Keeping your speargrass pastures productive—don’t overgraze

David Orr and Bill Burrows

On 26 March 2009, the Department of Primary Industries and Fisheries was amalgamated with other government departments to form the Department of Employment, Economic Development and Innovation.

Foreword

While there are areas within the coastal and sub coastal black speargrass zone which lend themselves to intensive development, the majority of the country will continue to be utilised as native pasture, or alternatively native/legume mix grazing for many years to come—hence the importance of the siting and development of the research dealt with in this publication.

The research project studied the impacts of grazing management options on soil, pasture and animal productiity in a *Heteropogon contortus* (black speargrass) pasture in central Queensland.

This information would not have been achieved without the funding provided by the then Meat Research Corporation (MRC) and the generous support of the Neill-Ballantine and Lattimer families of Galloway Plains who willingly agreed to lease the land required for such a large scale project for an initial five years and then extended the lease to enhance the research results.

Thanks go to the many individuals who lent their support to the project especially those researchers involved, some of whom are either retired or approaching retirement, having spent their whole career working for the beef cattle industry.

I commend this publication to new and old operators of grazing lands within this zone as a useful and easy to understand guide.

Bruce Chapman
Rowanlea, Calliope

Acknowledgements

Meat industry research funds (via Meat & Livestock Australia) provided critical capital and operating support which enabled the Galloway Plains grazing experiment to be established and maintained from 1987–2001. Dr Barry Walker was particularly helpful in co-ordinating the DEEDI and Meat Research fund inputs into the experiment. Land and Water Research and Development Corporation funded the rainfall runoff and soil movement measurements.

The Neill-Ballantine family made the land available and were enthusiastic co-operators throughout the duration of the experiment. Special thanks go to Jim, Chris, Des and Gordon Neill-Ballantine for their continued support and advice. A Galloway Plains Producer Advisory Committee— comprising producers David Corr (chair), John Bowes, David Parsons, Dennis Quinn, Sandra Waterson and other research representatives—also provided constructive advice on the conduct of the experiment.

Past and present staff in the Department Employment, Economic Development and Innovation (formerly Dept. Primary Industries and Fisheries and the Department Environment and Resource Management (formerly Dept. Natural Resources and Mines) contributed to the running of the experiment over the years. These included (in alphabetical order): Eric Anderson, Paul Back, Gary Blight, Bill Burrows, David Chapman, Roger Cheffins, Bob Clem, John Compton, Maurie Conway, Col Esdale, Bruce Forster, Gavin Graham, Vicki Hansen, Ron Hendricksen, Madonna Hoffmann, Bill Holmes, Dick Holroyd, Alan Lisle, Ian Loxton, Col Middleton, Len Mikkelsen, Ken Murphy, Don Myles, David Orr, Col Paton, David Reid, Mal Rutherford, Grant Stone, Mark Sallaway, David Waters, Kerrie White, John Wildin and Michael Yee.

Bob Lindley (initial three years) and Keith Jensen competently undertook the maintenance of the experimental site (including fences, stock water and animal health) throughout its duration.

This summary of research results has been prepared by David Orr and Ian Partridge. Heather Lees was responsible for the layout and design of this document.

The main messages

Growing steers on black speargrass in sub-coastal central Queensland is most profitable and sustainable if the pastures are stocked at no heavier than one Animal Equivalent (AE) on about 4–4.5 hectares.

Grazing continuously at heavier stocking rates is not sustainable because:

- the valuable perennial speargrass plants gradually decline
- less desirable grasses increase
- fewer desireable perennial grass plants results in poorer ground cover
- more rainfall runs off, taking with it precious top soil
- rainfall is lost for grass growth
- pasture production declines over time
- stock grow more slowly
- the whole landscape functions less efficiently.

The main messages from this study are:

1. Stocking rate is the overriding management factor determining the stability and productivity of pastures.
2. If total stocking rate exceeds the carrying capacity, the condition of both pasture and the landscape will decline over time. On sub-coastal speargrass, this occurred when average utilisation rate exceeded 30% of yearly growth.
3. Legumes sown into native pastures should be used for improving growth rates of steers rather than for carrying more stock.
4. Lighter stocking allows planned use of fire for managing pasture composition and controlling woody regrowth.
5. Lighter stocking is less risky and more profitable, especially as market specifications are tightened.

Other findings include:

6. The effects of short-term overstocking can be recovered by stocking lightly or by a return to good rainfall conditions. Long-term overstocking can induce an unrecoverable degradation event.
7. More permanent changes in the condition of speargrass pastures may take a number of years to show.
8. Cattle preferentially graze different pasture species and types at differing times of the year.

Experience at the Galloway project also supports the following guidelines:

9. The carrying capacity of a native pasture depends on the present condition of the vegetation and soils.
10. Stocking rates should either be aligned to a long-term sustainable average or be adjusted to match seasonal conditions.
11. Observe and monitor the pastures to pick-up short-term and long-term changes in vegetation.

Contents

Introduction

Native pastures are the most important source of forage for the Queensland beef herd, with black speargrass (*Heteropogon contortus*) country being the most important in terms of carrying capacity and potential for improvement.

Managing these native pastures so that they can continue to be productive presents a challenge to beef producers.

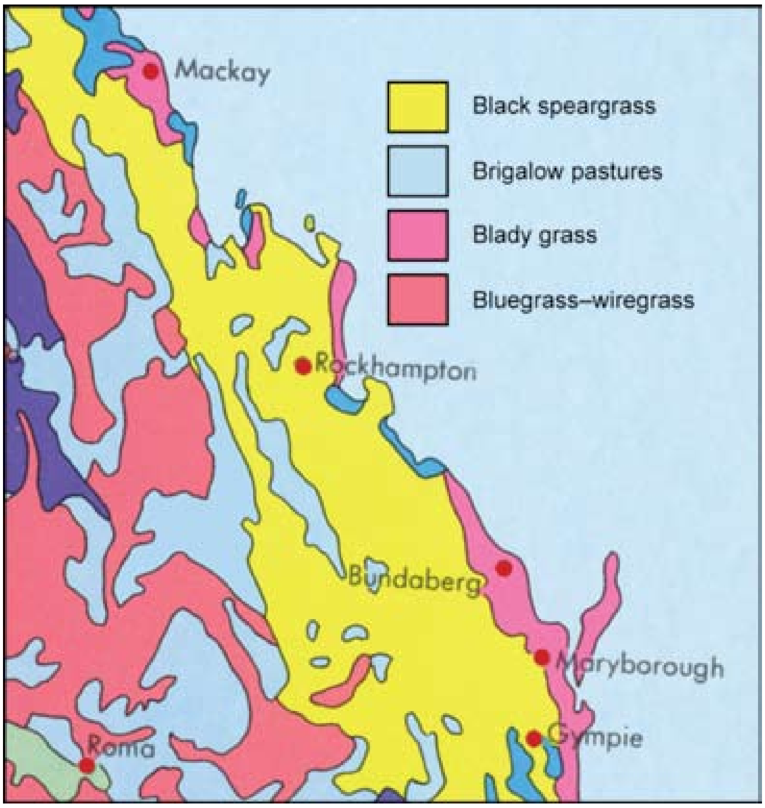
By the 1980s, the movement to Brahman-cross cattle, adoption of urea-based dry season supplements and the introduction of hardy legumes were improving profitability of beef production. However, these new technologies were allowing increased grazing pressure on our native pastures, and this heavier stocking was resulting in deleterious changes to the pastures in many regions of northern Australia.

We needed to better understand what was happening to the plants in the pastures so that we could help producers to develop management strategies that sustain their productivity.

The Australian Meat Research and Development Corporation (now Meat and Livestock Australia) agreed to co-fund a long-term detailed study of the effects of stocking rates, oversown legume, dry season supplements and fire on the productivity and stability of native pastures. This research was located at Galloway Plains, Calliope with the enthusiastic co-operation of the Neill-Ballantine family. Grazing commenced on the experimental paddocks in October 1988 and the study continued until June 2001.

General guidelines for managing speargrass country—developed from the long-term experiences of many graziers and pasture agronomists—have been published previously as *Managing southern speargrass: a graziers guide* (1993), and more information is available in MLA's EdgeNetwork course on Grazing Land Management (GLM).

This booklet concentrates on the more detailed findings of the Galloway Plains trial on sub-coastal black speargrass pastures in central Queensland. It shows how individual components of the pasture and landscape react to grazing, and provides the scientific evidence upon which the general recommendations for managing this native pasture resource can be based.



Understanding the ecosystem

There are no fixed recipes for managing native pastures. Rather grazing land managers need to:

- understand the grazing ecosystem—the interactions between the grasses, soils, grazing animals, trees and climate
- understand the role and impact of fire
- follow practical guidelines based on experience and research
- monitor for changes in vegetation and soil and respond appropriately
- understand the long-term impact of their management decisions on herd composition and economics.

The Galloway Plains grazing trial sought new information about the speargrass region of central Queensland with emphasis on the ecology of these pastures. In this small publication, these findings are summarised as some key messages for grazing management.

More complete details of the grazing trial design are included in Appendix I. In brief, the effects of different grazing management on the pasture were studied over 13 years (1988–2001). The different treatments imposed were:

- native speargrass pasture grazed continuously at stocking rates ranging from 2 to 8 hectares per steer.
- native speargrass pasture oversown with Seca stylo and grazed continuously at stocking rates ranging from 2 to 4 hectares per steer.
- native speargrass pasture grazed continuously at stocking rates ranging from 2 to 5 hectares per steer and burned when possible in spring.
- a dry season supplement treatment was discontinued after four years because its response was similar to native pasture at similar stocking rates.
- native speargrass pasture fenced off from grazing by cattle.

The treatments were duplicated on the two major soil types at the site:

- Hard-setting texture contrast soils originally carrying silver-leaved ironbark woodland and now largely dominated by black speargrass pasture
- Grey clay soils originally carrying woodlands of poplar box or blue gum and now largely dominated by forest bluegrass pasture.

Yearling steers entered the trial averaging 250 kg (0.55 AE) and were removed a year later averaging between 360 kg (0.8 AE) and 420 (0.93 AE) depending on the treatment.

What is growing in the paddock?

Recognising the grass species present in the paddock and monitoring them is the basic tool for understanding and managing the pasture resource.

In this trial, we monitored pastures each year to record:

- Standing pasture yield — the weight of herbage present (as dry matter)
- Composition — the relative proportion of each major species or species group
- Frequency — the presence of each major species or species group in sample plots (%).

Indicator species

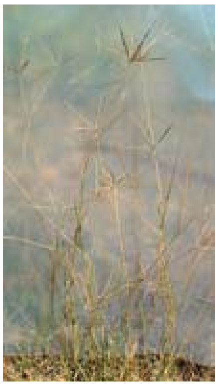
We can classify grass species according to the way they react to grazing. Under consistently heavy grazing, some species decrease, some increase while others may be unresponsive. Thus the present composition of a pasture indicates the past grazing management.

Decreaser grasses

Decreaser grasses are the species that usually decline under heavy grazing because they are selectively grazed by cattle. These most valuable species are often referred to as '3P grasses' because they are perennial, productive and palatable.

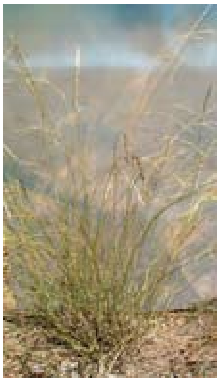
Black speargrass (*Heteropogon contortus*), hereafter just called speargrass and forest bluegrass (*Bothriochloa bladhii*), are the two perennial grasses that usually dominate in well managed pastures in this region. Their reduction or loss indicates long-term overgrazing.

Increaser grasses



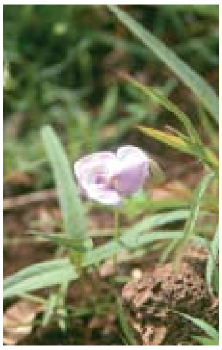
Increaser grasses are the species for which cattle have less preference; thus they increase as a proportion of the total botanical composition under heavy grazing. However, they are eaten when there is less other palatable foliage available. Pitted bluegrass (*Bothriochloa decipiens*), slender chloris (*Chloris divaricata*) and woodland lovegrass (*Eragrostis sororia*) are relatively short-lived increaser grasses. They usually dominate in pastures which have been heavily grazed.

Intermediate grasses



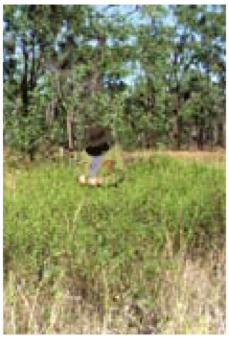
Some species have no immediate value as indicators; some appear palatable, others are not. These include the edible species golden beard grass (*Chrysopogon fallax*) and early spring grass (*Eriochloa* spp.) but also the undesirable wiregrasses (*Aristida* spp.).

Native legumes and forbs



Forbs (broad-leaved herbs) include 'weeds', such as sida (*Sida* spp.) and native legumes such as woolly glycine (*Glycine tomentosa*), rhyncosia pea (*Rhyncosia minima*) and indigo (*Indigofera* spp.). These native legumes are usually small plants and make up a small proportion of the forage eaten, but they are often high in protein.

Introduced legumes



A number of legume species have been introduced into native pastures in this region to improve animal production. These hardy legumes directly improve the quality of cattle diets—particularly during autumn as the grasses mature.

Common introduced legumes include Seca stylo (*Stylosanthes scabra*), Verano stylo (*Stylosanthes hamata*) and Wynn Cassia (*Chamaecrista rotundifolia*). Seca stylo has been the most successful introduced legume at Galloway Plains.

Behind the main messages

1 Stocking rate is the overriding management factor determining the stability and productivity of pastures

Changes in total yield and species composition

Total pasture yield

Yield describes the amount of pasture present in the field at the time of inspection (not the total growth from an ungrazed pasture). Higher stocking rates have an obvious immediate effect on yield in the paddock because more pasture is being eaten. However, there will also be a longer term effect on pasture growth if land condition declines over time. While stocking rate is the main management factor affecting yield, yields vary considerably from year to year in response to variable rainfall (figure 1).

Species composition

As the stocking rate increased, the total amount of herbage available progressively declined and pasture composition deteriorated. Adding legumes did not affect the total amount of herbage available but burning reduced it; both altered pasture composition (table 1).

With increasing stocking rate, the amounts of speargrass and forest bluegrass (the 'decreasers') tended to decline whereas the amount of pitted bluegrass, slender chloris and woodland lovegrass (the 'increasers') tended to increase over time (figure 2).

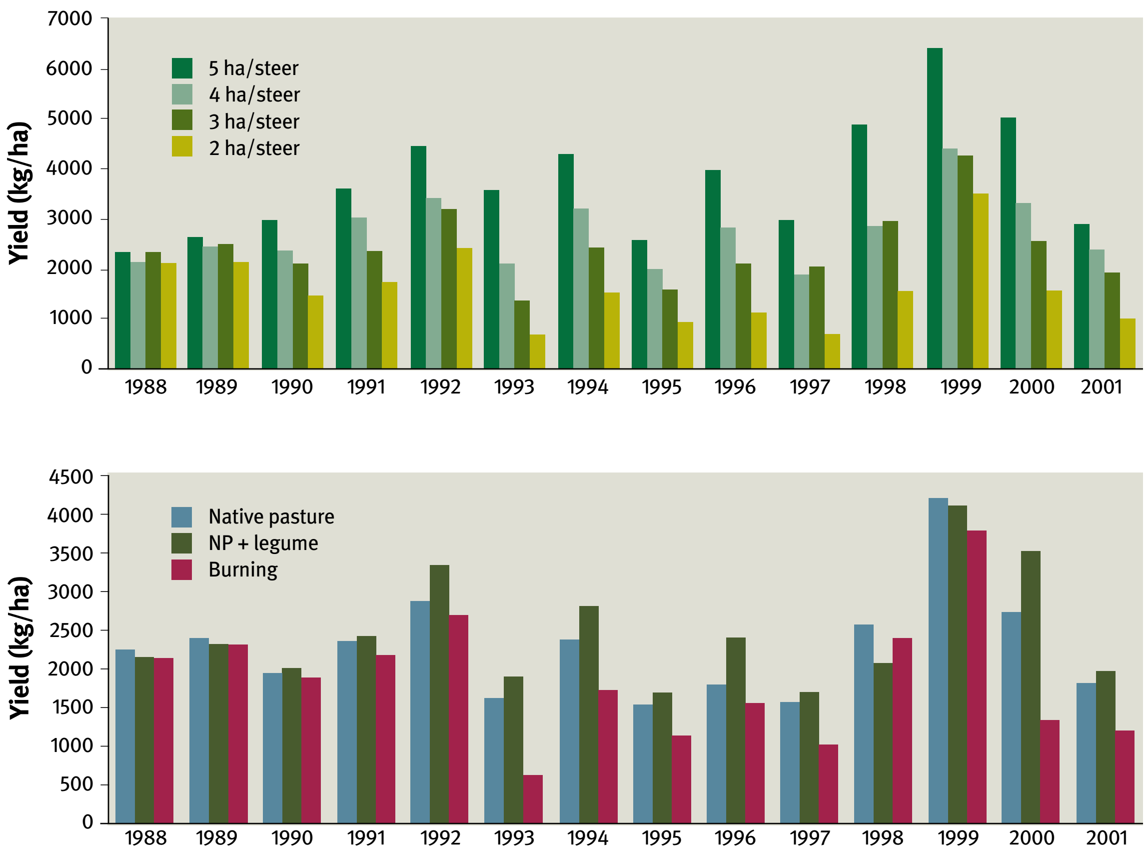


Figure 1. Effect of stocking rate and pasture treatment on pasture yield — averaged over three pasture types (bottom) and averaged over four stocking rates (top).

Species	Increasing stocking rate	Sowing legume	Burning in spring
Black speargrass	Decreases	Decreases	Increases with burning at light stocking rate
Forest bluegrass			Decreases with burning at light stocking rate
Pitted bluegrass	Increases		
Slender chloris	Increases		
Golden beard grass			Increases with burning
Woodland lovegrass	Increases		Increases with burning
Wiregrass	Increases with lower stocking rate		Decreases with burning
Barbwire grass	Increases with lower stocking rate		
Hairy panic	Decreases		
Sporobolus	Increases		
Purpletop rhodes grass		Increases	
Small burr grass	Increases		
Other grasses			Decrease with burning
Sedges			Decrease with burning
Native legumes		Decrease	
Malvaceae	Increases		
Other forbs		Decrease	

Table 1. Impacts of stocking rate, oversowing legumes and burning on pasture composition

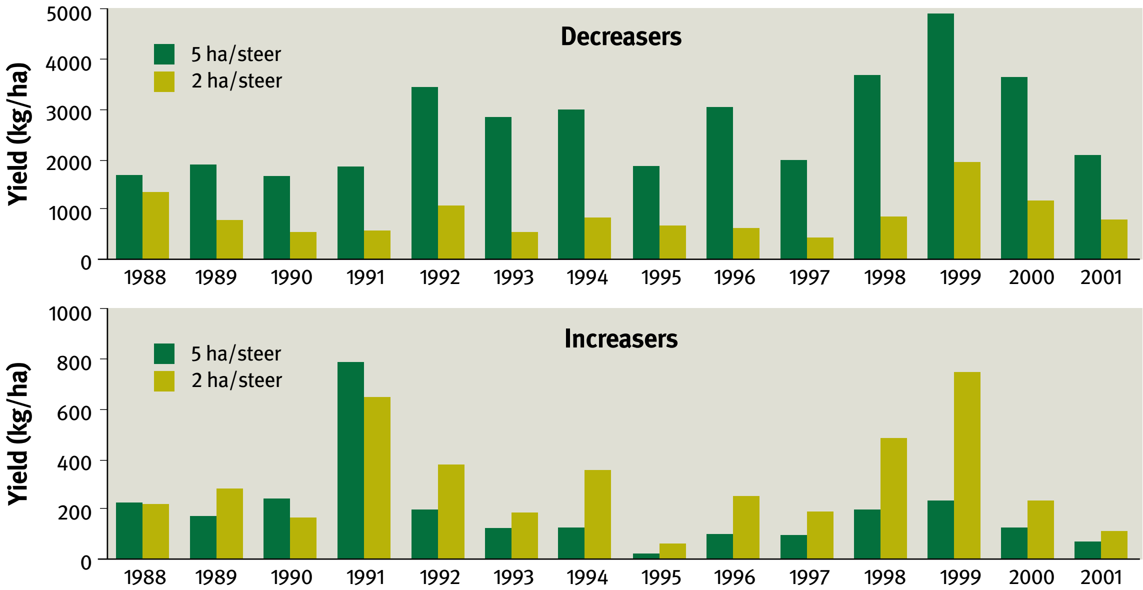


Figure 2. Effect of stocking rate on the yield of decreaser species and increaser species over time

There were just as many plants of the decreaser grasses but they were smaller—the plants were being '*grazed down*' rather than being '*grazed out*'.

In contrast, the higher yield of increaser grasses was because there were more plants—they were spreading through the pasture.

The unpalatable wiregrasses (*Aristida* spp.) increased in both number and yield of plants under light grazing in the unimproved pasture because cattle did not to eat them (figure 3).

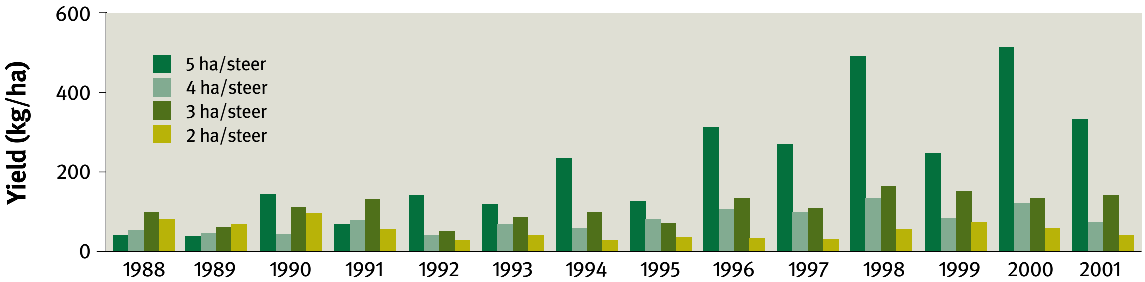


Figure 3. Effect of stocking rate on the yield of wiregrass in unimproved native pasture over time

The number of plants of small burr grass, Sporobolus and the *Malvaceae* forbs all increased under heavy stocking, but they contributed little to yield.

Size and number of the perennial grass tussocks

'Basal area' measures the area of the bases of the tussock grasses as a percentage of the soil surface area covered. It indicates potential grass production and the pasture's ability to buffer rainfall run-off and erosion (see page 9).

In the unimproved native pasture, total basal area of all perennial grasses was higher under the high stocking rate than under the low stocking rate.

At low stocking rates, the basal area of the big decreaser tussock grasses remained consistently high while that of the increaser grasses did not change.

At the high stocking rate, the basal area of decreaser grasses declined in the first four years, but then recovered slightly. However, the basal area of the increaser grasses rose as the numbers of short-lived perennial species such as the less productive chloris, lovegrass and pitted bluegrass increased (figure 4).

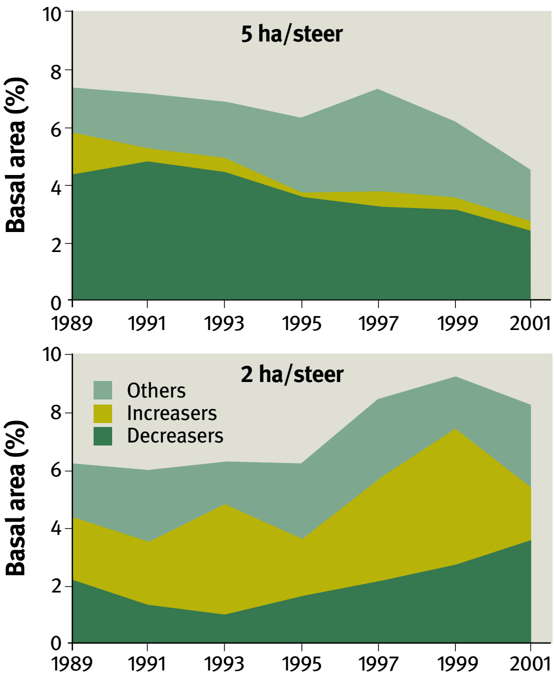


Figure 4. Changes in basal area of perennial decreaser and increaser grasses at 5 ha/steer and 2 ha/steer in unimproved pasture.

Stocking rate and diet selection

Stocking rate has a major impact on what the steers eat. At low stocking rates, the animals could select a high proportion of decreaser grasses and ate little of the increaser grasses. At high stocking rates, the steers could select less and less of the decreaser grasses over time and so were forced to eat more of the increaser grasses (figure 5).

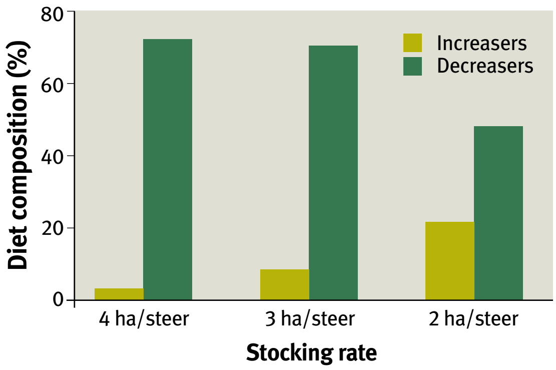


Figure 5. The effect of stocking rate on the proportion of decreaser and increaser grasses selected by steers.

However, steers actively selected speargrass rather than forest bluegrass (figure 6) even though the latter was more plentiful. With double the stocking rate, the speargrass in the pasture dropped from 20% to 10% while the speargrass in the diet dropped from 50% to 20%. In contrast, steers consistently selected about 25% forest bluegrass in their diet in autumn, irrespective of the proportion in the pasture or the stocking rate.

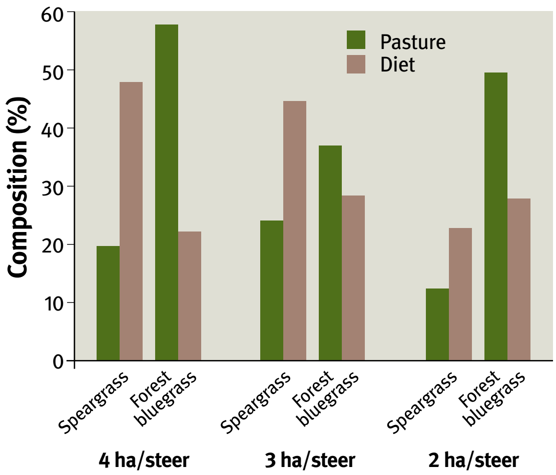


Figure 6. The effect of stocking rate on the ability of steers to select their favoured speargrass.

Although slender chloris and woodland lovegrass increased with stocking rate, they usually comprised less than 5% of the pasture yield; only at 2 ha/steer did they comprise more than 10% of the diet (figure 7). Slender chloris is more palatable than lovegrass.

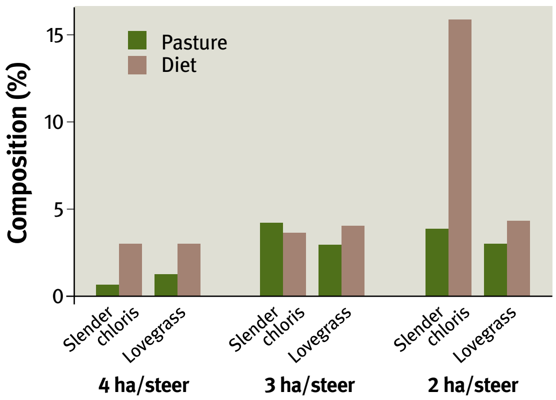


Figure 7. The effect of stocking rate on the proportions of slender chloris and woodland lovegrass available in the pasture and actually eaten.

Stocking rate and animal production

Average annual liveweight gains of steers were related to stocking rate, pasture type and seasonal rainfall. The highest annual liveweight gain of 175 kg/steer came off pasture oversown with legume at 4 ha/steer and the lowest was 112 kg/steer at 2 ha/steer on unimproved native pasture (figure 8a).

On a per hectare basis, the highest annual liveweight gain of 65 kg/ha came off the oversown legume at the highest stocking rate (figure 8b).

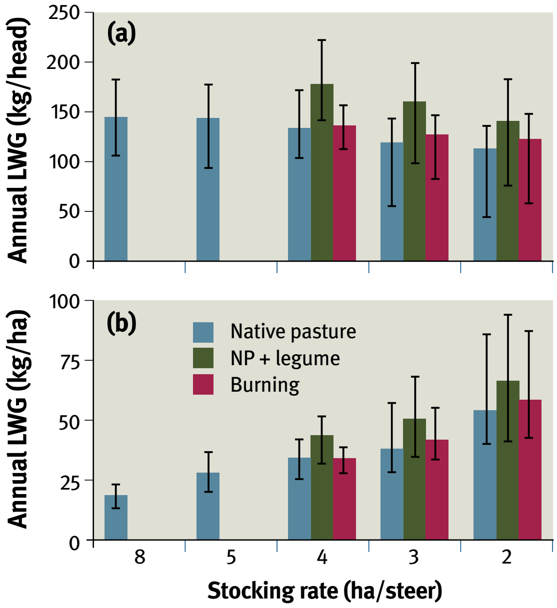


Figure 8. The effect of stocking rate and pasture treatment on (a) average annual liveweight gains of steers ***per head*** *and (b) liveweight gain* ***per hectare****. (Vertical lines represent the range of liveweight gains)*

Weight gains on unimproved pasture started to decline when the stocking rate increased above about one steer on 4 ha, as diet selection was hindered.

On the unimproved pastures, weight gains during spring were responsive to effective storm rains, but most of the annual gain occurred during summer (December to April). After good rainfall in late summer-autumn 1996, steers continued to gain weight at low stocking rates but could only maintain weight at higher stocking rates (4, 3 and 2 ha/steer) (figure 9a).

During the drought years of 1993–94, all steers stopped gaining weight in May but those at light stocking rates subsequently had lower weight losses (figure 9b).

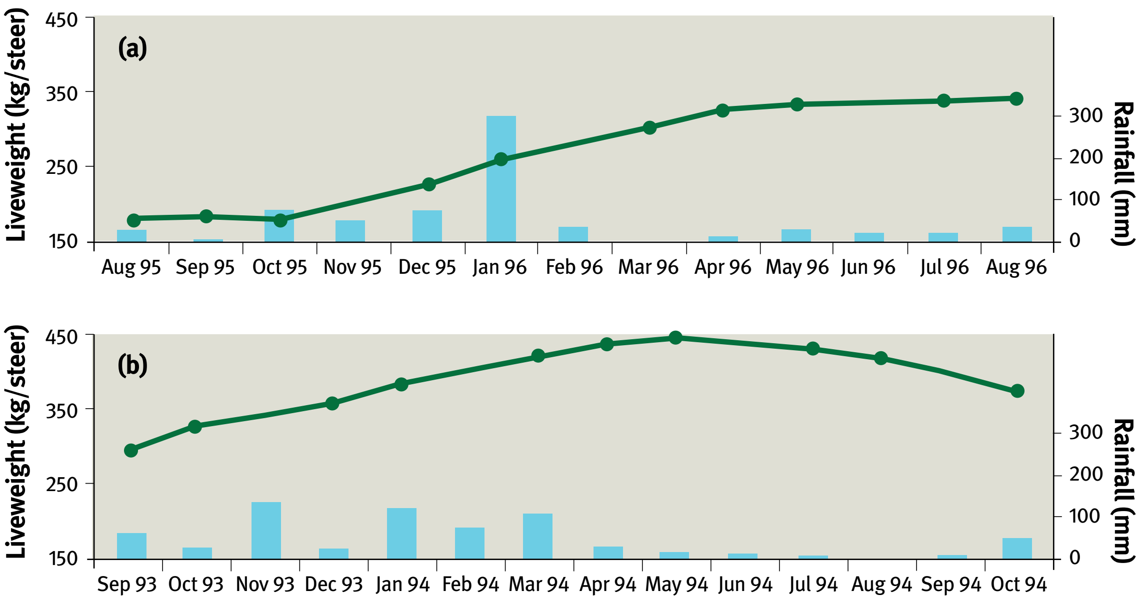


Figure 9. Comparison of steer growth patterns in (a) a 'wet' year (1995–96) and (b) a 'dry' year (1993–94) (note differing start weights and entry times).

2

If total stocking rate exceeds the carrying capacity, the condition of both pasture and the landscape will decline over time. On sub-coastal speargrass, this occurred when average utilisation rate exceeded 30% of yearly pasture growth.

Pasture utilisation

Utilisation measures the proportion of herbage grown that is eaten. On speargrass pastures, the average threshold level of utilisation is thought to be about 30%. Levels consistently above this progressively degrade the soil and pasture although the rate of degradation depends on the rainfall pattern. Over the trial period, average pasture utilisation rates increased with increasing stocking rate. Stocking rates of 8, 5 and 4 ha/steer resulted in sustainable levels of pasture utilisation (under 30%) in most years, but stocking at 3 or 2 ha/steer is considered unsustainable due to decline in 3P grasses and loss of soil condition.

Utilisation levels were slightly lower on the more productive grey clay soils than on the texture-contrast soils because total pasture growth was higher (figure 10).

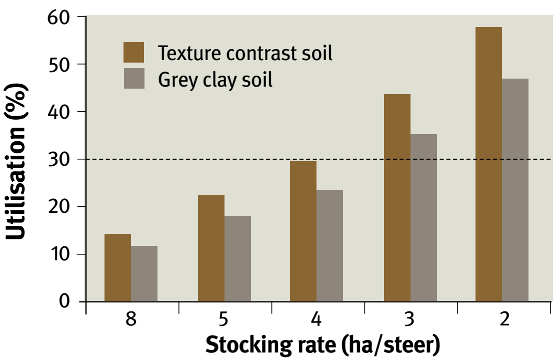


Figure 10. The effect of stocking rate on average levels of pasture utilisation (1988–2001).

Landscape function through rainfall runoff and soil movement

Stocking rate can indirectly affect rainfall infiltration, and hence runoff and soil movement, through its effect on plant cover and on the soil surface.

Runoff and soil movement were recorded in small catchments of about 2000 square metres on slopes of 4–6%. The catchments were in a fenced-off, ungrazed area and in pastures grazed lightly

(4 ha/steer) and heavily (2 ha/steer) on the hard setting, more erodible texture-contrast soil.

Cumulative run-off (figure 11) and soil loss (figure 12) in the ungrazed area were similar to those that were grazed lightly, but cumulative run-off *doubled* and the soil loss increased *fourfold* when the stocking rate was doubled to 2 ha/steer.

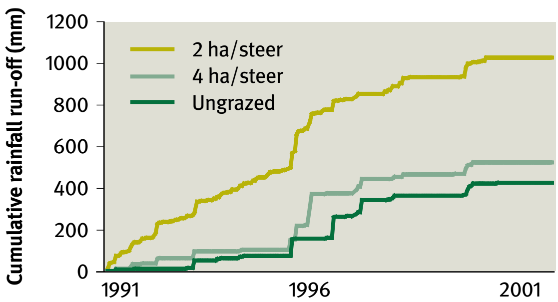


Figure 11. The effect of stocking rate on cumulative (over 10 years) rainfall run-off under speargrass pasture.

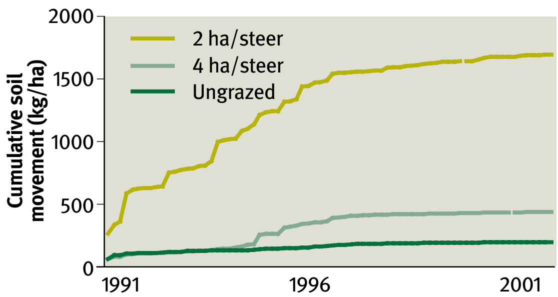


Figure 12. The effect of stocking rate on cumulative soil loss (over 10 years) under speargrass pasture.

Slightly better animal weight gains per ha come at the cost of greatly increased soil loss (figure 13).

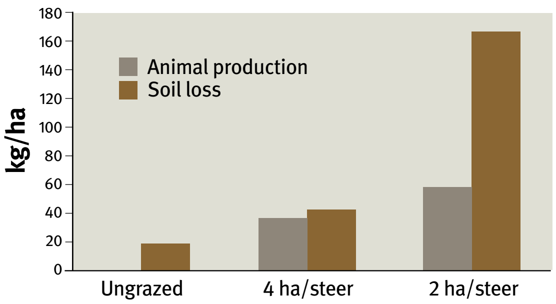


Figure 13. The effect of stocking rate on animal production and soil loss.

Landscape function and patch grazing

Landscape function analysis looks at the distribution of grassy patches to assess soil productive potential across the landscape. Ungrazed or lightly grazed patches are usually dominated by perennial grasses which encourage the infiltration of water into the soil and the retention of nutrients and surface soil. Inter-patches are often bare ground which have poor infiltration and can permit water, nutrients and soil sediments to move across the soil surface and away from the pasture. The size and distribution of these patches and inter-patches determines the 'leakiness' of a pasture system.

By December 2000, the condition of paddocks at Galloway Plains reflected the impact of 13 years of grazing on the landscape. Landscape function was assessed at high and low stocking rates in the unimproved pasture and at the high stocking rate in the pasture with oversown legume.

Spatial patterning of resources

Perennial grass cover was highest at the low stocking rate in unimproved native pasture, intermediate at high stocking rate and lowest at high stocking in the pasture oversown with legumes. Sedges and forbs were highest in heavily stocked unimproved pasture (figure 14).

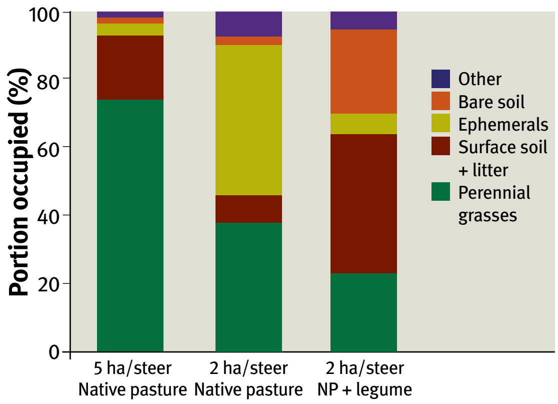


Figure 14. Proportion of transect length occupied by components of landscape at three treatments in December 2000.

Soil surface indicators

Landscape stability, infiltration and nutrient cycling were all highest on lightly stocked unimproved native pasture (figure 15).

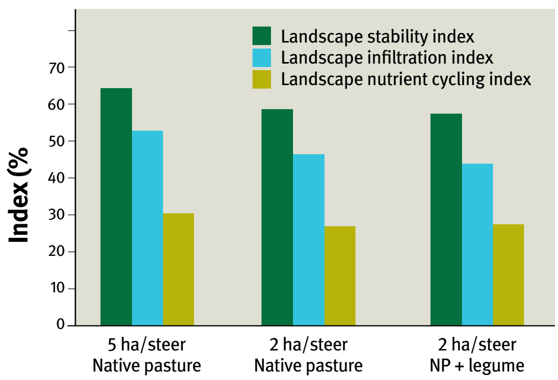


Figure 15. Landscape stability, infiltration and nutrient cycling under different pasture treatments in Dec 2000.

Patch grazing was rare under light stocking, was seasonally well developed at moderate stocking rates and disappeared at heavy stocking rates where the whole paddock was heavily grazed. But heavy grazing to remove patches can lead to many long term deterious consequences – as detailed above and earlier.

3 Legumes sown into native pastures should be used for improving growth rates of steers rather than to carry more stock

Changes in botanical composition

Seca stylo was the most successful of the legumes sown and it progressed from less than 1% of total pasture present at the start of the trial to about 50% within 8–9 years regardless of stocking rate (figure 16). Its percentage contribution did drop markedly over the last year of the trial but the population was still very dense. Density started at 1–2 plants per square metre and increased gradually to around 15 plants per square metre; the rate of increase then accelerated such that within 8 years there were 60 plants/m² at higher stocking rates and 90/m² at the lower stocking rate of 4 ha/steer. Competition between legume seedlings at very high densities may reduce their own survival while preventing young speargrass seedlings establishing (figure 17).

Stylo seedling density is related to the amount of legume seed in the soil. There were more than 600 seeds of stylo per square metre in the lightly grazed pasture, about 70% of these can germinate quickly, the rest is 'hard' seed that may germinate after favorable rain in the future (figure 18).

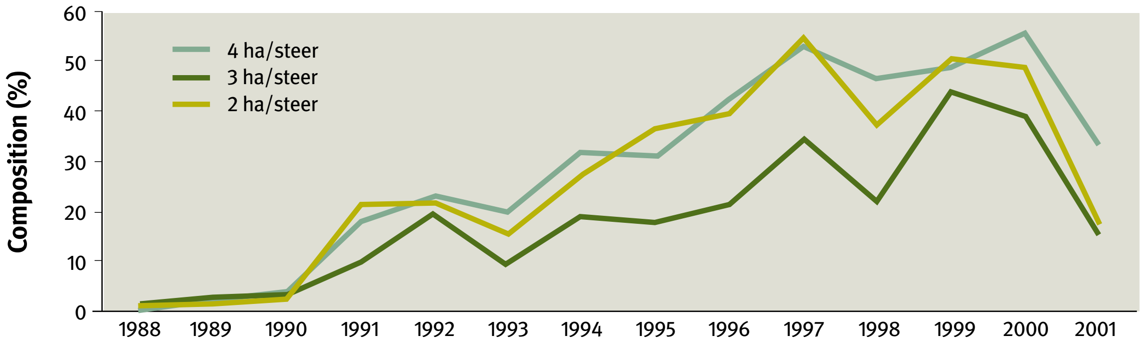


Figure 16. The increasing contribution of legume (Seca stylo) to the pasture over time.

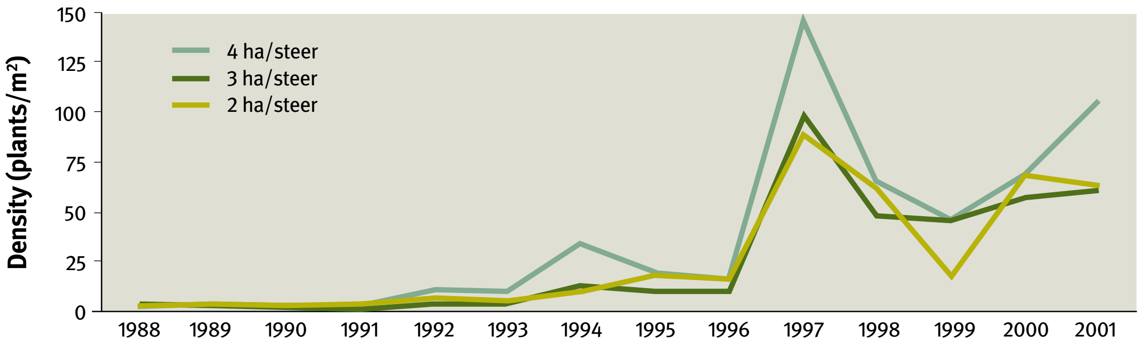


Figure 17. The effect of stocking rate on Seca stylo density.

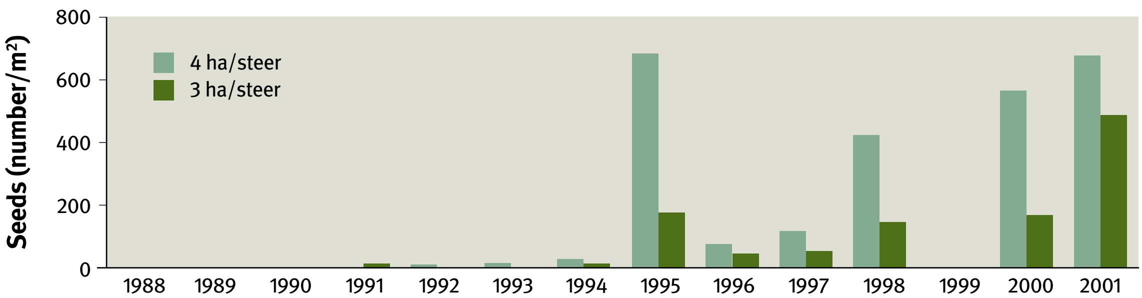


Figure 18. The effect of stocking rate on the build-up of Seca seeds in the soil.

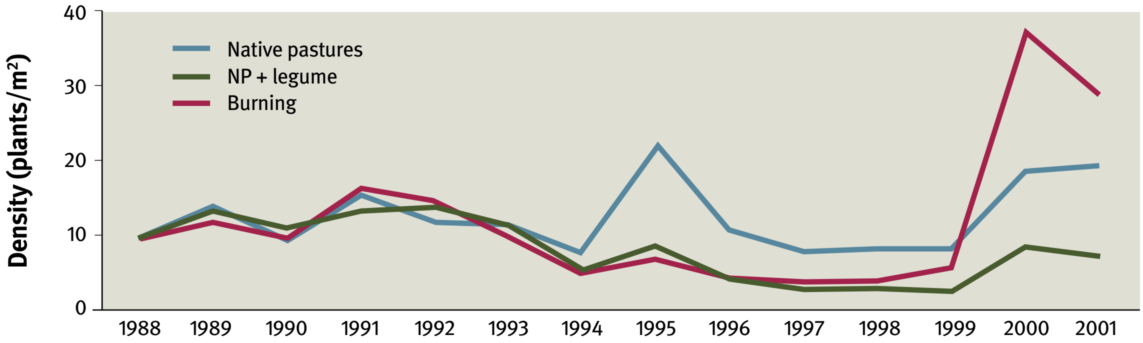


Figure 19. Sowing legume and burning affects the density of speargrass (averaged over three stocking rates).

In the legume paddocks, speargrass became less and less dense over the period of the trial at all stocking rates as the seed bank of grass declined (figure 19). This decline was more pronounced under heavier stocking rates.

Sowing Seca stylo also affected some minor species; purple top rhodes grass (*Chloris inflata*) invaded while both the native legume and 'other forbs' groups became less common.

Animal production

Average cattle weight gains have been described earlier. Over the 13 years, the highest average weight gain per animal of 175 kg/year came off the Seca pasture at the low stocking rate (4 ha/steer) whereas the lowest average gain of 112 kg/year came off heavily stocked native pasture at 2 ha/steer.

On a per hectare basis, the highest annual weight gain of 65 kg/ha came off pastures oversown with legume at the highest stocking rate.

Performance varied considerably between years and reflected rainfall. The highest gains recorded were 221 kg/head at 4 ha/steer on Seca pastures and 182 kg/head on native pasture at 8 ha/steer in 1995–96. The lowest gain was 43 kg/head off unimproved native pasture at 2 ha/steer in the drought year of 1992–93.

Extra weight gain from legumes

The more legume present, the better the weight gain by steers. The animals did not respond much until the legume contribution reached about 10%; thereafter the extra weight gain increased until about half the pasture was legume and the steers were putting on an extra 40–50 kg per head per year (figure 20).

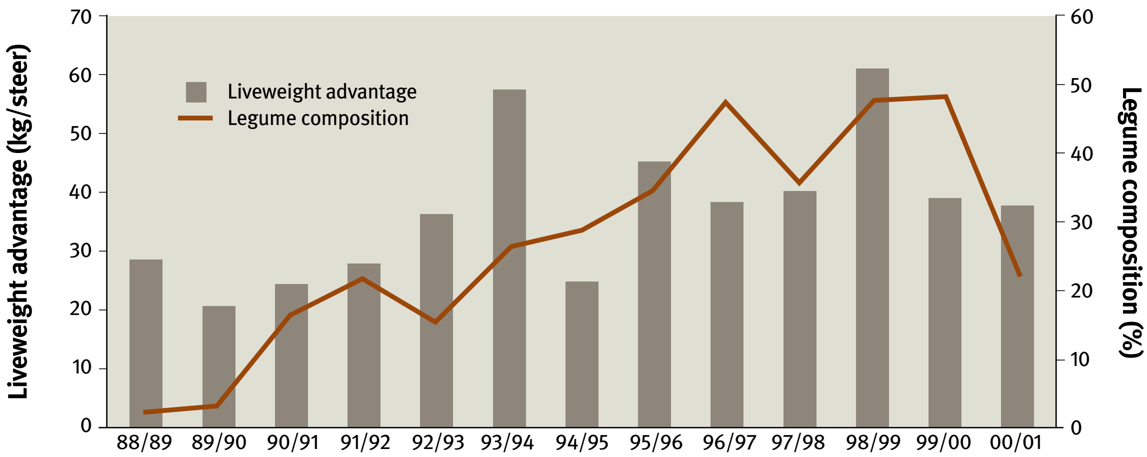


Figure 20. Extra weight gains by steers grazing legume and the percentage of legume in the pasture (averaged over three stocking rates).

Note 1: The good gains in the first year were probably because of nitrogen release when strips of soil were disced to establish legume seed.

Note 2. Although this diagram suggests that more stylo in the pasture will give better weight gain, the steers did not appear to be eating ever increasing amounts of legume in autumn.

The main benefit from the legume occurs in the autumn and early winter period as the native grasses seed and mature. At this time, steers actively select stylo and their diet can contain up to 40–60% legume.

With the good rainfall of 1995–96, steers on Seca pastures continued to gain weight during winter whereas those on unimproved pasture at the same stocking rates only maintained body weight. In the drought year of 1993–94, steers on legume more or less maintained weight whereas others at the same stocking rates lost weight.

At low stocking rates, cattle had sufficient pasture available for them to select and eat as much legume as they wanted, but not when heavily stocked. Despite the lower intake of legume at 3 and 2 ha/steer, the steers still gained more weight than those on unimproved pasture at the same stocking rate.

Legume and the diet

In autumn, steers selected legume in preference to grass at all stocking rates, but were forced to eat more grass at higher stocking rates (figure 21).

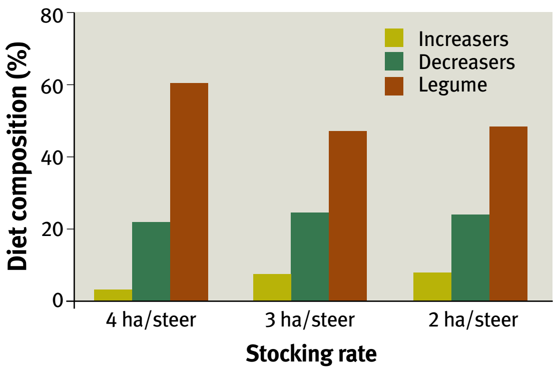


Figure 21. The effect of stocking rate on the proportion of decreaser and increaser grasses and legume eaten by steers in autumn.

Nitrogen content of the diet

The nitrogen content of steer diets, measured during 1993 and 1996, was consistently higher (at 1.3% N) in the legume paddocks than in the unimproved pasture and burning treatments.

Despite the good weight gains, producers should not be tempted to graze legume pastures at high stocking rates because they risk losing the good perennial grasses.

The loss of grass that occurs when Seca becomes dominant (above 50% of the pasture) should be avoided because:

- perennial grasses protect the soil surface better than the stemmy stylo plants
- stylo dominance without a vigorous grass to use up surplus soil nitrogen may acidify the soil over the longer term (although we found no evidence of this).
- feed may run short at times when Seca gets frosted and drops its leaf.
- feed could run short more seriously if Seca stylo becomes susceptible to a disease or pest, such as a new strain of anthracnose fungus (as happened to Townsville stylo in the past).

Stylo dominance can be prevented by:

- resting the pastures during summer. As cattle selectively graze green grass during the summer, resting over this period allows the perennial grasses to strengthen.
- burning in spring. Burning kills old stylo plants and creates space in the pasture for perennial grasses. For an effective burn in spring, the pasture may need to be rested in the previous autumn. After the burn, the grasses should be allowed to grow (and preferably set seed) before grazing re-commences.

Lighter stocking allows planned use of fire for managing pasture composition and controlling woody regrowth

4

Low fuel loads experienced during the trial were caused by a combination of grazing pressure treatments and the series of dry years. The native pastures at higher stocking rates (2, 3 and 4 ha/steer) could be burnt only in the springs of 1992 and 1999 because there was insufficient fuel load following low rainfall.

Burning increased the yield of speargrass, at the expense of forest bluegrass, at the lowest stocking rates, but did not affect its frequency or the yield of forest bluegrass at the 4, 3 and 2 ha/steer. Speargrass needs the combination of fire and a good supply of seed in the soil for a response (figures 22 and 23).

Paddocks are best burnt after 25 mm of rain has fallen in spring; this gives a relatively cool fire and a chance of grass growth if follow-up rain is poor. If the intent is to control woody regrowth, a hot fire will be required.

Burning reduced the yield of wiregrass by removing the uneaten bulk but did not affect its frequency (figure 24); it increased the amount of woodland lovegrass (*Eragrostis* spp.) and golden beard grass (*Chrysopogon falax*) and the frequency of sedges.

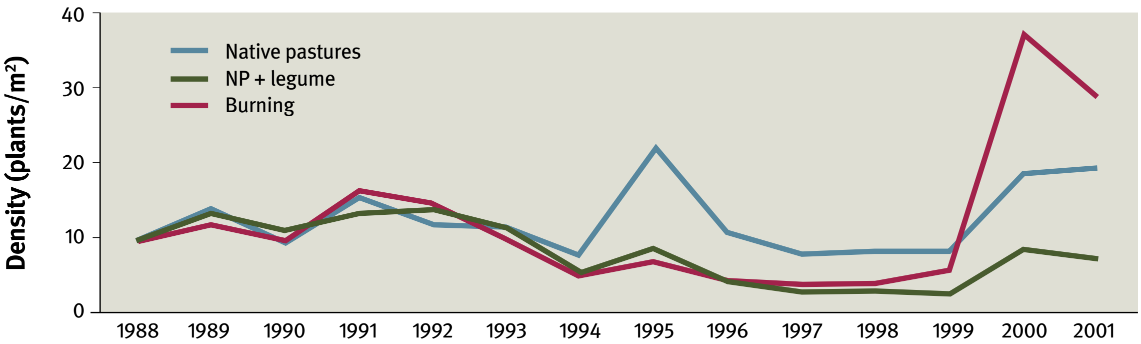


Figure 22. Changes in the density of speargrass with fire and with oversown legume (averaged over 3 stocking rates).

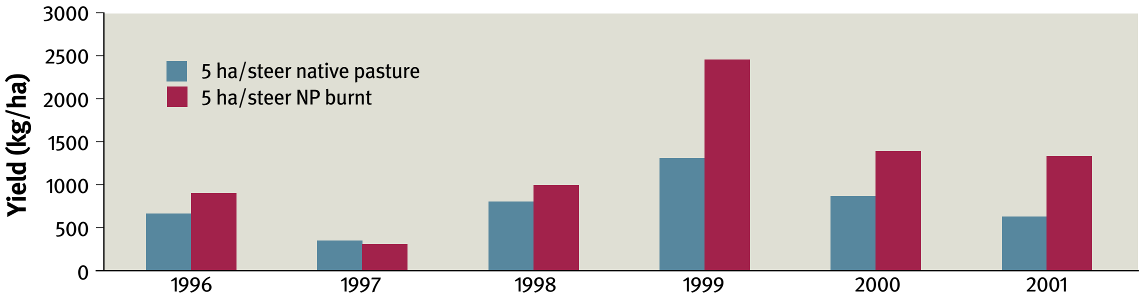


Figure 23. The effect of fire on the yield of speargrass under light stocking.

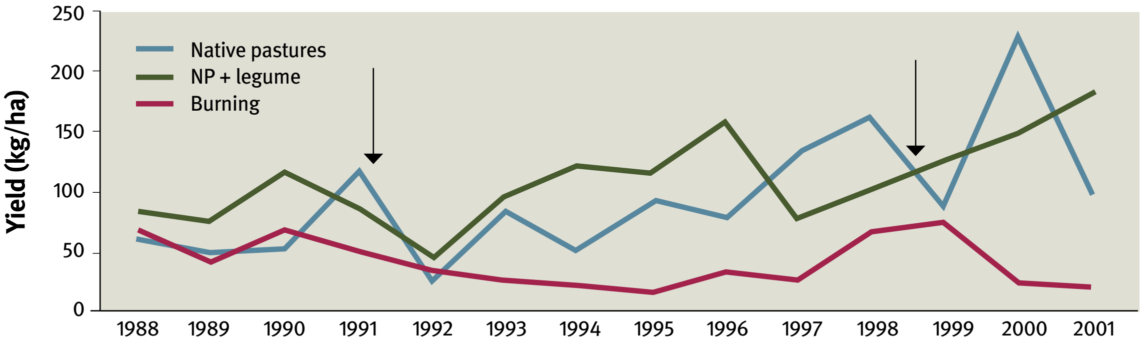


Figure 24. Changes in the yield of wiregrass with fire (averaged over 3 stocking rates). Arrows depict time of burn.

Burning and speargrass seed

Light grazing allows speargrass to drop plenty of seed while the associated fuel load allows a good fire. A spring fire directly stimulates these seeds to germinate and speargrass seedlings, will establish if summer rains are adequate.

In spring 1999, there were 500 seeds of speargrass per square metre under low stocking rates but only 20 per square metre under the high stocking rate (figure 25). The density of speargrass in the lighter-grazed paddocks increased substantially in 2000 after good rainfall over the spring and summer of 1999–2000.

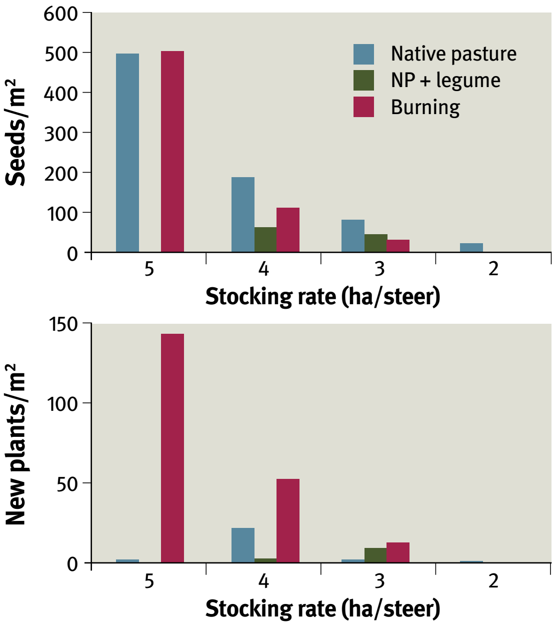


Figure 25. The effect of stocking rate and burning on soil seed banks of speargrass in spring 1999 (top) and on seedling recruitment by autumn 2000.

Protein in diet

After burning the grass in the spring of 1992, the nitrogen content (protein) of the steers' diet increased in the next autumn, but this did not occur in 1996 (figure 26). Higher nitrogen content was probably related to the easily reached 'green pick' in contrast to the unburned pasture where the bulk (1750 kg/ha) of standing mature forage would have made fresh green leaf less accessible to the stock.

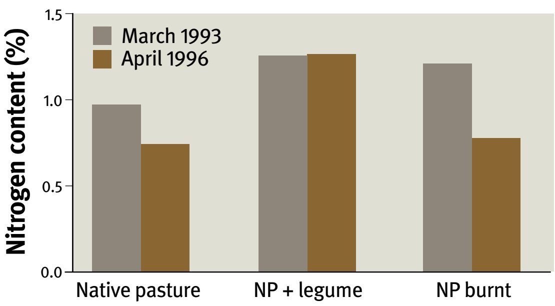


Figure 26. Nitrogen content of the diet of steers in the autumn (1993 and 1996) following spring burning compared to that of unimproved and legume pasture (average of 3 stocking rates)

Burning and cattle performance

The overall effect of burning on weight gain was inconsistent (figure 27). In spring 1992, burning improved steer weights and some of this effect carried over into the next year. By 1994–95 however, steers at the high stocking rate gained less weight because of poor pasture growth under low rainfall. In spring 1999, burning improved weight gains at 2 and 3 ha/steer but not at 4 ha/steer. There was some carry-over effect at all stocking rates into the next year.

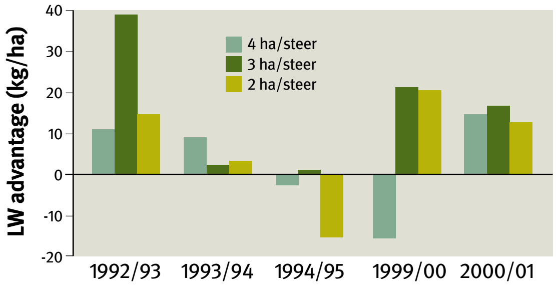


Fig 27. The effect of burning pasture on the weight gain of steers at 3 stocking rates in 1992–93 and 1999–2001.

The impact of burning on weight gain on lightly grazed (5 ha/steer) pasture was also variable. Burning in spring 1996 and 1998 achieved only modest weight advantages but it marginally reduced weight gains in 1999 (figure 28).

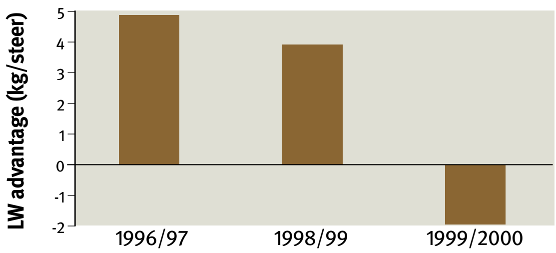


Figure 28. The effect of burning lightly grazed native pasture on weight gains of steers.

The overall impact on animal performance from burning is therefore inconsistent although it has an important impact on pasture composition particularly at light stocking rates. A spring fire every 3–5 years is beneficial to speargrass pastures given careful grazing management following the fire.

Burning native pasture can improve weight gains in steers provided there is follow-up rain. If summer rains fail after a fire, heavily stocked cattle may have insufficient feed and gain less weight than on unburnt native pasture. Seasonal climate forecasting based on the Southern Oscillation Index (SOI) in winter-spring can provide a guide to the advisability of burning.

Lighter stocking is less risky and more profitable, especially as market specifications are tightened

5

Cattle performance

Weight gain per animal grazing unimproved native pasture increases (up to a point) as stocking rate is lightened; weight gain per hectare is reduced. The pattern is similar for native pastures oversown with legume but the overall weight gains are considerably higher.

Lighter stocking also reduces risk by keeping a reserve of grass in case the rains fail.

We have seen that, averaged over the 13 years of the trial, the highest weight gains per head (175 kg/year) came off the legume pasture at the lowest stocking rate (4 ha/steer) and the lowest gains were 112 kg/year off the unimproved native pasture at the highest stocking rate of 2 ha/steer.

While the highest annual weight gain per hectare (65 kg/ha) came off the oversown legume at the highest stocking rate, these steers may not reach a target weight for sale, and the loss of perennial grass under this pressure makes this unsustainable in the long run.

Our measurements at Galloway Plains suggest that cattle are unlikely to consistently achieve 'Jap Ox' market specifications on native pasture without legume. Breeding and store production would be more profitable in this sub-coastal speargrass zone.

Economic analysis

The economics of grazing management and improvement of these speargrass pastures were compared using Net Present Value (NPV).

This economic analysis assumed:

- Animal weight gains based on the results from the Galloway Plains study (based on the liveweight gain per steer for each grazing treatment averaged for the 12 drafts of steers).
- A 1000 ha paddock, a 12-year time scale, capital (livestock) inputs with borrowings and discount rate of 6% applying over the period.
- Steers enter the paddock at 180 kg liveweight, graze until they average 450 kg, then sold as stores for finishing.
- Steers are priced into the paddock at $1.95 per kg liveweight (store steer price at Gracemere Saleyards in central Queensland on 19 March 2004).

Financial returns are similar at 3, 4 and 5 ha/steer but are reduced at 2 ha/steer because of the lower weight gain per head (figure 29).

Thus somewhat heavier stocking rates may be profitable in the short term but become unsustainable as the condition of the land and pasture declines. There is no significant economic incentive to overstock unimproved speargrass pastures.

Returns from grazing pastures oversown with legume were higher than those from unimproved native pasture at the same stocking rate. Although stocking these oversown pastures at 3 and 2 ha/steer appears to be more profitable, the deleterious effects on soil and pasture condition make this unsustainable. To maintain land condition, continuous grazing would have to be at an average stocking rate lighter than 3–4 ha/steer. At higher stocking rates, the pastures would require a more complex management system that includes forage budgeting, regular assessment of land condition and targeted use of wet season spelling.

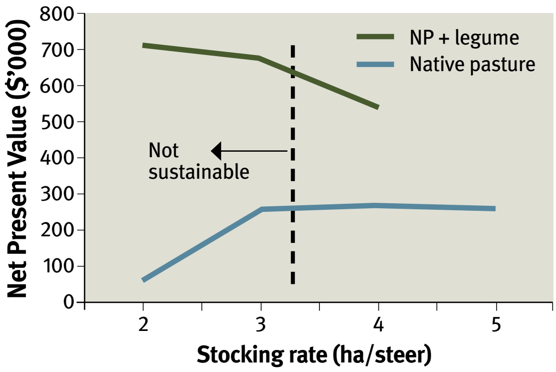


Figure 29. Economic evaluation of grazing using Net Present Value

6 The effects of short-term overstocking can be recovered by stocking lightly or by a return to above-average rainfall conditions. Long-term overstocking can induce an unrecoverable degradation event

What happens to speargrass plants?

At the start of the study in 1988, we identified about 60 individual speargrass plants in 25 marked locations in selected treatment paddocks. In 1996, we located another bunch of individual plants in the 5 ha/steer burnt treatment to examine the impact of burning at this light stocking rate. We recorded the density, survival and size of these initial plants and the presence of new plants each autumn between 1988 and 2001.

The original speargrass plants survived best at the low stocking rate of 5 ha/steer. Overall, speargrass plants became more dense under light stocking, reflecting better seedling establishment and survival, whereas they declined in number under heavier stocking rates (figure 30).

Flushes of new plants are related to the amount of seed in the soil from the previous year and the rainfall during the growing season (figure 31).

Figure 30. The effect of stocking rate and rainfall on the density of speargrass plants over time.

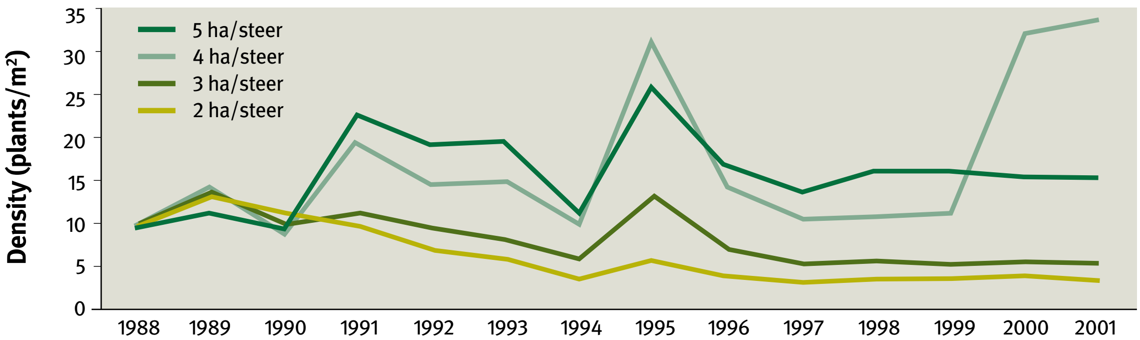
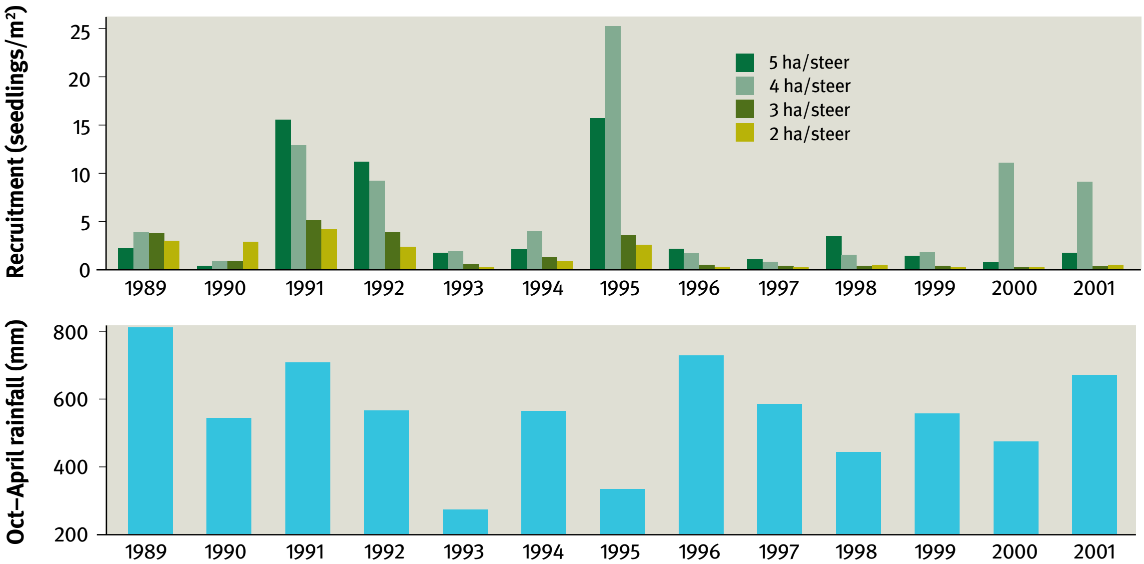


Figure 31. The effect of stocking rate and rainfall on the establishment of new speargrass plants.



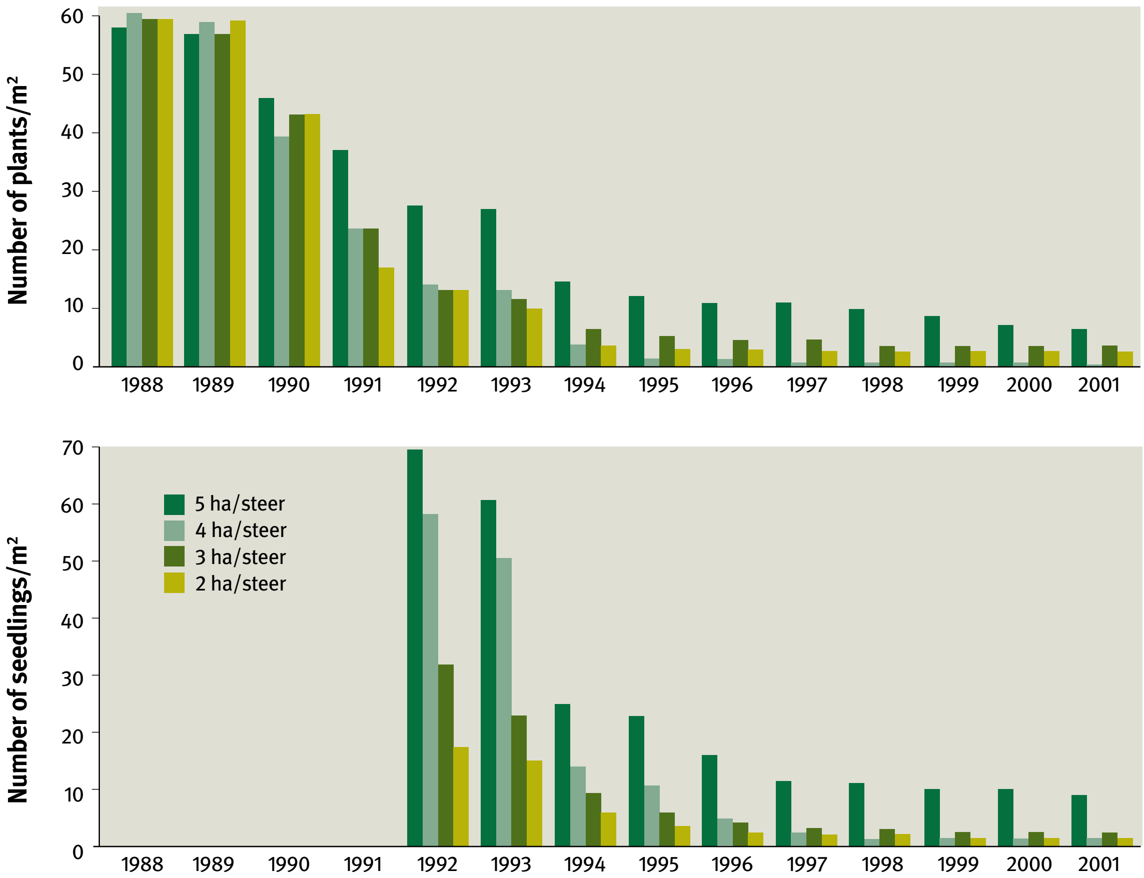


Figure 32. Survival of the original speargrass plants (top) and seedlings from 1992 (bottom) at four stocking rates.

Speargrass plants appear to have a half-life of 3–4 years (i.e. the time over which half of a group of plants will die) but individual plants can live for more than 12 years. Under heavy grazing many more plants die before seven years of age (figure 32).

Grass seed banks

Speargrass seed in the soil was measured by taking soil cores to 5 cm depth from each paddock each spring. These cores were watered in a glasshouse for 30 minutes each day for 6–8 weeks; and the seedlings of speargrass counted.

Seed banks in the soil were much higher under light grazing (figure 33). Under heavy grazing, the speargrass plants flower less, drop less seed onto the soil and so fewer seedlings establish in the next spring. Eventually the mature plants die and as they are not replaced, the overall number of speargrass plants declines.

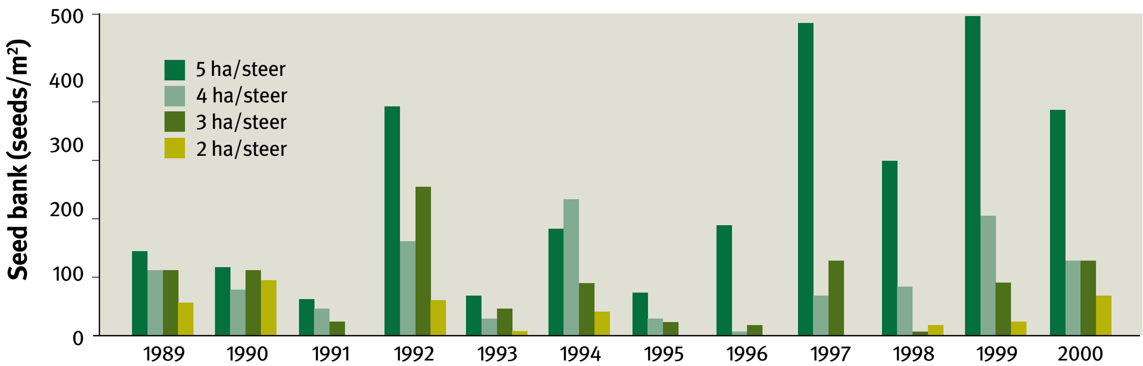


Figure 33. The effect of stocking rate on the seed banks of speargrass.

7 More permanent changes in the condition of speargrass pastures may take a number of years to show

Permanent changes for better or worse take time. Our heavier grazing treatments took at least five years to markedly affect soil and pasture condition and, even then, the effects were less obvious than expected. The increaser species did not build up under the heaviest grazing treatment until the fifth year of grazing, small burr grass did not become abundant until after seven years of grazing (figures 2, 3 and 4).

Oversowing legumes did not substantially reduce the abundance of the native legumes or increase purpletop rhodes grass until after 7 or 8 years.

Speargrass plants survived at 3 and 2 ha/steer over the 13 years of this experiment although there were fewer of them, especially in patches where forest bluegrass was more common.

The apparent resilience of this central Queensland speargrass country was tested only with utilisation rates up to about 50%. Under the continuous heavy grazing pressures often seen in practice, speargrass can eventually be grazed out as has happened in higher rainfall coastal regions and in northern Queensland. Studies in inland and northern regions have shown utilisation rates consistently above 50% result in rapid declines in soil and land condition.

8 Cattle preferentially graze different pasture species and types at times of the year

Seasonal trends in diet selection

The diets of cattle eating these mixed speargrass and forest bluegrass pastures were measured every two months over the summer between October 1995 and April 1996 (figure 34).

Steers selectively grazed speargrass throughout the year, and selected forest bluegrass only when there was insufficient speargrass.

When the pasture started growing in spring (October), steers in lightly-stocked paddocks selected equal amounts of speargrass and forest bluegrass; those in more heavily-stocked paddocks were forced to eat more of the forest blue. As the pasture continued to grow in summer, light grazing allowed steers to select more of their preferred speargrass whereas heavier stocking forced them to eat more forest blue.

This was unexpected. Forest bluegrass has been regarded as being as good in quality and palatability as speargrass. Maybe forest bluegrass should no longer be classified as a decreaser species on these land types. It did not decline greatly even at 2 ha/steer and tended to replace speargrass when the latter declined in the absence of spring burning. Although forest bluegrass increased initially under our heavier stocking rates, we expect that it also would decline under long periods of gross overgrazing.

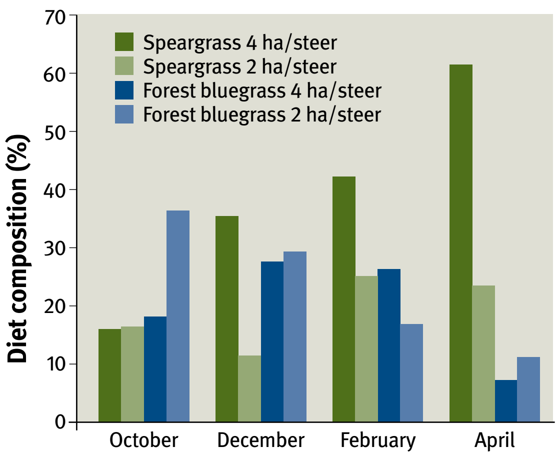


Figure 34. Seasonal changes in the proportion of speargrass and forest bluegrass eaten by steers under light and heavy grazing.

The carrying capacity of a native pasture depends on the present condition of the vegetation and soils

9

Expectations of the long-term carrying capacity of the coastal and sub-coastal black speargrass country are usually based on local experience. These should reflect factors such as soil types, the density of trees, long-term average rainfall and the present condition of the soil and pasture. Expectations are usually modified by changes in rainfall patterns over the past one or two decades.

In addition to local experience, it is possible to assess long-term carrying capacity objectively. Potential grass production is calculated from the factors mentioned above using pasture growth 'models'; carrying capacity is calculated by allowing certain levels (usually below 30%) of utilisation (consumption) of this pasture growth. The carrying capacity in the Calliope region has traditionally been estimated at 3.5 hectares per beast (about 8.5 acres per breeding cow)—although many graziers admit to higher stocking rates.

The Galloway trial had treatments on both ironbark duplex soils and on box clays although any remaining trees were killed to remove confusion from tree-grass competition.

Higher grass production on the more fertile clay soils resulted in lower utilisation rates than on the lighter soils at the same stocking rate.

The trial results suggest that the long-term carrying capacity on these land types is about one animal equivalent for 4 hectares, based on an average rate of annual pasture utilisation of 30%.

10 Stocking rates should either be aligned to a long-term sustainable average or be adjusted to match seasonal conditions

Stocking rates chosen for this trial were based on local experience and pasture growth calculations. The long-term carrying capacity based on the local soils, lack of trees and average rainfall is around 3.3 ha/steer assuming 30% utilisation of the pasture growth. For trial purposes, we applied stocking rates that ranged from very low to relatively high so that we could measure and understand the effects on soil, pasture and animals.

Also for trial purposes, the stocking rates in each paddock remained constant from year-to-year. As they were not adjusted according to rainfall, weight gains and levels of utilisation varied from year to year.

The long-term average monthly rainfall from adjacent Calliope Station is shown in figure 35a.

Summer rainfall over the trial period of 1988 to 2001 was generally well below the long-term average and these generally dry conditions had considerable influence on the results from the trial and on their interpretation (figure 35b).

While most tropical grasses survive winter, frosts kill their leaf and so affect pasture quality (figure 36). Early frosts can cause tropical legumes such as Seca stylo to rapidly lose leaf during the late autumn period when the extra protein would have the largest impact on animal performance.

Our results suggest a sustainable safe stocking rate of 4–4.5 ha per Animal Equivalent (AE) continuously grazed on sub-coastal speargrass country. If cattle numbers can be varied to match feed availability, they should be lightened off in poor years and maybe increased when there is a run of good years. Excess grass from good years can also then be used to control woody regrowth with a hot fire.

Figure 35. Rainfall at nearby Calliope Station (a) long-term averages and (b) interannual variability and trends.

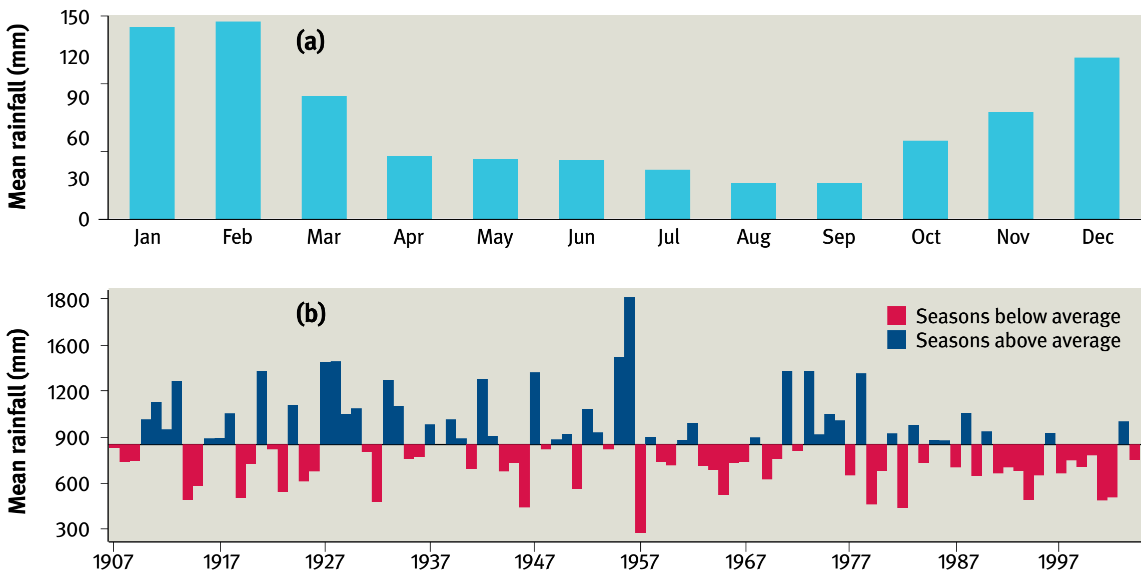
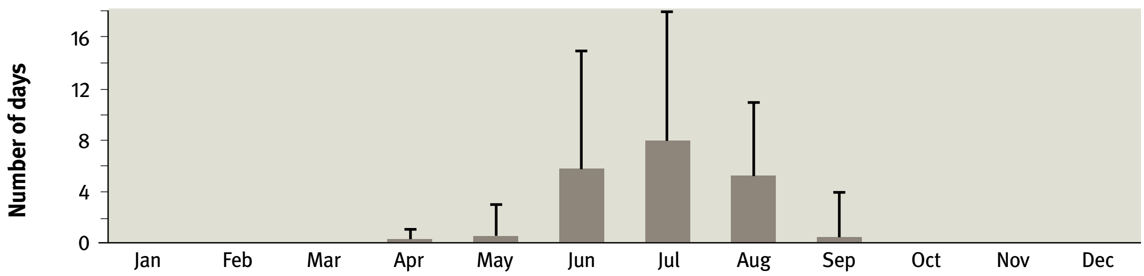


Figure 36. Average incidence of frost at Galloway Plains during the experiment. Vertical bars indicate maximum and minimum values.



Observe and monitor the pastures to pick-up short-term and long-term changes in vegetation

11

Paddock-based measurements of pasture yield and composition

Each year, all paddocks were monitored at the end of the growing season and at the end of the dry season to record:

- pasture yield (the weight of herbage present as dry matter)
- composition (the relative proportion by weight of each major species or species group)
- frequency (the presence of each major species or species group in sample plots (%)).

The major species, such as speargrass and forest bluegrass, were recorded individually as were some minor species, such as pitted bluegrass. Other minor species, such as hairy panic (*Panicum effusum*), were recorded to genus level while still others, such as native legumes, were grouped. This classification along with the range of values recorded for each of these species groups is shown in table 2. The density of sown legumes was recorded in the legume treatment paddocks, and classified as mature plants or seedlings.

All pasture components were affected by the treatments and by rainfall between years.

In general, grazing pressure is too high if the frequency of pitted bluegrass, slender chloris and woodland lovegrass is above 10%, or if the frequency of small burr grass exceeds 1%.

Site-based monitoring

Long-term changes in the composition of native pastures are monitored along permanent transects at a wide range of sites throughout Queensland using the QGRAZE method. Pasture composition is measured as the presence/absence of pasture species in 20 quadrats in 5 parallel transects 200 metres in length.

Table 2. Classification of plant species into groups (See appendix 2 for botanical names)

Group	Species	Herbage present (kg/ha)	Composition (%)	Frequency (%)
Major	Black speargrass	0–3100		4–88
	Forest bluegrass	8–4500		17–83
	Wiregrass	0–1500		0–46
Intermediate	Pitted bluegrass		0–18	0–72
	Slender chloris		0–36	0–84
	Golden beard grass		0–9	
	Barbwire grass		0–20	
	Woodland lovegrass		0–15	0–52
	Early spring grass		0–23	
	Seca stylo		0–60	
Minor	Hairy panic			0–27
	Sporobolus			0–40
	Purpletop Rhodes grass			0–30
	Small burr grass			0–31
	Other grasses			3–55
	Sedge			2–76
	Native legumes			3–69
	Malvaceae			0–59
	Other forbs			7–80

Similar monitoring sites were established in all 'Galloway Plains' paddocks and assessed every two years between 1991 and 2000. Photos from three QGRAZE sites illustrate changes in pasture yield and composition. The overall results from the two methods of site monitoring were similar and matched up well with the overall paddock assessments described above.

5 ha/steer

2 ha/steer

2 ha/steer + stylo

Monitoring site photo points

Appendix I

The Galloway Plains grazing trial

The major perennial tussock grasses dominating native pastures in coastal subtropical Queensland from Gayndah to St Lawrence and 150 km inland are black speargrass (*Heteropogon contortus*) and forest bluegrass (*Bothriochloa bladhii*). The former is usually more dominant on the 'lighter' soils (low clay content in the surface) while forest blue tends to dominate as clay content in the soil increases. However both species overlap in the same habitat. The Calliope catchment between Gladstone and Biloela has a long tradition of beef cattle raising, based on a typical mixture of soil types supporting black speargrass/forest bluegrass pastures. This led to the selection of the Galloway Plains trial site which is located in the Calliope valley. Furthermore, Galloway Plains had willing co-operators and suitable land available for research to include both these major pasture dominants. Grazing commenced in August 1988 and continued until June 2001.

Dr Bill Burrrows (Project Leader), Jim Neill-Ballantine (Galloway Plains Pastoral Company) and Dr David Orr (Principal Pasture Investigator) at the trial site.

Black speargrass

Forest bluegrass

Describing stocking rates

Researchers and graziers tend to express stocking rates for extensive pastures in different terms. In a trial, the number of animals in different treatments is usually constant and the size of the small trial paddock is set accordingly. Thus the researcher may describe stocking rates as, say, 3 ha/steer or 1 steer on 3 ha.

The grazier has large paddocks of a size fixed by the fencing, and alters stocking rates by adjusting the numbers of animals in the paddock. Thus the grazier may describe stocking rates as, say, 33 steers/100 ha.

This report expresses stocking rates as ha/steer with the original range of stocking rates selected in this trial of 2, 3, 4, 5 and 8 ha/steer

Stocking rate description	
Trial (ha/steer)	**Commercial (steers/100 ha)**
2	50
3	33
4	25
5	20
8	12.5

Animal equivalents

A farm management specialist knowing that steers can range in weight from 150 kg to 650 kg needed a tighter definition. Thus a standard Animal Equivalent (AE) represents a steer of 450 kg.

In the design of this trial, yearling steers averaging 250 kg (0.55 AE) were introduced each year and replaced after about 12 months. Because of the different treatments, the groups of steers averaged between 360 kg (0.80 AE) and 420 kg (0.93 AE) at the end of the year. Rather than reclassify each group of steers each year by body weight, we are expressing the treatments as ha/steer for comparison.

However, in terms of broad recommendation for setting carrying capacity, we can equate 30% utilisation at 3.5 hectares per trial steer to about 4 hectares per Animal Equivalent.

Experimental design and layout

The following stocking rate and pasture type treatment combinations were imposed.

- Native pastures stocked at 2, 3, 4, 5 and 8 hectare per steer respectively.
- Native pasture oversown with introduced legumes stocked at 2, 3 and 4 hectare per steer.
- Native pasture stocked at 2, 3 and 4 hectare per steer with a dry season supplement supplied to the stock in late winter-spring.
- A small area of 2 ha which was closed off to domestic livestock.

The treatments were duplicated on the two major soil types on Galloway Plains:

- Hard-setting texture contrast (duplex) soils originally supporting silver-leaved ironbark woodland, and now largely dominated by black spear grass pasture (east block)
- Grey clay soils originally supporting woodlands of poplar box or blue gum trees, and now largely dominated by forest bluegrass pasture (west block).

Most trees growing on the experimental paddocks (apart from those retained as shade trees) had previously been killed or were killed so that tree-grass competition did not confound the treatment responses.

The various stocking rates were achieved by placing five steers (average entry weight 260 kg) in paddocks ranging from 10 to 40 hectares. A new draft of *Bos indicus*-cross steers was introduced each year although in some years six animals were introduced to each paddock to help amplify stocking rate effects.

Animal weights

A new draft of *Bos indicus* cross steers weighing 170 to 330 kg was introduced each year, usually during winter.

The steers was weighed after fasting at the start and end of each draft, and unfasted every 4 or 6 weeks.

Trial layout

Overall layout of the grazing study

In paddocks oversown with introduced legumes, scarified seed of Seca stylo and Verano stylo was broadcast into the native pasture at 2 kg per ha. Wynn cassia was planted at 0.5 kg/ha into lightly scarified strips placed about 10–20m apart. However, Seca stylo was the only legume to establish successfully.

Changes to experimental design

Dry season supplements: The treatments feeding a supplement (mainly cotton seed meal) during the dry season showed little impact on pasture condition or animal performance over the initial four years. Graziers rated fire as a more important option for their management of native pastures and a spring burning treatment was substituted. The plan was to burn 80% of the pasture while leaving 20% of the paddock adjacent to the watering point unburnt.

The burning treatments varied in their effectiveness depending on the year and the stocking rate, both of which impacted on fuel loads. At 2 and 3 ha/steer, burning was possible only in spring 1992 and 1999. At 4 ha/steer, burning was conducted in spring 1992, 1998 and 1999 while a 'patchy' burn was achieved in 1996.

Very light grazing: In 1996, the 8 ha/steer native pasture treatment was discontinued because pastures and animal production were similar to those at the 5 ha/steer treatment. This 8 ha/steer treatment was then changed to evaluate the impact of burning but at the lighter stocking rate of 5 ha/steer. This new 5 ha/steer burning treatment gave sufficient fuel load for burning every year from 1996 until 1999. (No paddocks were burned in spring 1997 because seasonal climate forecasting indicated a poor chance of adequate follow-up rainfall).

Results reported in this booklet

The overall results from Galloway Plains are presented in terms of the impacts of stocking rate and of pasture 'type'.

For the impacts of stocking rate, we present the impacts of the four stocking rates that continued from 1988 until 2001; these are 2, 3, 4 and 5 ha/steer. Data are also included for the 8 ha/steer treatment which was discontinued in 1996.

For the impact of pasture 'type', we present the impacts of three stocking rates (2, 3 and 4 ha/steer) for three pasture 'types' (native pasture, native pasture with legumes and native pasture with burning). Additional results for the burnt 5 ha/steer treatment are presented to indicate the impacts of more frequent burning.

Common species found in speargrass pastures of central Queensland

Common name	Scientific name
Black speargrass	(*Heteropogon contortus*)
Forest bluegrass	(*Bothriochloa bladhii*)
Wiregrass	(*Aristida* spp.)
Pitted bluegrass	(*Bothriochloa decipiens*)
Slender chloris	(*Chloris divaricata*)
Golden beard grass	(*Chrysopogon fallax*)
Barbwire grass	(*Cymbopogon* spp.)
Woodland lovegrass	(*Eragrostis sororia*)
Early spring grass	(*Eriochloa* spp.)
Seca stylo	(*Stylosanthes scabra*)
Hairy panic	(*Panicum* spp.)
Sporobolus	(*Sporobolus* spp.)
Purpletop Rhodes grass	(*Chloris inflata*)
Small burr grass	(*Tragus australianus*)
Sedge	*Cyperacae*
Wooly glycine	*Glycine tomentosa*
Rhyncosia pea	*Rhyncosia minima*
Indigo	*Indigofera* spp.
Yellow daisy burr	*Calotis lappulacea*
Malvaceae	*Sida* spp.
Maynes pest	*Verbena tenuisecta*

Further reading

If after reading this booklet you would like more information on grazing management, please contact DEEDI on 13 25 23 or your nearest DEEDI office; these contacts can also help with enquiries about the GLM and *StockTake* workshops which have been specially designed for different regions of Queensland and the Northern Territory with regional GLM workshops available for the Burdekin catchment, the Fitzroy Basin and for south-east Queensland. DEEDI also has a part-day workshop, called *StockTake*, which focuses on the skills needed to assess pasture condition and conduct forage budgets.

Managing native pastures: a grazier's guide – by Ian Partridge (1992) DPI Queensland

Managing northern speargrass: a grazier's guide – by Ian Partridge (1995) DPI Queensland

Managing southern speargrass: a grazier's guide – by Ian Partridge (1993) DPI Queensland

Native pastures in Queensland: the resource and their management – Edited by W.H. Burrows, J.C. Scanlan and M.T. Rutherford (1988) DPI Queensland

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

Fire in the management of northern Australian pastoral lands – edited by Tony Grice and Sonja Slatter (1997) Occasional Publication No. 8, Tropical Grassland Society of Australia, Brisbane.

Monitoring grazing lands in northern Australia – edited by John Tothill and Ian Partridge (1998) Occasional Publication No. 9, Tropical Grassland Society of Australia, Brisbane.

Stylo and grass – keeping your balance – by Ian Partridge, Col Middleton and Kev Shaw (1998) DPI Queensland.

Stylos for better beef - by Ian Partridge, Col Middleton and Kev Shaw (1996) DPI Queensland.

The Ecograze Project: - developing guidelines to better manage grazing country – by Andrew Ash, Jeff Corfield and Taoufik Ksiksi (2001) CSIRO Townsville.

[The formal results of the Galloway Plains Grazing Study have been published in scientific journals. Reference citations can be obtained from the DEEDI office in Rockhampton].