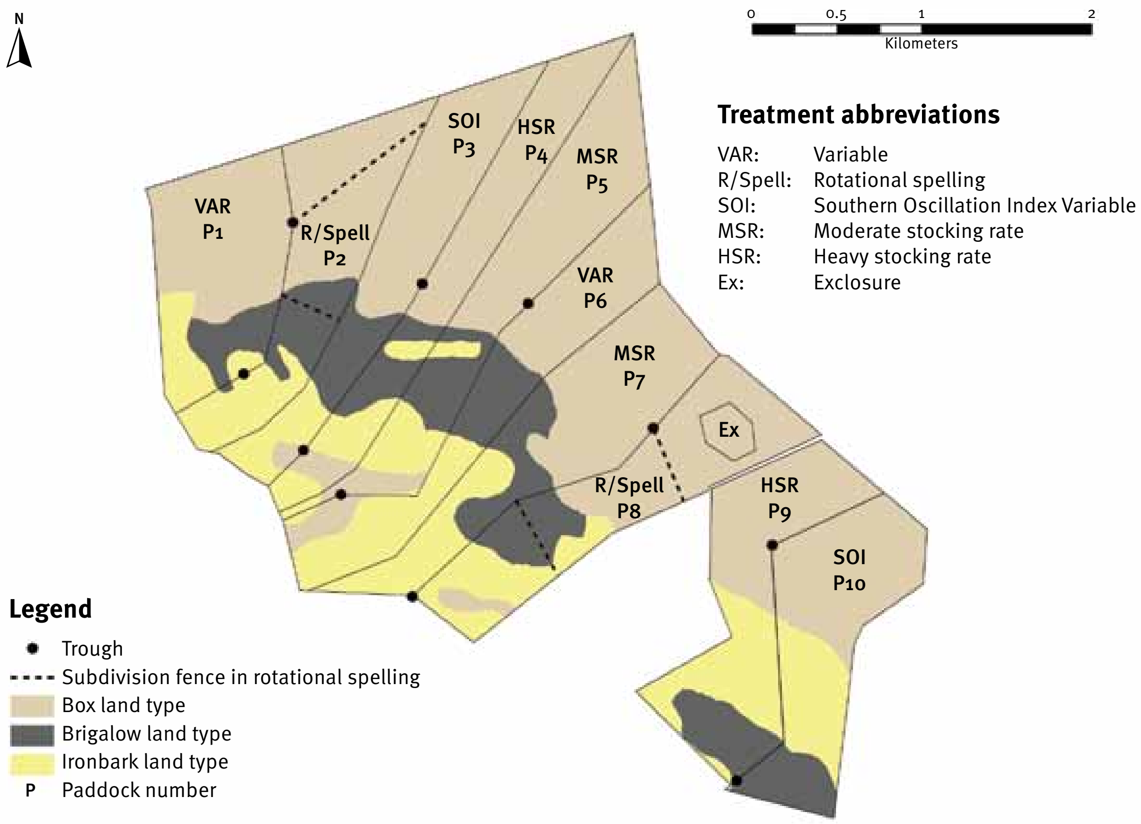


Figure 1: *Layout of paddocks, associated grazing strategies and water points across the three major soil-vegetation associations at the Wambiana grazing trial.*

The 1040 ha trial area is divided into ten paddocks ranging in size from 93 to 115 ha i.e. the five grazing strategies are replicated twice (see figure 1). Paddocks are fenced so that the proportion of the main soil types was similar in each paddock: box (55%), ironbark (25%) and brigalow-box (20%). This design was used to simulate the complexity in larger commercial paddocks where cattle have access to a range of soil-vegetation associations.

2.2.2 Treatments and stocking rates

Five grazing strategies that were either current practice and/or recommended for managing for climate variability were chosen for testing (for more detail see O'Reagain et al. 2009). All reflect an underlying management philosophy and approach to climate variability. These strategies and their approximate stocking rates are as follows:

- *Moderate stocking (MSR)*—relatively constant stocking at the calculated LTCC of the site of approximately 8–10 ha per adult equivalent (AE). (AE defined as a 450 kg steer).

  Management philosophy: conservative stocking rates reduce exposure to drought, minimise years in which a feed deficit will occur and maintain land condition.

- *Heavy stocking (*HSR)—relatively constant stocking at twice the LTCC, that is, approximately 4–5 ha/AE. However, in May 2005, the HSR stocking rate had to be reduced to 6 ha/AE due to ongoing feed shortages in the treatment. The full stocking rate was restored in May 2009.

  Management philosophy: high stocking rates are required for profitability with the increased drought risk to be managed with drought feeding*;* the effects of heavy grazing in drought years are presumed to be short term with recovery occurring in better seasons.

- *Variable stocking (*VAR)—stock numbers adjusted annually at the end of the wet season (May) according to total standing dry matter (TSDM) of the pasture (range: 3–12 ha/AE).

  Management philosophy: annual adjustment of stocking rates to match feed availability minimises the risk of overgrazing and feed deficits in dry years, but also allows the full economic benefits of good rainfall years to be captured.
- *Southern Oscillation Index* (SOI)—variable strategy with stock numbers adjusted annually at the end of the dry season (November) according to pasture TSDM and SOI-based climate forecasts for the next wet season (range: 3–12 ha/AE).

  Management philosophy: as for the VAR strategy but the use of the SOI should allow proactive rather than just reactive adjustment of stocking rates.
- *Rotational wet season spelling (*R/Spell*)*—relatively constant stocking rate at about 50% above LTCC with a third of the area spelled annually during the wet season, from approximately November to May, on a rotational basis. Initially stocked at 7–8 ha/AE but reduced to 10 ha/AE in November 2003 due to the combined effects of fire in 2001 and low follow-up rainfall (see section 2.3.4). Stocking rates in the R/Spell have been gradually increased in later years as rainfall improved.

  Management philosophy: spelling buffers the effects of rainfall variability on fodder availability and could allow increased rates of pasture utilisation without causing pasture degradation. Spelling also allows the use of fire for woodland and pasture management.

Wambiana treatments and approximate stocking rates:

- **Moderate stocking rate**—relatively constant stocking at 8–10 ha/AE*.
- **Heavy stocking rate**—relatively constant stocking at 4–5 ha to May 2005; thereafter stocked at 6/AE until May 2009 when stocking rates were returned to 4 ha/AE.
- **Variable stocking**—stocking rates adjusted upwards or downwards in May based on end of wet season feed availability (3–12 ha/AE).
- **SOI variable stocking**—stocking rates adjusted upwards or downwards in October based on feed availability and SOI forecasts for the next wet season (3–12 ha/AE).
- **Rotational wet season spelling**—spell a third of the paddock each wet season; relatively constant stocking at 7–8 ha until November 2003 and at 8–10 ha/AE thereafter.

**1 AE = 1 animal equivalent or 450 kg steer.*

2.2.3 Cattle management

Experimental animals were Brahman X steers between 18 to 30 months old. There were 11–35 animals per paddock depending upon treatment. Cattle remained on the trial for two years. Animal husbandry follows standard industry practice and was based upon advice of the grazier advisory committee. From 2003 onwards, cattle were supplemented with a dry season urea (32%) lick and a wet season phosphorous (14.76% P; 21.87% urea) lick. Animals were vaccinated annually against botulism and in later years, 3-day fever. *Compudose* (Dow-Elanco) hormone growth promotants were used in all years after 2003.

Molasses and 8% urea (M8U) drought survival feeding (with protein meal added in severe droughts) had to be provided to the HSR in the late dry seasons of 2003–04, 2004–05, 2005–06 and 2006–07 due to extremely low pasture mass (<300 kg/ha) and poor animal condition. In November 2004 in particular, conditions were so bad that steers were removed from one of the HSR paddocks for three months.

Main data collected at the Wambiana trial:

- cattle weight changes, condition score, frame growth
- diet quality via faecal near infra-red spectroscopy (NIRS)
- supplementation and drought feeding costs
- carcass grades and meatworks price
- pasture mass, species composition and ground cover
- rainfall, run-off and soil loss
- fire effects on woody plant survival
- pasture growth and rainfall relationships
- land type selection and grazing distributions

Other

- nutrient inputs via tree litter
- decomposition rates of tree and grass litter
- soil health and rainfall infiltration rates (CSIRO)
- faunal biodiversity (CSIRO)
- grazing effects on soil carbon (DERM)

2.2.4 The grazier advisory committee

A 10-person grazier advisory committee (GAC), comprised of graziers from across the Dalrymple shire, was established to advise on trial management. This maximised the trial's relevance to the grazing industry and ensured it reflected current industry practices. The GAC has been critical to the long-term success of the trial, advising on matters such as stocking rates, burning, supplementation and animal husbandry practice. The GAC's input and discussion has also provided a major learning experience for all involved.

3. Rainfall, stocking rates and pasture utilisation

3.1 Rainfall over the trial period

The first four years of the trial were relatively wet, but from 2000–01 onwards, conditions were a lot drier with six successive seasons of poorly distributed, below average rainfall (see figure 2). The 2002–2003 dry season was particularly dry with virtually no rain for 11 months, leading to the death of many grass tussocks. When the rains finally fell in late February 2003, army worms (*Leucania separata*) caused substantial pasture damage, particularly on the box country.

Rainfall in 2005–06 (469 mm) was also below average but was well distributed. Conditions improved substantially in later years with 2007–08 and 2008–09 the fourth and fifth wettest years on record respectively. These latter years were also unusual with good dry season rainfall.

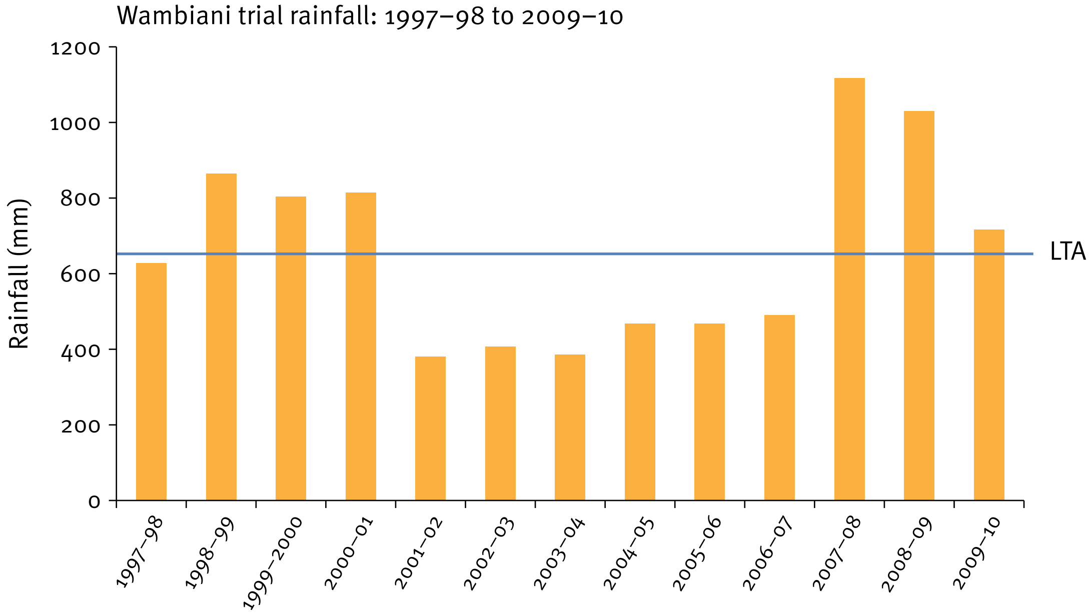


Figure 2: *Annual rainfall recorded between 1997–98 and 2009–10 at the Wambiana grazing trail and long-term average rainfall (LTA) for the area.*

3.2 Stocking rates

In the MSR strategy, stocking rates were relatively constant at between 8 to 10 ha/AE in most years (see figure 3). In the HSR, stocking rates were markedly higher for the first eight years at around 4 to 5 ha/AE. However, in May 2005 stocking rates in the HSR had to be cut to about 6 ha/AE due to the scarcity of forage in this treatment. HSR stocking rates were restored back to their former level (4 ha/AE) in May 2009 following good seasons in 2007–08 and 2008–09. Previous experience and the decline in pasture composition detailed in later sections suggest that it is unlikely that this stocking rate will be able to be maintained when drier years return.

A note on trial stocking rates

At the start of the grazing year on 1 June, paddock stocking rates were set based on the expected average mass of the experimental animals over the year (assumed to be their initial weight plus 50 kg). However, due to rainfall differences, the stocking rate actually applied, calculated retrospectively from the actual weight of animal, was invariably different (see figure 3) from the target stocking rate (see section 2.2.2).

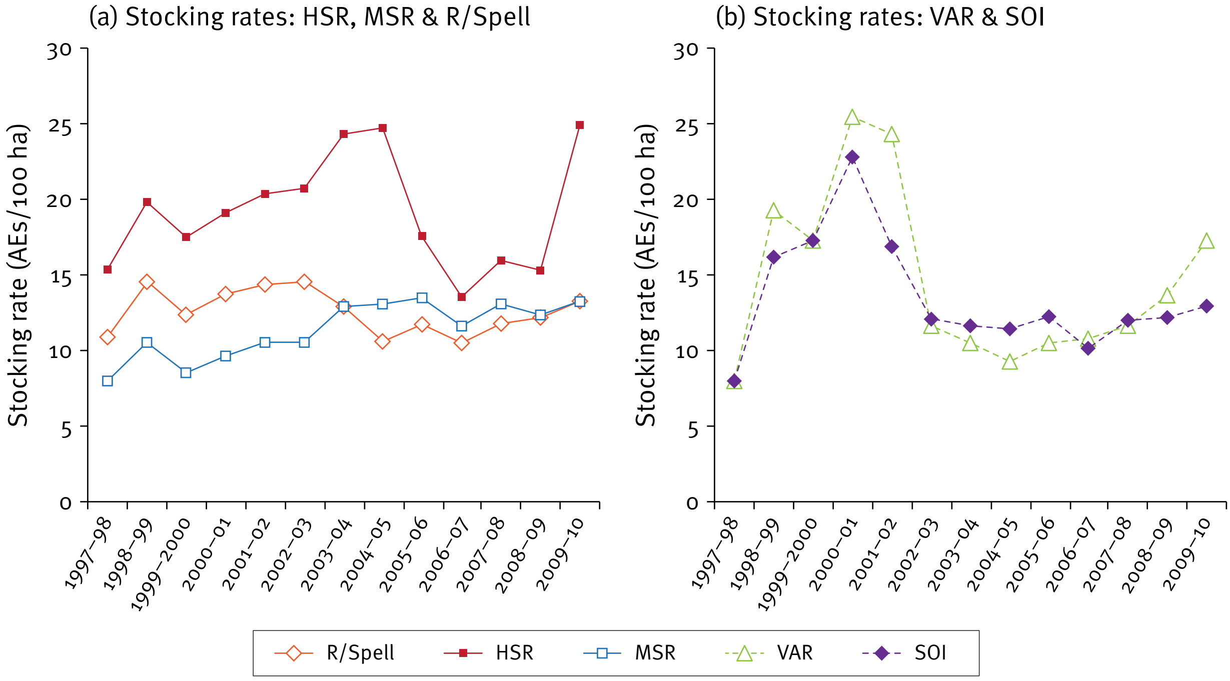


Figure 3: *Change in the applied stocking rates for the different grazing strategies for (a) the R/Spell, MSR and HSR strategies and (b) the VAR and SOI strategies over the duration of the trial. Stocking rates are expressed as AEs/100 ha for clarity.*

Stocking rates in the VAR and SOI varied with pasture mass and for the latter strategy, pasture mass and the SOI (see figure 3). Both treatments were stocked more heavily (3.5 ha/AE) than the HSR between 1999 and 2001. However, stocking rates were then cut as rainfall and pasture mass (and the SOI) declined. Due to poor seasons, both the SOI and VAR were more lightly stocked (10–12 ha/AE) in these drier years than the MSR. Stocking rates were subsequently increased again in May 2009 due to the improvement in seasonal conditions.

Stocking rates in the R/Spell were relatively constant at about 6–7 ha/AE until November 2003 when they were cut to 10 ha/AE due to drought and the after effects of the November 2001 fire (see section 2.3.4). The R/Spell strategy is now run at 8 AEs/100 ha as a combined moderate stocking and wet season spelling strategy.

3.3 Pasture utilisation

Pasture utilisation rates are defined as the percentage of annual pasture growth consumed and were estimated retrospectively using the GRASP pasture growth model for the years 1998 to 2006. Utilisation rates were initially low (<20%) in all strategies but increased three to sixfold after 2001–02 due to reduced pasture growth and, in the case of VAR and SOI, high stock numbers. Although utilisation rates in the VAR and SOI strategies declined somewhat after 2003, utilisation rates in the HSR remained high (>70%) until 2006.

Figure 4: *Exclosure cage after nine months of protection from grazing (background) and its matching grazed plot (foreground) in July 2006 in the HSR.*

Between 1998 and 2006 average utilisation rates (45%) in the HSR were almost double those in the VAR, R/Spell, SOI and MSR. Although average utilisation rates in these latter treatments were similar (20–25%), the number of years which were light was greatest in the MSR. Similarly, while the HSR and VAR had a similar range of utilisations over the different years, heavy rates occurred far more frequently in the HSR.

4. Production and utilisation of land types

4.1 Pasture production

Pasture production was highest in the box and brigalow landtypes and lowest in the blackbutt (*E. cambageana*) and ironbark (see figure 5). These differences reflect the variation in soil fertility and water holding capacity. Blackbutt areas are reasonably fertile, but are shallow and have low water holding capacity. Soils on the ironbark are deeper and store a greater amount of water than box areas but pasture yields are restricted by low nutrient levels. Pasture composition, and hence the production of grazeable forage, also varied between land types. Production on ironbark country was not only relatively low but was largely comprised of unpalatable wire (*Aristida*) and wanderrie (*Eriachne mucronata*) grasses. Yields on the blackbutt areas were also relatively low but contained a reasonable proportion of perennial, productive, palatable (3-P) species like *B. ewartiana* or relatively palatable grasses like windmill grass (*Enteropogon acicularis*).

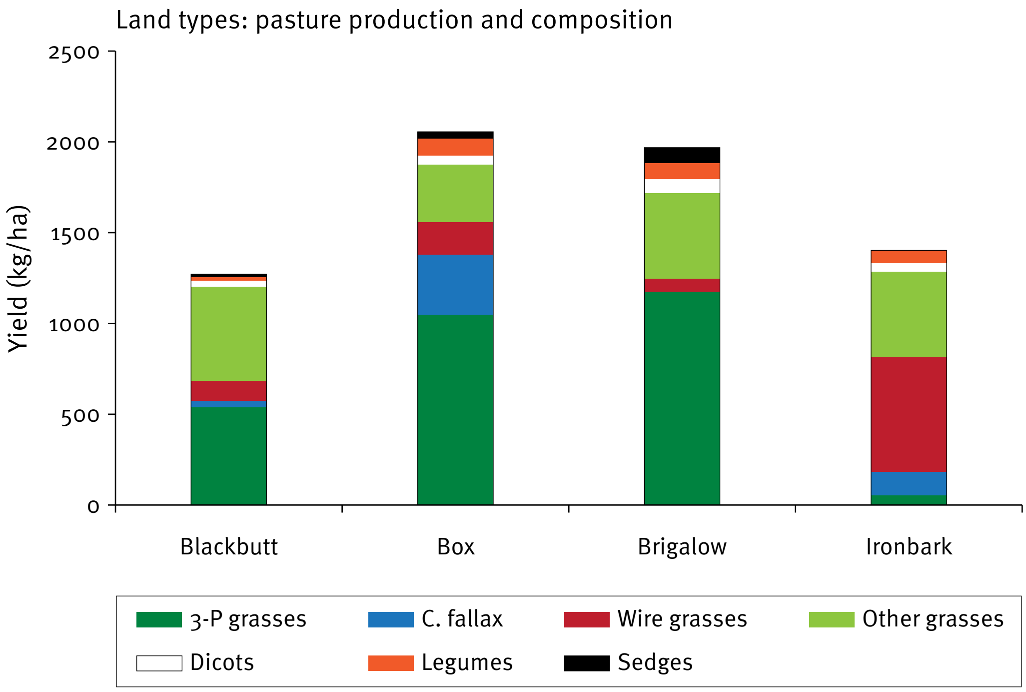


Figure 5: *Average annual pasture production and composition on the different land types at Wambiana between 1999 and 2005. Yields were measured annually in exclosures.*

4.2 Land type and patch selection

Cattle selected strongly for preferred land types (see figure 6) even in the MSR where average paddock utilisation rates were relatively light. Utilisation rates tended to be far higher on the box and brigalow then on the ironbark areas, although the extent of utilisation was dependent upon rainfall and stocking rate. Thus in the first dry year (2001), utilisation of the brigalow areas increased to nearly 50% while those on the ironbark remained at about 20%. Peak utilisation of the ironbark only occurred in 2003 after the box and brigalow had been heavily grazed.

There was also strong selective grazing of patches within land types. In the brigalow for example, utilisation rates varied from 79% on the *Lysiphyllum* (*Bauhinia*)-brigalow associations to 49% on the brigalow-blackbutt and 37% on the open coolabah (*Eucalyptus coolabah*) areas. Utilisation rates within the ironbark areas were also patchy with fertile areas under trees heavily utilised, but adjacent stands of wanderrie grass (*Eriachne mucronata*) untouched. By 2005, these wanderrie grass patches had been heavily grazed in the HSR but still remained largely ungrazed in the adjoining MSR paddock.

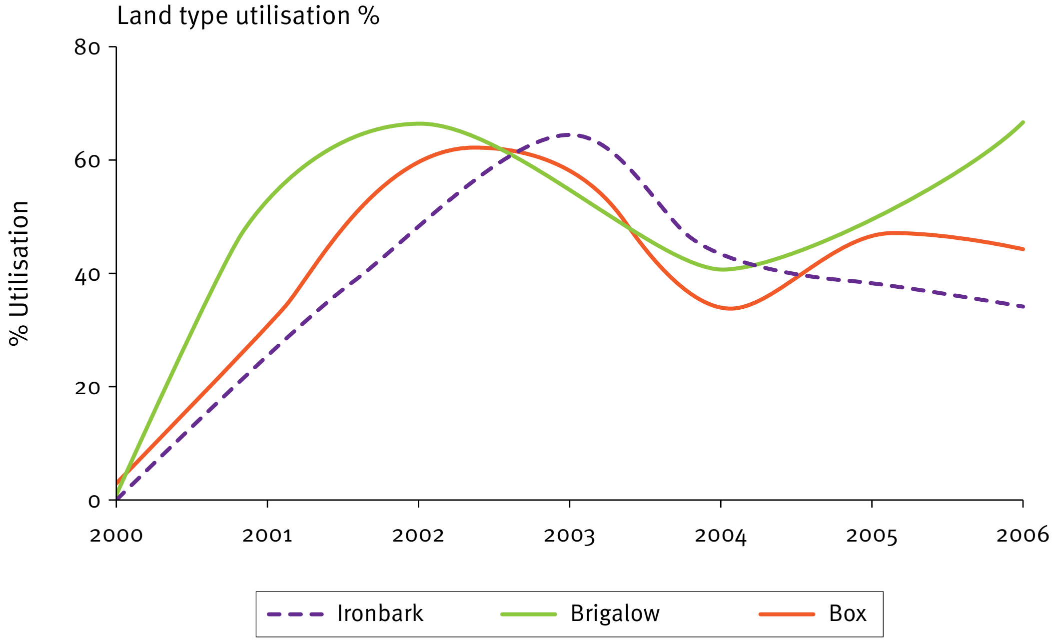


Figure 6: *Utilisation of different land types at Wambiana between 2000 and 2006.*

4.3 Summary: landtype production and selection

1. Land types differed substantially in their production of grazeable forage.
2. Intense area and patch-selective grazing occurred in all paddocks irrespective of stocking rate applied or the average pasture utilisation rate at the paddock level.

5. Effect of rainfall and grazing strategy on pastures

5.1 Pasture mass and ground cover

Pasture mass and ground cover were largely driven by rainfall. Both pasture mass and ground cover were highest in the early wetter years and declined in the drier years from 2002 to 2006, before recovering in later high-rainfall years (see figure 7). Interestingly, the decline in ground cover lagged about a year behind the decline in rainfall. Pasture composition also changed dramatically with rainfall, resulting in large fluctuations in the amount of annuals and weaker perennials. However, perennial grasses were relatively stable and, with the exception of the 2002–03 drought, their abundance did not fluctuate greatly in response to rainfall (see note on perennial grasses).

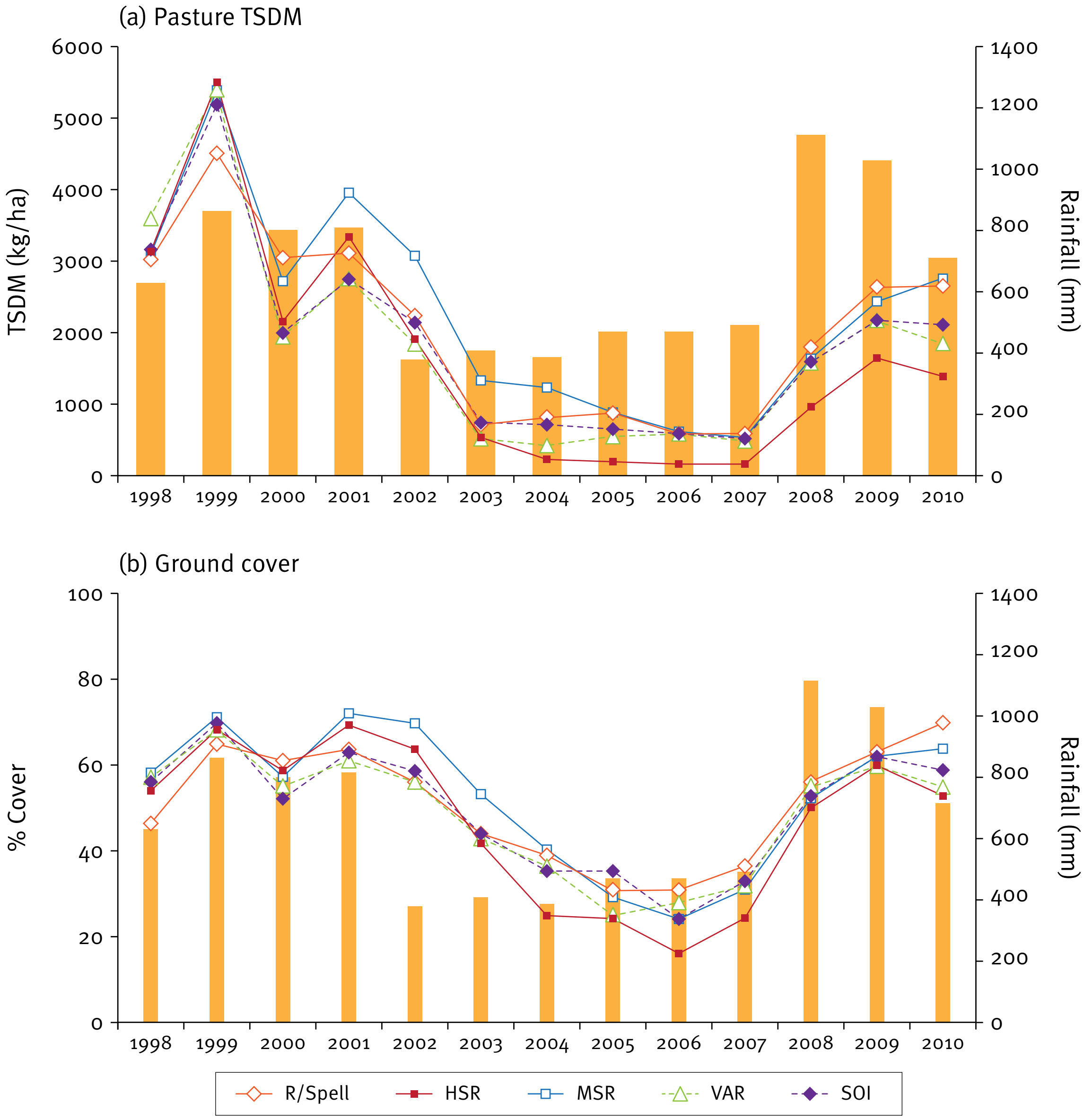


Figure 7: *Change in (a) pasture total standing dry matter (TSDM) and (b) ground cover with rainfall between 1998 and 2010 for different treatments at Wambiana. Both pasture TSDM and ground cover values are averaged over end of wet (May) and end of dry (November) season measurements.*

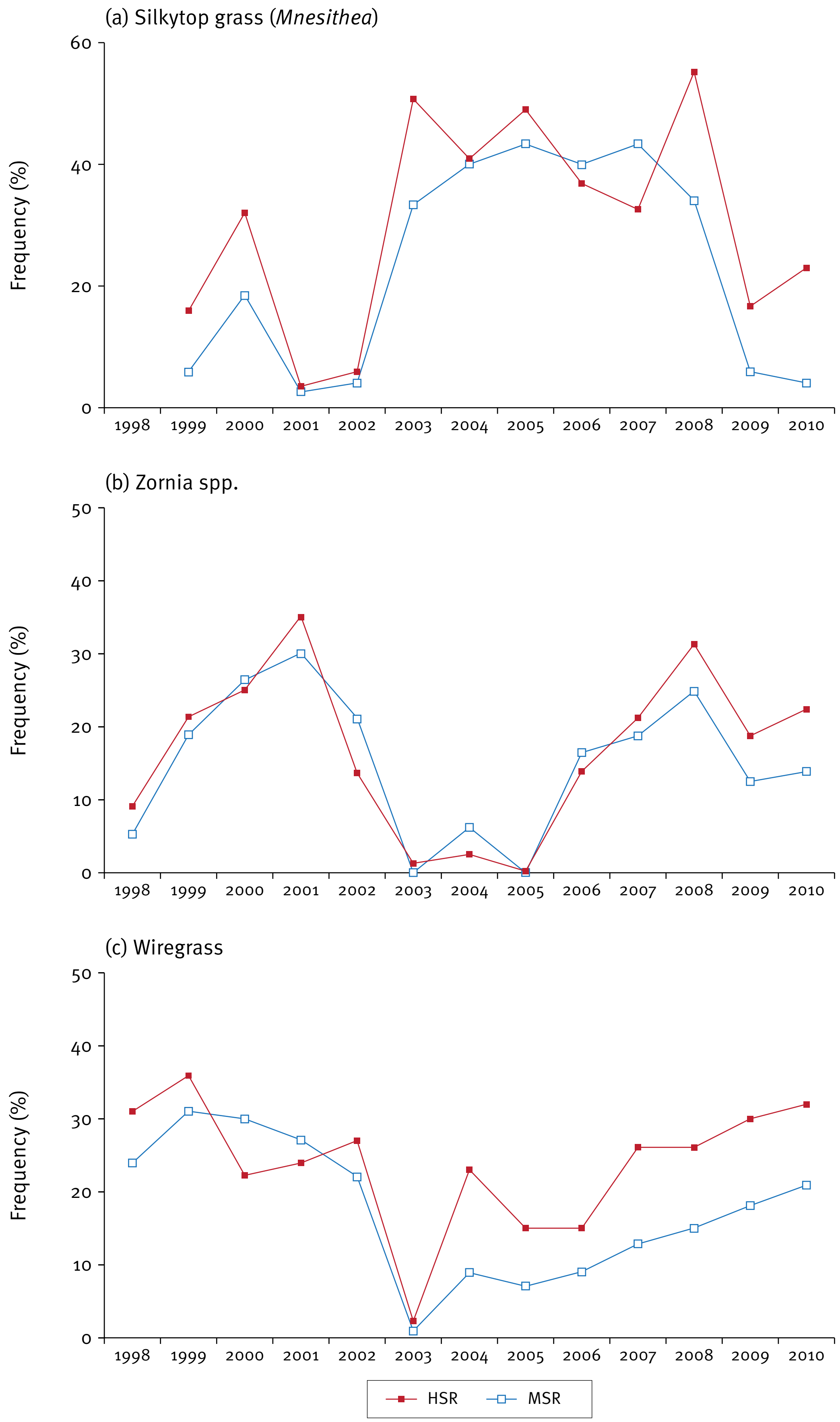
Pasture mass and ground cover both declined as stocking rate increased. This was most obvious in low-rainfall years with the HSR being almost bare by the end of the dry season. Initially, the lower HSR yields simply resulted from heavier pasture utilisation but in later years increasingly reflected a decline in land condition and an obvious reduction in rainfall use efficiency. However, ground cover was very low in all paddocks in the dry years (see figure 7). This suggests that targets of 40% cover recommended to meet water quality guidelines are not always achievable, even under good management.

Perennial grasses: the backbone of a production system

Although rainfall had a large effect on the abundance of annual grasses like firegrass (*Schizachyrium*) and silkytop grass (*Mnesithea*) and weaker perennials like wiregrass (*Aristida benthamii*), perennial grasses were far less sensitive to rainfall (see figure 8). Some mortality occurred in perennials in the severe drought of 2002–03, particularly in black speargrass, a relatively shorter lived (5–10 years) perennial species. However, desert bluegrass, Queensland bluegrass, silky browntop and the unpalatable wanderrie grass were far more drought-hardy and had far lower mortality rates. Perennial grasses are therefore the stable matrix within which other, weaker species fluctuate. Perennials are obviously critical for sustainable beef production because of their relative reliability across even the worst of seasons.

5.2 Treatment effects on pasture condition

Grazing management had a major impact upon pasture condition. After 13 years the frequency of annual grasses like firegrass was greater in the HSR than in other treatments. In contrast, after 13 years, desert bluegrass frequencies were far higher in the MSR, than in the HSR (see figure 9). Black speargrass was also higher in the MSR and R/Spell than in the HSR. In the VAR and SOI, the frequencies of both species were slightly lower than the MSR and R/Spell, but still far higher than in the HSR. Although average utilisation rates over time in the SOI and VAR were relatively moderate, the frequency of desert bluegrass and black speargrass was reduced by heavy pasture utilisation immediately prior to the 2002–03 drought. As of 2011, recovery in these treatments was still occurring (see section 2.6).


(a) Silkytop grass (*Mnesithea*)
Frequency (%)
60
40
20
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
(b) Zornia spp.
Frequency (%)
50
40
30
20
10
0
(c) Wiregrass
Frequency (%)
HSR
MSR

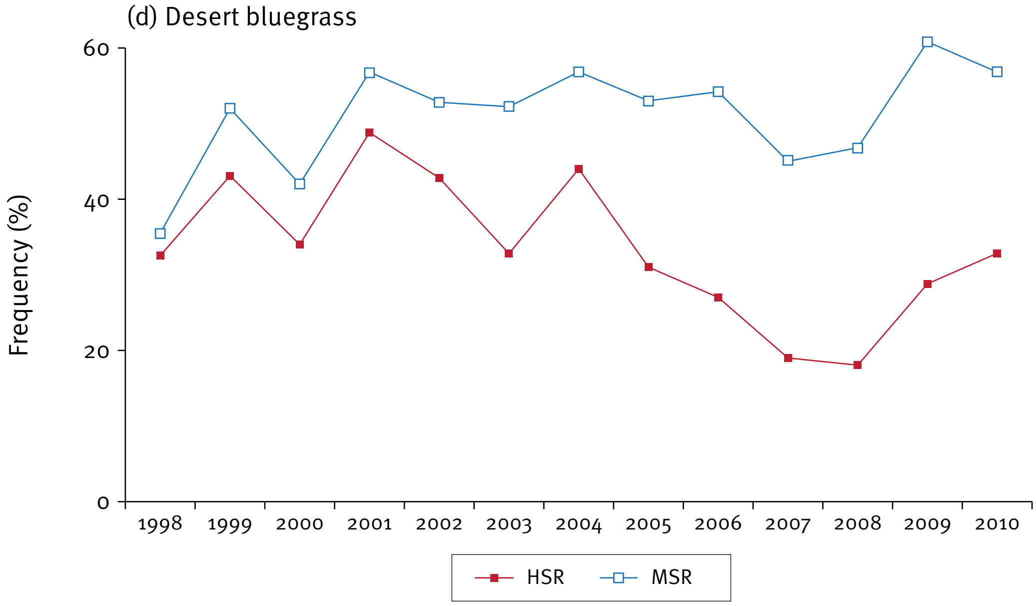


Figure 8: *Change in frequencies of (a) an annual (silkytop grass,* Mnesithea*), (b) a native legume (*Zornia*), (c) a weak perennial (wiregrass) and (d) a perennial (desert bluegrass) over different rainfall years from 1998 to 2010. For clarity only data from the HSR and MSR treatments are shown.*

Moderate stocking (MSR) or light-moderate stocking with wet season spelling (R/Spell), promotes 3-P species like desert bluegrass, while relatively constant heavy stocking adversely affects these species. Relatively short-term heavy utilisation rates combined with low rainfall can also inflict severe damage on 3-P species as happened in the SOI and VAR strategies.

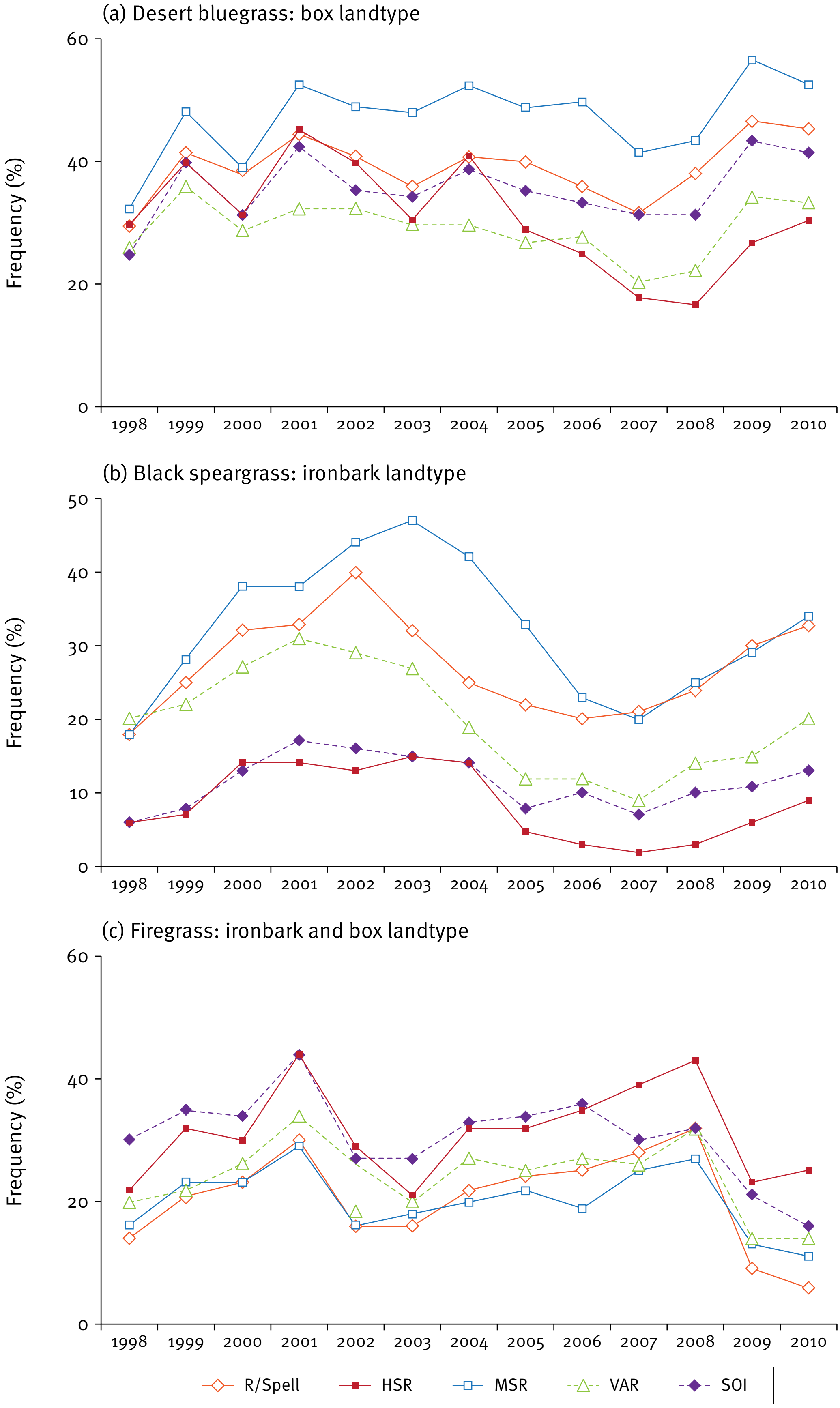


Figure 9: *Change in the frequency of (a) desert bluegrass (*B. ewartiana*), (b) black speargrass (*H. contortus*) and (c) firegrass (*S. fragile*) over the period 1998 to 2010.*

In 2010, after 13 years of grazing, the density of 3-P grasses was also highest in the MSR and R/Spell, somewhat lower in the VAR and SOI, and by far the lowest in the HSR (see Table 1). The lower densities in the VAR and SOI are unexpected as these two strategies had been run at slightly lower stocking rates than the MSR between 2003–04 and 2008–09.

The 3-P densities measured in 2006 (when density measurements started) also tell a story. In 2006, 3-P densities were lowest in the HSR indicating that heavy utilisation and low rainfall had caused significant mortality of these species in this treatment. 3-P densities in the VAR and SOI were also relatively low due to the heavy utilisation rates that occurred going into the drought of 2002–03. This again indicates that 3-P density is determined by both the longer term average pasture utilisation rate and the timing of heavy utilisation in relation to drought.

Table 1: *Mean tussock density (tussocks/m^2) of 3-P grasses across all soil types in 2006 and 2010, over the five grazing treatments at the Wambiana trial.*

Treatment	2006	2010	Change
VAR	2.63	3.87	+1.24
R/Spell	3.03	4.95	+1.92
SOI	2.82	3.49	+0.67
HSR	1.30	1.75	+0.45
MSR	3.90	5.15	+1.26

The change in 3-P densities from 2006 to 2010 also reveals a very important point about recovery following drought. With very good rainfall, 3-P densities increased in all treatments except the HSR, despite the reduced stocking rate applied in the HSR between May 2005 and May 2009. This shows that pasture recovery is slow and does not occur automatically with a return to higher rainfall. It also indicates that despite the dramatic increase in ground cover and pasture TSDM in the HSR since 2006, the apparent improvement in pasture condition is largely cosmetic and will not be sustained with a return to drier years.

The density of 3-P tussocks was sharply reduced under heavy pasture utilisation rates. Tussock densities can take many years to recover despite reduced stocking rates and good seasons.

R/Spell: April 2000

Spelling, moderate stocking and good seasons ensured the R/Spell was in very good condition in 2000.

R/Spell: April 2003

But heavy stocking pressure in the un-spelled sections and low rainfall led to a decline in condition.

R/Spell: March 2010

A reduction in stocking rates, spelling and better seasons have ensured good recovery in the R/Spell.

VAR: April 1998

In 1998 the VAR was in good condition. Good seasons allowed heavy stocking rates to be applied until 2002.

VAR: April 2003

Heavy stocking rates were cut sharply as rainfall declined in 2002, but this was not enough to prevent a substantial decline in pasture condition.

VAR: March 2010

Light stocking rates and better seasons have ensured recovery in VAR, but pasture condition is still not as good as in the MSR.

HSR: July 1998

MSR: July 1998

In 1998, both the MSR (above right) and HSR (above left) were in good condition with a good stand of 3-P grasses.

HSR: April 2005

MSR: April 2005

But by 2005 the HSR was in very poor condition due to heavy grazing pressure and drought. Although ground cover declined in the MSR, a healthy stand of 3-P grasses was still maintained.

HSR: March 2010

MSR: March 2010

Good rains in 2007–08 and a reduced stocking rate has brought only a superficial improvement in pasture conditions to HSR while in the MSR, condition has improved further.

Figure 10: *Monitoring site changes over time (box land type) for different treatments at the Wambiana trial.*

5.3 Population dynamics of desert bluegrass

Detailed research by David Orr over 13 years at the Wambiana trial also revealed that while other weaker species come and go, desert bluegrass is long lived and individual tussocks can easily live up to 30 years with moderate stocking (Orr and O'Reagain 2011). This contrasts with species like wiregrass (*Aristida*) and hairy panic (*Panicum effusum*) which survive for only a few years.

Desert bluegrass is also far more drought tolerant than other species. During the dry years of 2001 to 2006, the majority (80%) of desert blue tussocks survived while virtually every plant of the weaker species died. Its survival was strongly influenced by grazing with mortality being far higher under heavy stocking. Of real concern however, is that no seeds of this species were located in the soil seed bank and virtually no recruitment of new plants occurred under either moderate or heavy stocking rates.

These results show that species like desert bluegrass are long lived, can withstand severe droughts and are therefore dependable as a source of forage in some of the driest years. However, if they are not managed properly and grazed too heavily during dry years they eventually die. Existing tussocks therefore need to be retained at all costs because of low recruitment rates from seed and the slow and unpredictable nature of recovery.

Desert bluegrass is a long lived species but survival is reduced by heavy grazing and drought. Recruitment rates from seed are very low, so recovery can be slow and unpredictable.

5.4 Effects on pasture composition

Any change in the frequency and density of 3-P grasses will also obviously affect pasture composition and yield. After 13 years of grazing, pasture total standing dry matter (TSDM) in the HSR in May 2010 was 1500 kg/ha, or 40–50% less than that in other strategies (see figure 11). Significantly, the actual yield of 3-P grasses in the MSR and the other strategies was between three and seven times greater than that in the HSR.

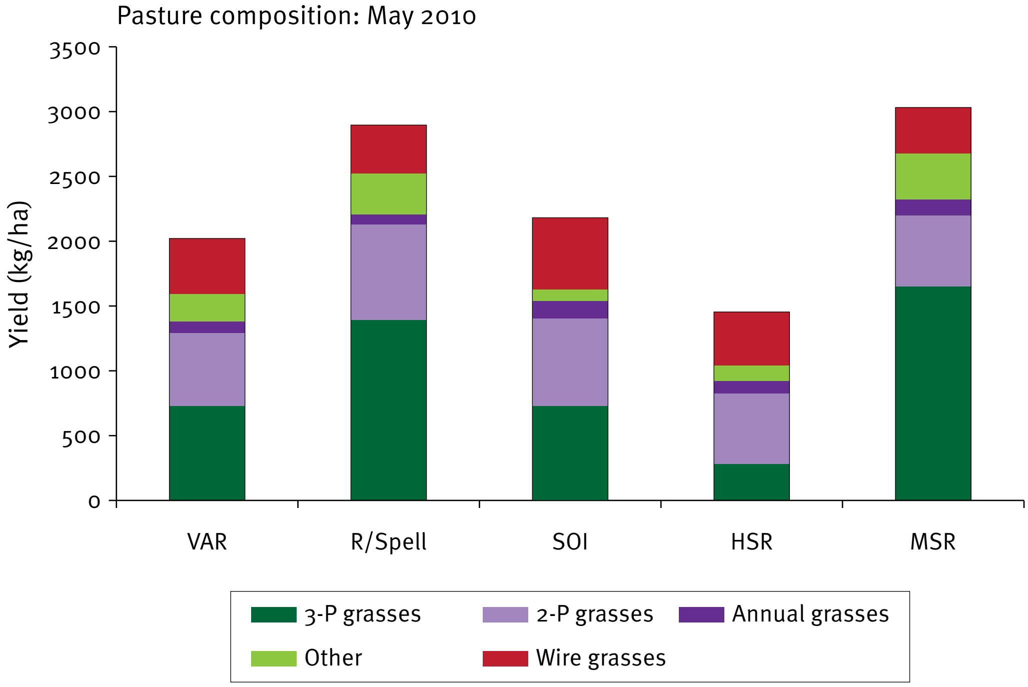


Figure 11: *Contribution (kg/ha) of different species groups to pasture TSDM in May 2010 after 13 years of applying different grazing strategies at Wambiana. 3-P = perennial, productive, palatable species, 2-P = perennial/productive or palatable, other = sedges, forbs and legumes, wiregrasses =* Aristida *and* Eriachne *species.*

Since 1998 when the first pasture measurements were made, the contribution of 3-P species to pasture TSDM has increased in the MSR, R/Spell and VAR strategies, remained unchanged in the SOI, and declined in the HSR (see Table 2). Conversely, the contribution of 2-P grasses i.e. palatable, productive and/or perennial species, to yield has increased by far the most in the HSR, but shown very little change in the MSR, R/Spell and VAR. The HSR has thus declined in its ability to produce grazeable forage, particularly in drier years, with obvious consequences for longer term animal production.

Table 2: *Absolute change from 1998 to 2010 in the % contribution of different species groups to end of wet season pasture TSDM.*

Sp. Group	VAR	R/Spell	SOI	HSR	MSR
3-P Grasses	+9	+15	0	-9	+19
2-P Grasses	+3	+1	+7	+23	0
Wiregrasses	-7	-17	0	-9	-17

5.5 Effects on land condition rating

After 13 years of grazing, land condition (based on the ABCD land condition framework) was best in the MSR and R/Spell (B+ condition), followed by the two variable treatments (B- condition). Land condition in the HSR was by far the worst (C- condition). As all paddocks were initially in similar condition, it is obvious that land condition has declined significantly under heavy stocking.

5.6 Summary

1. Rainfall largely drives year-to-year variation in pasture mass and ground cover, but stocking rate also directly affects pasture availability and cover. This occurs directly through the effects of stocking rate on pasture utilisation and indirectly through its effects on land condition.
2. Perennial grasses like desert bluegrass were far less sensitive to rainfall variation than annuals or the weaker perennials like cotton panic. Maintaining a healthy pasture dominated by perennials is thus essential for a profitable beef production system.
3. Stocking rate had a major impact upon pasture condition. Moderate stocking rates maintained and improved pasture condition despite extremely variable rainfall. In contrast, relatively constant heavy stocking in combination with variable rainfall led to a marked decline in pasture condition with a reduction in the frequency and density of 3-P grasses.
4. Heavy utilisation rates in the VAR and SOI immediately prior to the 2002–03 drought also led to significant pasture damage. Accordingly, the timing of heavy stocking in relation to rainfall is possibly just as important in determining pasture condition as the average long-term utilisation rate.
5. Desert bluegrass is a long lived species with very low rates of plant recruitment from seed. Recovery from degradation can therefore be very slow despite favourable seasons and sharply reduced stocking rates.
6. Wet season spelling combined with light to moderate utilisation rates also maintained and improved pasture condition. However, there is no direct evidence to show that spelling can buffer the effects of heavier stocking rates on land condition.
7. In very wet years, relatively degraded pastures can appear to recover rapidly with significant improvements in ground cover and yield; this ‘recovery’ is invariably superficial with most of the improvement due to the abundance of annual grasses, weaker perennials and sedges that will disappear when dry conditions return.

6. Effects of different strategies on animal production

6.1 Individual animal performance

Annual live weight gain per animal (LWG) varied from 7 to 170 kg depending upon the treatment and the year involved (see figure 12). Rainfall, and in particular rainfall distribution, were the biggest determinants of LWG. For example, although total rainfall was identical in 2004–05 and 2005–06 (470 mm), weight gains in 2005–06 were 20 to 50 kg greater due to better rainfall distribution.

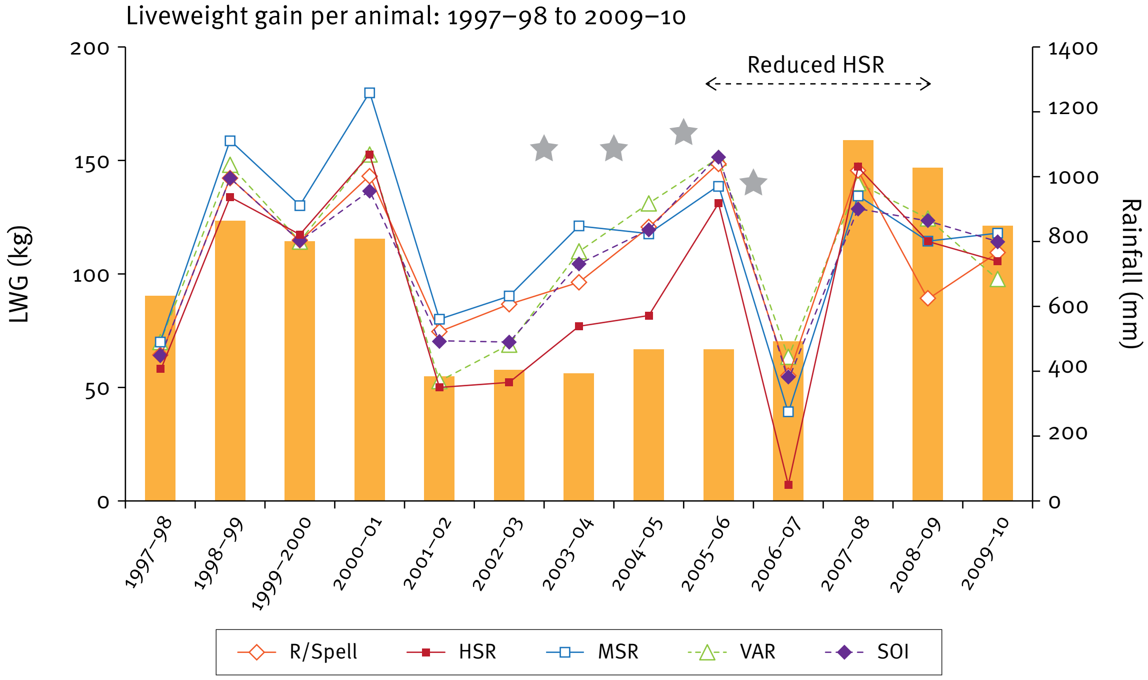


Figure 12: *Annual rainfall and live weight gain (LWG) per animal for different grazing strategies at the Wambiana trial between 1997–98 and 2009–10. Stars indicate years when molasses and urea drought feeding was provided to the HSR.*

Averaged over 13 years, LWG per annum was highest in the MSR (115 kg), followed by the VAR (110 kg), R/Spell (108 kg) and SOI (106 kg), but was by far the lowest in the HSR (94 kg). Regardless of rainfall, lighter or moderate stocking rates generally gave superior animal weight gains when compared to heavy stocking. The only exceptions to this trend occurred in 2007–08 and 2008–09. Here higher LWG occurred in the HSR due to a combination of very high rainfall, a change to a C- condition pasture dominated by annuals and a reduced stocking rate. Note however, that in the drier years of 2006–07, LWG in the MSR (38 kg/hd), which was in B+ condition, was four times greater than in the HSR (8 kg) on C- condition pastures.

Within the grazing year, cattle weights generally followed the seasonal pattern expected in the dry tropics, that is, rapid LWG in the wet season followed by maintenance or even weight loss in the dry season (see figure 14). Moderate dry season weight gains were recorded in some years when out of season rains occurred, such as 2005.

Figure 13: *Steers in the MSR treatment in August 2005. In all years individual animal performance was far higher under moderately stocked paddocks than in the HSR.*

Stocking rate effects were most marked in the dry season with heavily stocked cattle often losing large amounts of weight and drought feeding being required for these animals in very dry years. In contrast, cattle usually maintained or sometimes even gained weight over the dry season in light to moderately stocked treatments.

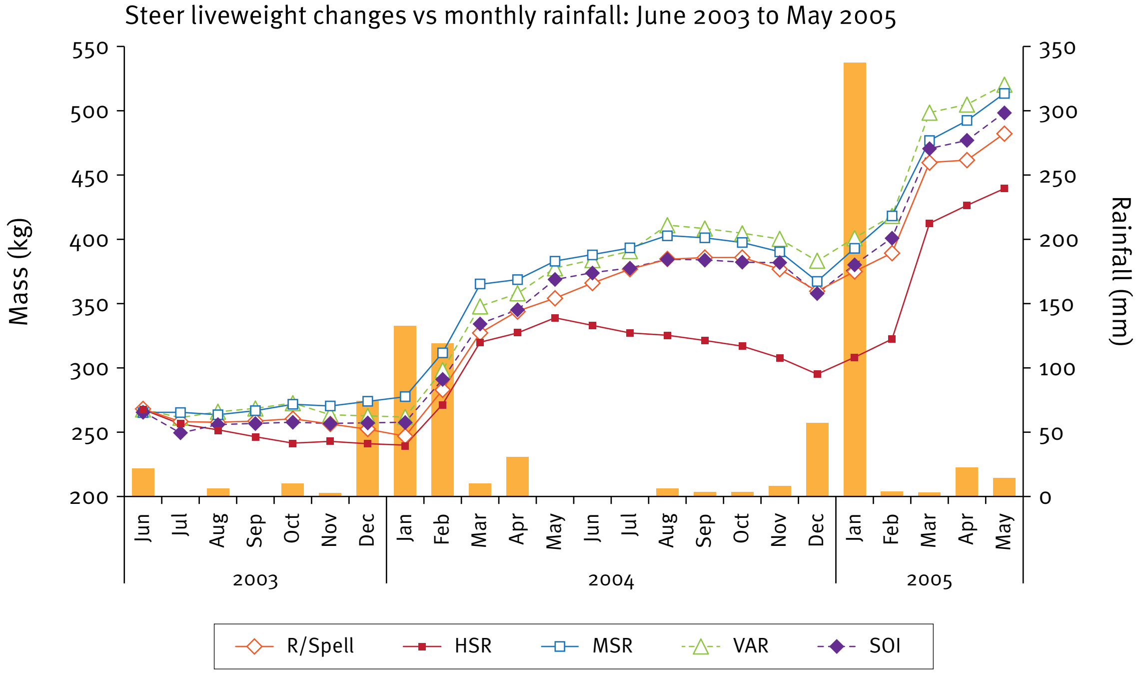


Figure 14: *Live weight of cattle in different treatments and monthly rainfall between June 2003 and May 2005 at the Wambiana trial.*

In all but one year (2007–08) heavily stocked animals did not display compensatory growth in the following wet season. Consequently, these animals never caught up with those in other treatments and the HSR steers typically weighed 30 to 60 kg less at the end of the year than those steers in lightly stocked paddocks. HSR steers had smaller frames in general and were in poorer condition, with obvious consequences for profitability at the meatworks.

Individual animal production tended to be higher under lighter or moderate stocking due to superior diet quality and intake. This resulted from greater pasture availability and reduced competition for higher quality dietary components. This gave a higher dietary crude protein and in vivo digestibility, giving a greater intake of digestible nutrients (see figure 15).

With the later change to C- condition pastures in the HSR treatment, this situation altered. In wet years like 2008–09, HSR diet quality was higher on short, green pastures dominated by higher quality annuals, forbs and sedges. Although diet quality was still higher in the HSR in drier years such as 2006–07, physical restrictions to intake on the short, sparse swards reduced LWG to a very low level i.e. 7 kg/annum (see figure 13).

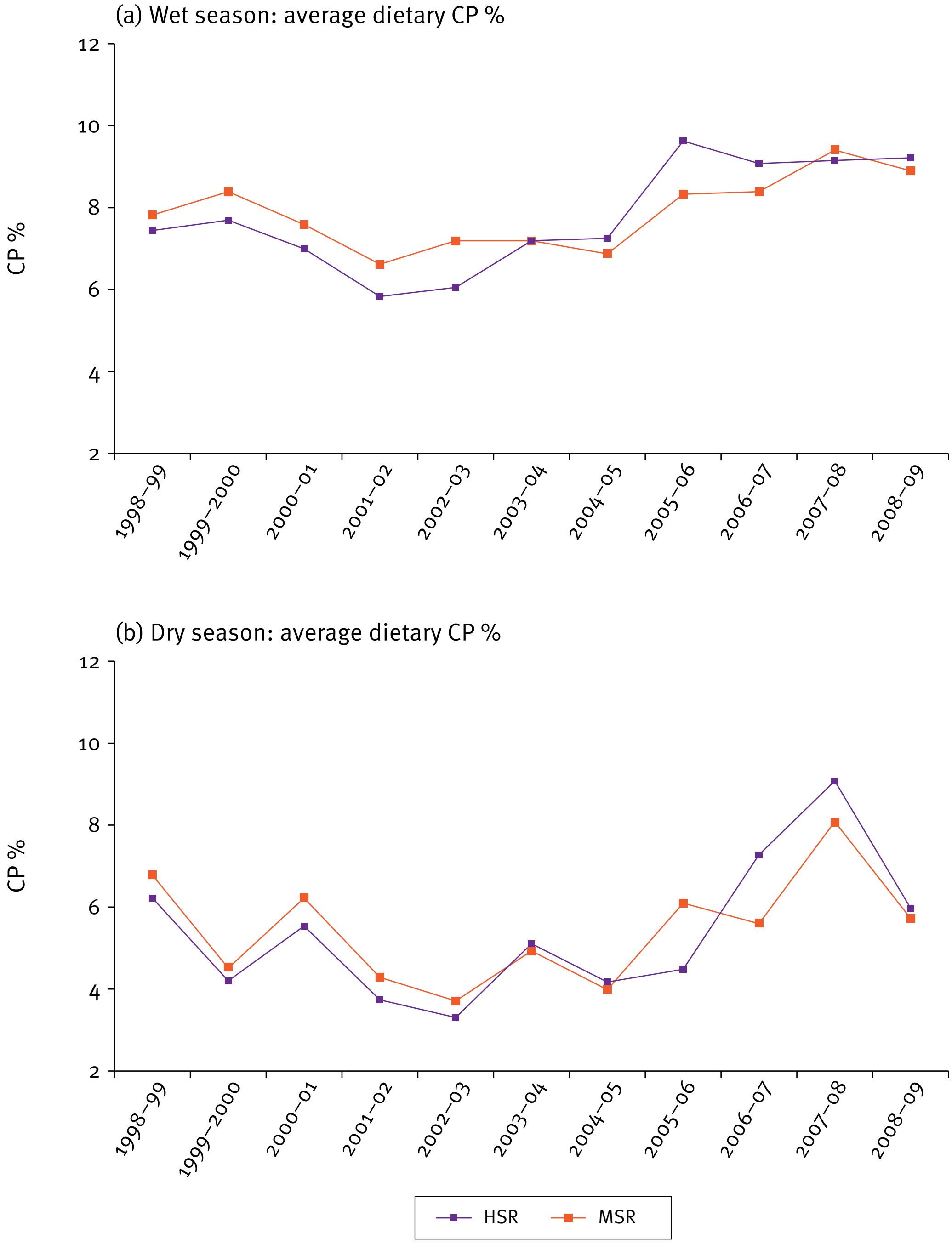


Figure 15*: NIRS predictions of dietary crude protein (CP) in (a) the wet season and (b) the dry season in the HSR* and MSR treatments over different years at Wambiana. Note: HSR* excludes data from dates when cattle were fed molasses and urea.*

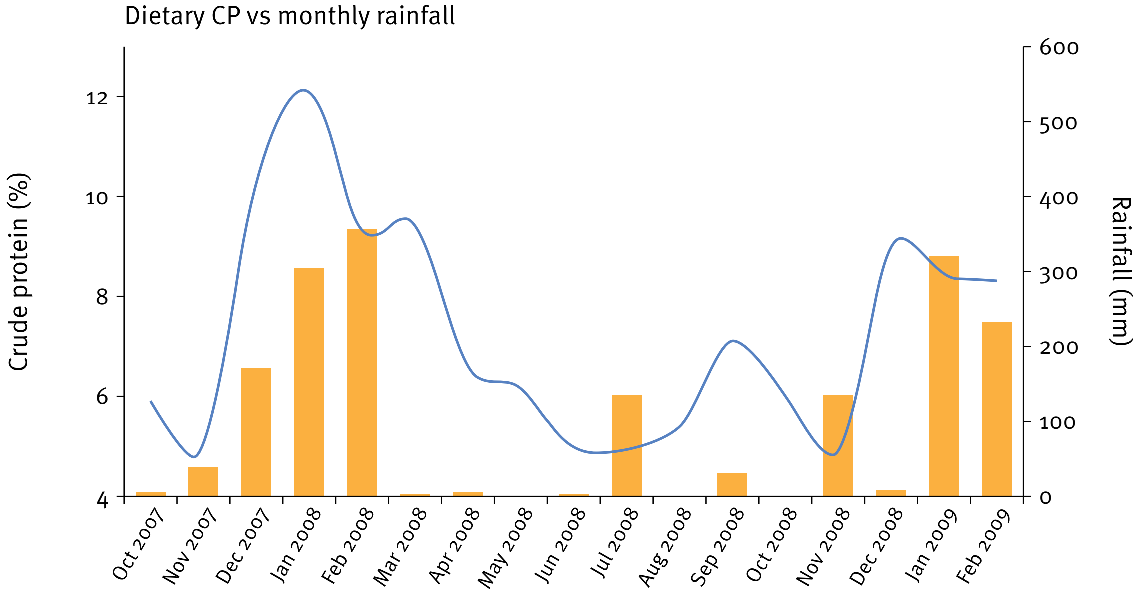


Figure 16: *Change in dietary crude protein (CP) in cattle diets (solid line) versus monthly rainfall (bars) between October 2007 and February 2009.*

What determines dietary quality?

- Dietary quality is a major determinant of weight gain in the dry tropics. Dietary crude protein and digestibility is closely linked to rainfall, generally peaking early in the wet when the nitrogen level in the soil is high and plants are leafy and green. Even with further rain, quality usually declines thereafter as soil nitrogen is depleted and plant stemminess increases (see figure 16).
- The non-grass component in the diet (forbs or woody browse) varies throughout the year. Generally, this tends to increase in the late dry season due to browsing of woody species and in the late wet season, due to the selection of legumes and forbs.
- Seasonal trends in diet quality vary markedly between years based on rainfall and its distribution. For example, crude protein levels were below animal maintenance requirements (about 6%) for only two months in 1998–99 compared to nine months in 2002–03. Absolute differences in diet quality also occur between years due to changes in soil nitrogen availability and hence forage quality. Dietary crude protein is reduced in the year following high rainfall compared to that following an average or dry year.
- Diet quality also tends to be lower under heavy stocking, because of increased competition for higher quality dietary items. In the later wet years of the trial, diet quality was higher in the HSR due to the short, green pasture. Nevertheless, in drier years quality (and intake) under heavy stocking would decline sharply due to the sheer scarcity of forage.

6.2 Market performance

In five of the seven years that cattle went to the meatworks, lighter stocking gave higher market values (see figure 17). This was due to better body condition, which improved carcass grades and price per kilogram of beef. This, together with greater carcass weight, increased total carcass value.

Although there was relatively little difference in price per kilogram in 2007–08, there was still a marked difference in total carcass price due to differences in carcass mass between treatments. The only time that HSR steers performed as well as more lightly stocked treatments was in 2008–09. This probably occurred because of the two exceptionally good years that these steers experienced before going to the meatworks.

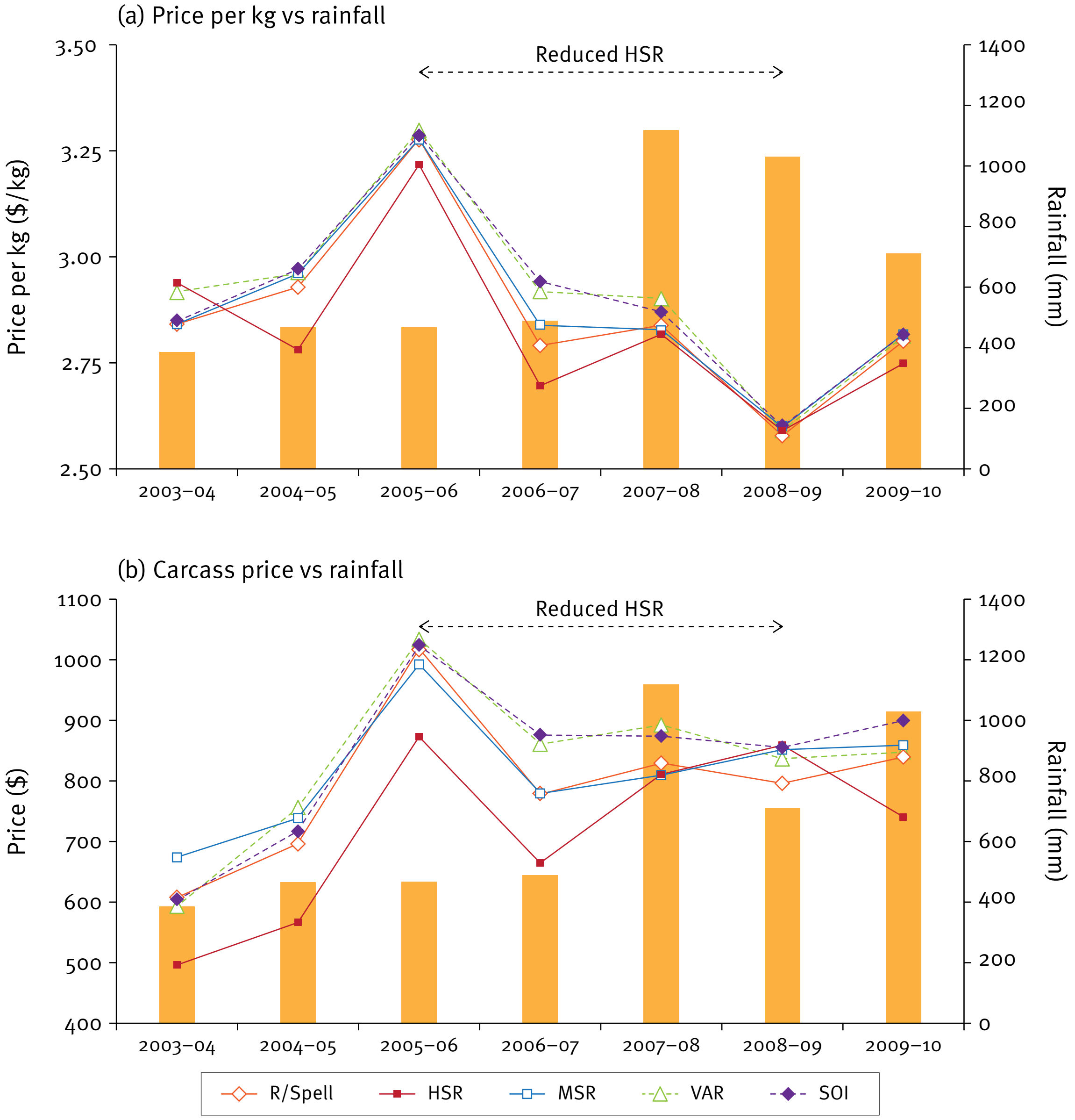


Figure 17: *Meatworks prices (a) per kilogram of dressed weight and (b) per carcass against annual rainfall from 2003–04 to 2009–10.*

Due to superior weights and condition, carcass values in nearly all years were higher under lighter stocking rates.

6.3 Total animal production

The total live weight gain per hectare (LWG/ha) varied from nearly 30 to 40 kg/ha in 2000–01 to less than 10 kg/ha in 2006–07 (see figure 18). This occurred due to variation in rainfall and, in strategies like the VAR and SOI, the stocking rate applied. In general, LWG/ha increased with stocking rate. Averaged over the 13 years, LWG/ha was greatest in the HSR (21 kg/ha) and least in the MSR (14 kg/ha). Production in the other strategies varied between these levels i.e. VAR (18 kg/ha), SOI (17 kg/ha) and the R/Spell (15 kg/ha).

It is important to note that the high LWG/ha in the HSR was subsidised by drought feeding in dry years. In contrast, none of the other strategies required drought feeding. As mentioned previously, HSR stocking rates also had to be cut by about a third in May 2005 due to a decline in carrying capacity in these paddocks.

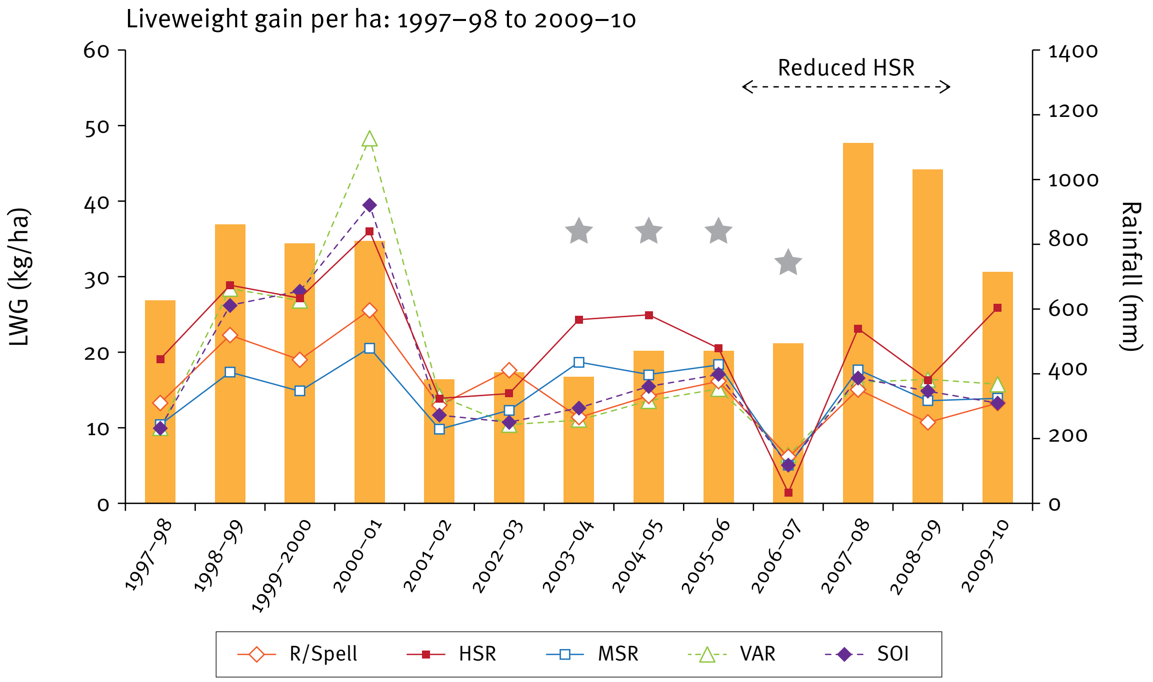


Figure 18: *Annual rainfall and live weight gain per hectare (LWG/ha) for different grazing strategies at Wambiana trial between 1997–98 and 2009–10. Stars indicate years when molasses and urea were fed to HSR.*

From 2001–02 to 2006–07 differences in LWG/ha between treatments narrowed due to lower rainfall and, in the VAR and SOI, the reduced stocking rates applied. In the HSR, LWG/ha also fell due to a decline to C- condition pastures. In 2006–07 the HSR had the lowest LWG/ha of all strategies, despite its reduced stocking rate (see figure 18).

LWG/ha in the HSR recovered well on these C- condition pastures in the later wet years of 2007–08 and 2008–09. The return to full, heavy stocking in the HSR gave particularly high LWG/ha in this strategy in 2009-10. This may reflect the emergence of a 'boom and bust' pattern in the HSR with good total production in very wet years but an almost complete collapse in production in poor years, as happened in 2006–07.

Total animal production per unit area was greatest under heavy stocking, but this was only achieved by drought feeding in dry years.

6.4 Summary: animal production

1. Light to moderate stocking increased total annual live weight gain by 30 to 50 kilograms per animal relative to heavy stocking.
2. After two years, light to moderately stocked cattle were generally 50 to 100 kilograms heavier than heavily stocked cattle. This, coupled with superior condition and frame growth, significantly improved market value of these animals.
3. Heavy stocking gave the greatest production per unit area but this strategy had to be subsided with drought feeding in dry years. Carrying capacity also declined under heavy stocking.
4. A decline to C- condition in the HSR appears to have led to a 'boom and bust' pattern with good LWG in very wet years but an almost complete collapse in production in drier years.

Fig 19a*: Animal production in the HSR was good in the initial wet years (left) but by November 2004 animals were severely stressed and had to be drought fed (right).*

Figure 19b: *In 2006–07 production in the HSR was particularly poor with steers only gaining 6 kg over the whole year (left). Although HSR steers performed well in later wetter years (right) land condition has not improved so production is likely to crash again when below average years return.*

7. Economic performance of different strategies

7.1 Gross margins

Annual gross margins (GM) for each strategy were calculated from the total value of beef produced per strategy, minus total costs (for more detail see O'Reagain et al. 2011). The value of beef produced was the total LWG multiplied by a market value of $1.50/kg for animals in good condition and $1.30/kg for animals in poorer condition. Cattle were assumed to be worth $1.50/kg at the start of the grazing year because of the market premiums on younger cattle. The costs used included the interest on livestock capital (7.5%), supplementation, vaccination and drought feeding costs. Accumulated gross margins (AGM) were calculated by progressively summing the gross margins from 1997–98 onwards and included compounded interest.

In the early wet years, and with good initial pasture composition, GMs were very high in the HSR due to good animal production and low production costs. However, GMs in the HSR declined sharply in 2001–02 with the change to drier years (see figure 20) and remained negative thereafter, despite the reduction in stocking rate from May 2005. Gross margins in the HSR only recovered in the last three years in response to better seasons. Overall, the HSR ran at a loss in 6 out of 13 years. Despite the greater LWG/ha, the HSR was penalised due to drought feeding costs, the reduced market value of heavily stocked animals and the ongoing high interest costs on livestock capital.

In contrast to the HSR, the MSR was profitable in all years irrespective of rainfall due to lower costs and good market values for sale cattle. Gross margins in the R/Spell were reasonably similar to the MSR but were compromised in 2003–04 and 2004–05 by the after effects of the 2001 fire and the forced sale of poor condition cattle in November 2003.

Like the HSR, the heavily stocked VAR and SOI were initially highly profitable but when rainfall declined, GMs fell sharply due to reduced animal production and the forced sale of cattle in poor condition. However, this sharp reduction in stocking rate avoided the drought feeding and interest costs incurred in the HSR, making the VAR and SOI profitable in all subsequent years.

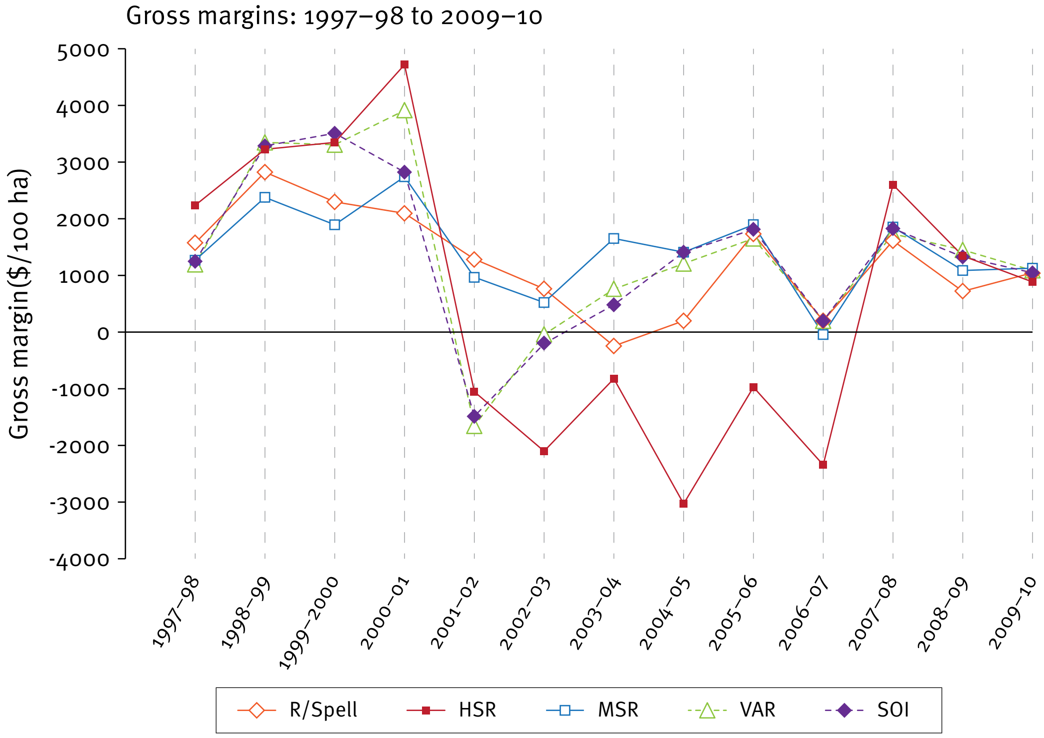


Figure 20: *Gross margin ($/100 ha) for five different grazing strategies at Wambiana from 1997–98 to 2009–10. Interest at 7.5% and price differential based on condition score.*

7.2 Accumulated gross margins

After 13 years, accumulated gross margin (AGM) was highest in the MSR and VAR followed by the SOI and R/Spell (see figure 21). Despite the positive GMs in the final three years, AGM in the HSR was by far the lowest of all strategies.

For an average north Queensland property of 20 000 ha, the difference in economic performance between the HSR and the MSR equates to more than $2 million in income over 13 years. This is sensitive to the interest rate used in the analysis, but even at 0% the predicted difference is still more than $600 000 in favour of the MSR.

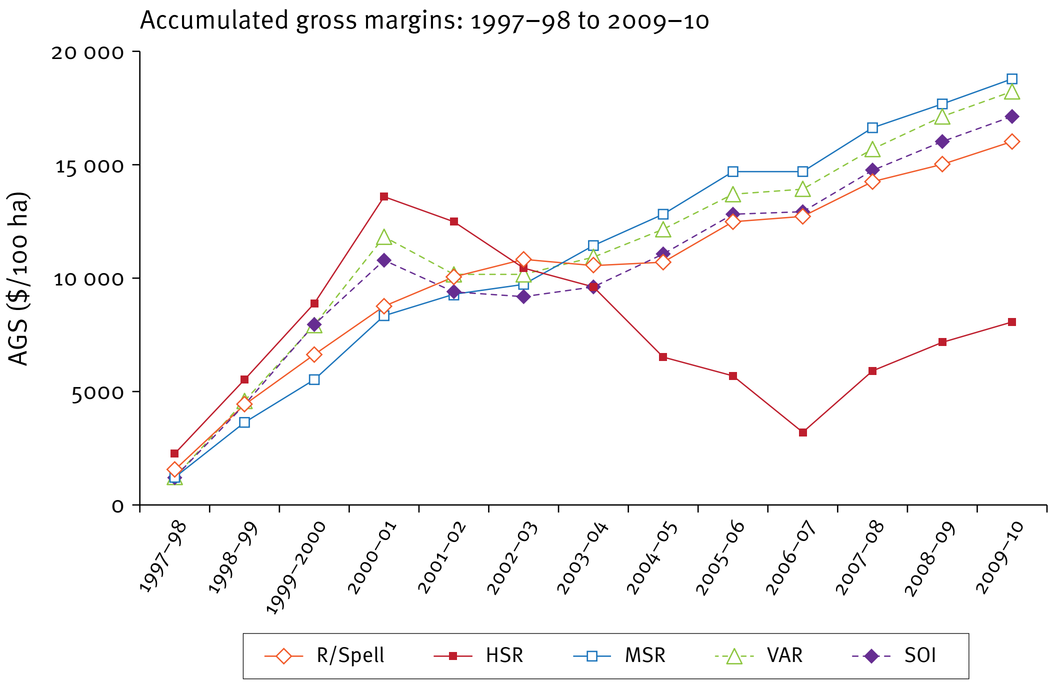


Figure 21*: Accumulated gross margin (AGM) for five grazing strategies from 1997–98 to 2009–10 (assuming an interest rate of 7.5 % on livestock capital).*

7.3 When does heavy stocking pay?

Sensitivity analysis of the 13 years of trial data showed that the only time it paid to stock extra animals over and above those in the MSR was in years with above average rainfall, if interest rates were relatively low (<10%) and the market premium for better condition cattle was less than $0.20/kg. Given the conditions that occurred in the trial, this probably only occurs when land is still in relatively good condition. We can assume that in the longer term, the decline in land condition under heavy stocking would presumably shift the balance even further against heavy stocking.

7.4 Summary: economic performance

- Heavy stocking was initially profitable in wet years and on fair to good, B- condition pastures but was very unprofitable in dry years due to high feeding and interest costs and lower meatworks prices.
- On C- condition country, and at 0.66 of its normal stocking rate, the HSR was also profitable in very good years. However, even at this lower stocking rate it was still very unprofitable in dry years.
- The MSR was profitable in all years due to lower interest costs, the absence of drought feeding and high product value. Profitability in the R/Spell was initially similar to the MSR but later declined due to the after effects of the 2001 fire and subsequent drought.
- The VAR and SOI had high returns in the initial good years, but lost money in the transition to dry years. However, cutting stocking rates avoided the costs of overstocking in later dry years, allowing a return to profitability.
- After 12 years, AGM was highest in the VAR and MSR followed by the R/Spell and SOI. However, AGM was by far the lowest in the HSR.

8. Effects on soil loss and run-off

8.1 Management effects on run-off

Run-off and soil loss at the trial was measured using a series of 1 ha bounded plots fitted with San-Dimas flumes (for more detail see O'Reagain et al. 2005). There were 5 plots with one plot in each treatment i.e. the plots were not replicated.

Figure 22: *The HSR run-off plot and flume in March 1999 (left) and December 2006 (right). The decline in cover was a direct result of heavy stocking and low rainfall.*

In the first five or six years of the trial, there were few if any differences in run-off and erosion between strategies due to good seasons, very high cover levels and fair to good land condition. In later years, important differences in the frequency and nature of run-off events emerged, particularly between the HSR and strategies with better land condition like the MSR and R/Spell. For example, the HSR and MSR had similar rainfall amounts and intensities between 29 November 2004 and 19 January 2005 (see figure 20). Five run-off events occurred in the HSR compared to only two in the MSR strategy. Similarly, three run-off events occurred in 2005–06 in the HSR compared to only one in the MSR.

Run-off events were also larger, faster and of shorter duration in the HSR. For example on the 8 January 2005, more than twice as much run-off occurred in the HSR compared to the MSR (9 cm versus 4 cm flow depth) and the duration of the event was also shorter and sharper than in the MSR. These differences will increase both the amount and speed, and hence the erosivity, of water moving off the landscape in heavily stocked paddocks.

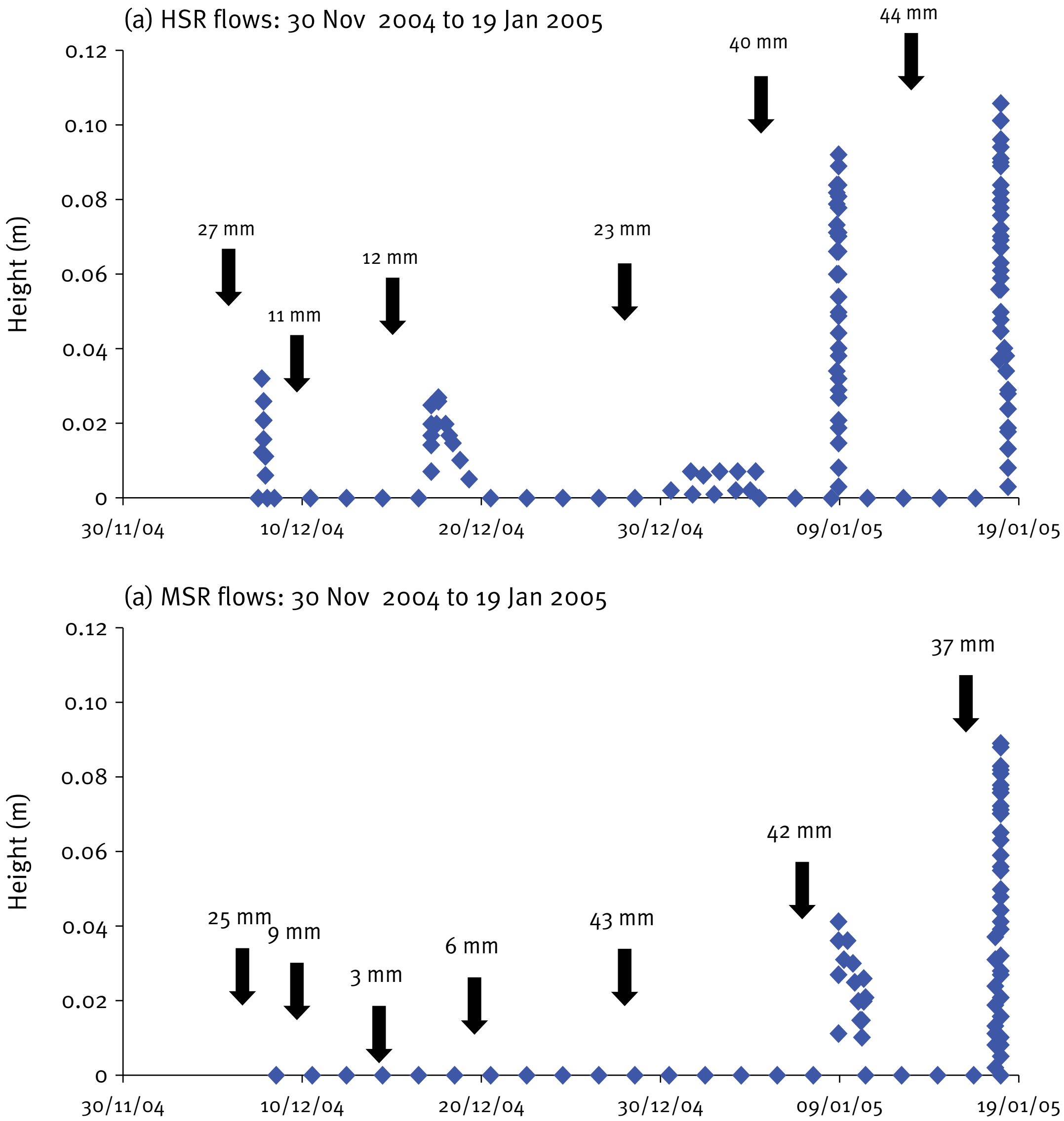


Figure 23*: Comparison of rainfall and run-off events for the HSR and MSR stocking strategies between 29 November 2004 and 28 January 2005.*

The increase in the amount and frequency of run-off in the HSR results from reduced rainfall infiltration due to declining soil surface condition and landscape functionality. This is illustrated by changes in soil moisture percentage measured in different patch types in the paddock. In general, soil moisture increased more and to a greater depth on 3-P grass patches compared to bare patches, following a rainfall event. This has obvious effects on rainfall use efficiency, and hence potential pasture growth and green leaf availability, particularly in the early wet season.

Figure 24: *Soil health is better under perennial grass tussocks (left) with higher faunal activity (right) and faster rainfall infiltration rates than bare patches or those dominated by annual plants. Photo: Grant Fraser*

8.2 Soil and nutrient loss

The amount of nitrogen and phosphorous, sediment and bed load also increased with better pasture utilisation rates and declining ground cover. Specifically, bed load movement increased sharply at grass basal areas of less than 1.5% and/or ground cover levels below 50%. Although the total nutrient and soil loss at Wambiana was relatively low compared to that measured on other steeper, more erodible land types in the Dalrymple shire such as the goldfields (Scanlan et al. 1996), in the longer term this loss of nutrients is still likely to negatively affect overall productivity.

8.3 Summary: Soil loss and run-off

1. There were more run-off events and these were of greater magnitude and intensity under heavy stocking than under moderate stocking.
2. This increased frequency and magnitude occurred due to reduced rainfall infiltration resulting from lower ground cover and reduced landscape functionality under heavy stocking.
3. The loss of nutrients, sediment and bed load increased with declining cover and increasing long-term pasture utilisation rates.
4. Increased run-off will have obvious impacts upon pasture production due to reduced soil moisture and loss of nutrients in run-off.

9. Fire effects on woodland and pasture composition

9.1 Why and how fire was applied

The trial site was burnt in October 1999 using an extremely hot, intense fire (for more detail see O'Reagain and Bushell 2003). The objective of burning was to suppress the numerous smaller, woody plants present, and maintain the tree-grass balance. Paddocks were spelled post-fire until 12 January 2000. Rainfall in the six months following the fire (1999–2000) was very good. Two subsequent fires were also applied as part of the burning/spelling treatment to sections of the R/Spell paddocks in October 2000 and November 2001 (see below).

Figure 25: *The entire trial site was burnt on the 11 October 1999.*

9.2 Pasture response

Overall, pasture recovery following the fire was good (see figure 6) due in part to favourable rainfall, post-fire spelling and possibly the long interval since the last fire (25 to 30 years). However, the response of individual species to the fire was mixed, with the frequency of desert bluegrass and dark wiregrass (*A. calycina*) declining slightly in the year post-fire. In contrast, black speargrass appeared to increase slightly in frequency following the fire.

9.3 Response of woody species

Woodland density and structure: The 1999 fire caused significant top kill to all or part of the canopy in most trees and shrubs. Despite this, most plants resprouted rapidly from basal or epicormic buds along the trunk and branches. The fire therefore had little apparent effect on woodland density with mortality rates ranging from 3.5% for box (see table 3) up to 16% for false sandalwood (*Eremophila mitchellii*). Mortality was generally greatest in the smallest size classes (<1 m) and declined with increasing tree size. Interestingly, mortality in the largest box and brigalow size classes (>12 m) was also relatively high but this largely occurred where trunks were hollow (box) and/or burning logs ignited nearby trees. Despite these relatively low mortality rates, in the long term, regular fires would still be important for maintaining an open woodland structure.

Table 3: *Percentage mortality of plants in different size classes following the application of fire at Wambiana (n denotes the number of plants across all size classes recorded for each species prior to burning).*

	Size class—height (m)						
Species	**<0.2**	**0.2–1**	**1–3**	**3–8**	**8–12**	**>12**	**All classes**
Brigalow (n=833)	14.5	13.5	8.1	3.3	0.0	37.5	11.9
Box (n=372)	0.0	10.8	1.2	0.0	3.5	5.3	3.5
Ironbark (n=370)	31.9	10.5	0.0	3.3	0.0	0.0	8.4
False sandalwood (n=231)	21.7	7.1	3.0	11.1	–	–	16.5

The fire nevertheless had a significant effect on woodland structure with a marked shift from the bigger to smaller size classes across all species, particularly in the 1–5 m size class (see figure 27). Many resprouting trees were then within easy reach of cattle and new shoots were sometimes heavily browsed, as happened with false sandalwood. Despite these initial effects on structure, recovery was rapid and by 2010 woodland structure and density was similar to or even greater than that pre-fire.

Figure 26: *Despite the intensity of the fire most woody species resprouted rapidly. Overall the fire had little effect on the density of trees but significantly changed woodland structure.*

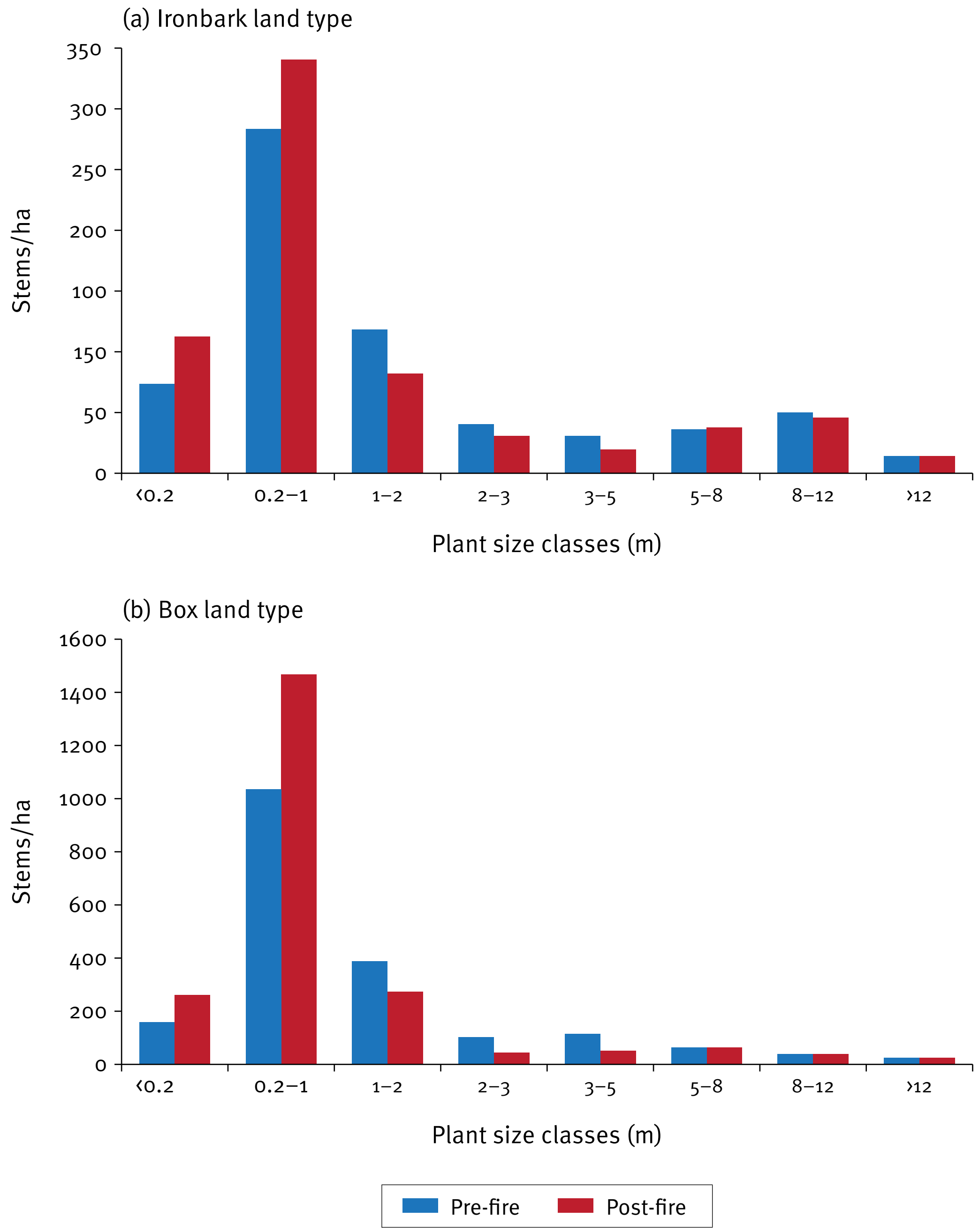


Figure 27: *The effect of fire on plant size structure in two plant–soil associations at the Wambiana trial. Post-fire measurements were made one year after the fire.*

9.4 Fire and seedling recruitment of Eucalypt species

The 1999 fire also stimulated some seedling recruitment in ironbark and blackbutt particularly in ash beds where soil was sterilised by the intense heat. However, most of the ironbark seedlings (>90%) died in the two years following, probably due to drought.

March 2000 April 2010

Figure 28: *After the fire in 2000, most brigalow suckers at this monitoring site were scorched and top killed (left) but by 2008 the suckers had grown back and were thicker than ever at the site (right) with the tall box tree in the left background hardly visible.*

9.5 Effect of fire on currant bush

Fire caused complete top kill in currant bush (*Carissa ovata*) resulting in a sharp, but relatively short-term decline in cover (see figure 29). However, rapid resprouting from underground buds in the subsequent good wet seasons ensured that *Carissa* cover recovered to pre-fire levels within two to three years. Since 2000, *Carissa* cover has increased on all soils, particularly on the box soils (see figure 30). On some of these areas, between 25 % and 30% is now covered by *Carissa* and is effectively non-productive.

Figure 29: *Regrowth of* Carissa ovata *three months post-fire.*

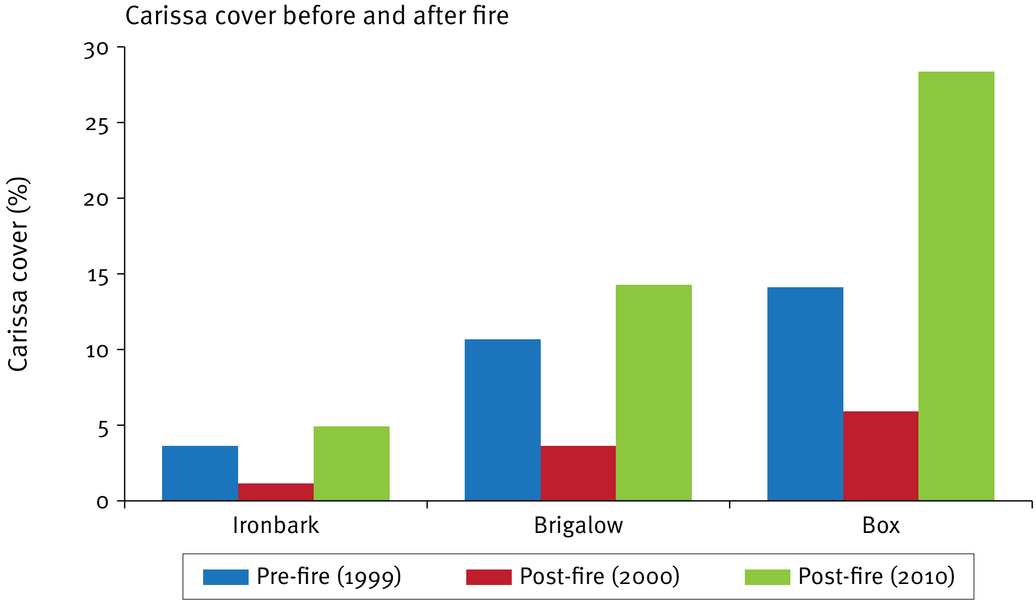


Figure 30: *Currant bush (*Carissa ovata*) cover pre-fire and one and eleven years post-fire on three landtypes at the Wambiana trial.*

9.6 Effects of follow-up fires

Two further fires were applied as part of the burning/spelling treatment to different sections of the R/Spell paddocks in October 2000 (box land type) and November 2001 (ironbark and brigalow land types).

The 2000 fire on the box land type was applied two to three days after rain and was relatively cool. This fire had no detrimental effects on pasture due to good seasons, and little apparent effect on woody species due to its coolness. Interestingly, some limited death of box saplings occurred that had previously been top killed in the 1999 fire and had then resprouted from basal buds.

The November 2001 fire on the ironbark and brigalow land types was applied immediately following rain (50 mm). Further rain fell the next day but this was followed by weeks of hot, dry weather. Rainfall was also below average in 2001–02 as well as in subsequent years. Despite six months of post-fire wet season spelling, pasture recovery was very poor with a substantial loss of cover, vigour and productivity that persisted over the next three to four years. These deleterious effects were mainly confined to the ironbark (see figure 31) with effects on the brigalow areas being relatively minor. This suggests that these low fertility ironbark areas are relatively fragile and vulnerable to short inter-fire intervals (two years) and/or the combination of fire and low rainfall.

Figure 31: *Pasture recovery on the ironbark land type in the R/Spell after the 1999 fire was good (left) but recovery from a later fire in 2001 was very poor.Right: the same site in 2003 after being spelled in the wet season in the previous two years.*

9.7 Fire and its role in sustainable management

While the effects of the single hot fire in 1999 on tree density appeared relatively minor, the mortality rates observed suggest that over time, ongoing use of fire would possibly be sufficient to keep woody species in check. The effects of fire on structure also suggest that it would be important in maintaining open woodland. However, the deleterious effects of the 2001 fire on pasture condition clearly show that fire can cause significant degradation if applied under the wrong conditions. Fire needs to be part of the management process, but must obviously be applied with caution and with regard for the inter-fire interval, land type and season.

9.8 Summary: fire effects

1. Fire had little effect on tree density with most individuals resprouting. Mortality rates ranged from 3–18% depending upon the species and were highest for the smallest size class (<1m^2).
2. Fire had a strong effect on woodland structure through top kill or partial top kill, with a large shift from larger to smaller tree size classes occurring.
3. Fire caused a significant decline in *Carissa* cover but good rainfall ensured almost complete recovery of the species in subsequent years. Since 2000, *Carissa* cover has increased by about 10% across all paddocks.
4. The effects of fire on pasture were land type and season dependent. Pasture recovery from the 1999 fire was very good on all soil types due to good rainfall.
5. A later, separate fire, followed by a dry year, resulted in significant pasture damage on the ironbark land type despite wet season spelling. Recovery from the fires on the brigalow land type was more satisfactory.

10. Key learnings from the Wambiana trial

Previous sections presented data demonstrating how the different grazing strategies coped with rainfall variability in terms of their effects on production, profit and pasture composition. In this section these findings are summarised and combined with observations and experience through the trial to produce a number of key learnings.

10.1 Heavy stocking is neither sustainable nor profitable

Heavy stocking at twice the LTCC was initially profitable due to a sequence of wet years. However in the longer term, the HSR generated far less profit than other grazing strategies, caused pasture degradation from B to C- condition pastures, increased erosion and reduced the quality of water leaving the paddock. Heavy stocking required far greater inputs (drought feeding, destocking) than the MSR and on a commercial property would also reduce management options (marketing, pasture management).

Recovery to B condition pastures in the HSR did not occur with reduced stocking rates in the latter part of the trial despite above average rainfall. Moderate to heavy stocking on these C condition pastures appears to have initiated a cycle of 'boom and bust' in production and profit, with busts likely to be more frequent due to the relatively low occurrence of above average rainfall years. With restoration of the former high stocking rate in May 2009 and an inevitable return to normal seasonal variability, further pasture degradation and economic loss in the HSR appears inevitable.

10.2 Moderate stocking is sustainable and profitable but could be improved

Moderate stocking at or near LTCC generated far more profit in the longer term than heavy stocking and was also as profitable as more complicated strategies such as variable stocking and rotational wet season spelling. Moderate stocking maintained pastures in B condition despite severe drought, and resulted in the best pasture and land condition in terms of 3-P tussock density, ground cover, species composition and pasture mass. Long-term carrying capacity was also maintained and run-off minimised.

Our observations of constant moderate stocking nevertheless suggest that some form of flexible stocking is required to prevent overgrazing and loss of animal production in drought years and periodic wet season spelling will still be necessary to counter the effects of area and patch selective grazing.

10.3 Variable stocking is no more profitable than moderate stocking and is far riskier and more difficult to manage

Varying stock numbers with available pasture (with or without the SOI) was initially very profitable, but in the longer term was no more profitable than moderate stocking at a constant rate. Very high stocking rates preceding drought caused significant pasture damage with recovery still occurring seven or eight years later. Rapid destocking with drought nevertheless avoided the costs and the severity of pasture damage recorded in the HSR strategy.

While there was some evidence that variable stocking could capture the opportunities associated with above average rainfall years, guidelines are needed to prevent overgrazing in subsequent below average years. Our experiences suggest that this can be achieved by setting clear upper limits to stocking rate based on LTCC and using a risk-averse approach to adjustment of stocking rates. As with moderate stocking, our observations also suggest that periodic wet season spelling is necessary to counteract area selective grazing.

10.4 Wet season spelling appears important for maintaining pasture condition

Wet season spelling in a 3-paddock system was profitable and maintained pastures in good condition. This is despite the ill effects of the 2002 fire, the subsequent drought and periods of heavy wet season grazing in some sub-paddocks. Although the R/Spell strategy was initially stocked at a moderately heavy rate, in November 2003 stocking rates were cut sharply in response to these latter factors. The good pasture condition in this treatment is therefore probably due to the combined effects of spelling and the change to a lighter stocking rate. There is no evidence that wet season spelling can buffer the effects of heavier stocking. Nevertheless, our observations strongly indicate that wet season spelling directly improves ground cover, pasture composition and pasture mass in the short term (see figure 32). While not conclusive, the evidence also suggests that wet season spelling can, to some extent, ameliorate the effects of moderate levels of mismanagement.

Figure 32: *Moderate stocking rate (LHS) vs the R/Spell treatment (RHS) in July 2006. The area shown was spelled for the whole of the previous wet season.*

10.5 Fire is important to limit woodland thickening but must be used with caution

Fire can be used to maintain an open woodland structure although its effects on woody density appear relatively minor. When applied under the wrong circumstances, fire was extremely damaging to pasture condition and should therefore always be used with caution. A major challenge is to effectively integrate fire with grazing management in an environment characterised by variable and unpredictable rainfall.

10.6 Overuse of certain land types occurs irrespective of the average paddock utilisation rate

Selective grazing occurs at the patch and land type scale irrespective of the level of pasture utilisation. This is likely to lead to degradation at a range of scales and should be managed accordingly. Wet season spelling appears to be at least a partial remedy to this problem.

10.7 The importance of adaptive management

Some of the management actions applied through the trial had unexpected and unfortunate outcomes. Major examples are the overgrazing and subsequent pasture degradation that occurred in both variable strategies in 2002–03 and poor recovery from the fire of November 2001 in the R/Spell.

Both outcomes required a sharp change to management. In the variable strategies, this required a more conservative and risk-averse approach to adjusting stocking rates. In the R/Spell, this involved adjusting the spelling schedule to allow the burnt area to recover and decreasing the stocking rate to prevent complete overgrazing of the non-spelled sections of these paddocks. In both cases, monitoring and adaptive, flexible management were essential in coping with the unexpected.

10.8 Conclusion

With the exception of the heavy stocking rate, all of the other strategies tested at the Wambiana trial were more or less sustainable and profitable. However, no strategy was optimal and all had deficiencies that either caused, or had the potential to cause, degradation and economic loss. We suggest that the optimal strategy would contain the best elements from those tested. This would include moderate stocking at or about long-term carrying capacity, some flexibility in stocking rates in response to seasonal condition, wet season spelling, control or amelioration of area selective grazing and, if required, periodic fire to control woodland thickening. Various forms of this suggested strategy will be tested in the next phase of the Wambiana trial as well as the existing heavy and moderate stocking rates.

Appendix

Wambiana publication list

O'Reagain, PJ, McKeon, GM, Day, KA, Ash, AJ 2003, *Managing for temporal variability in extensive rangelands—a perspective from northern Australia,* Proceedings from VII International Rangeland Congress, Durban, South Africa, July 2003, pp. 799–809. Eds. Allsopp, N, Palmer, AR, Milton, SJ, Kirkman, KP, Kerley, GIH, Hurt, CR, Brown, CJ.

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