Pasture management in semi-arid tropical woodlands: effects on ground cover levels

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Abstract

The effects of a range of pasture management options (introduced legumes and grasses, superphosphate, timber treatment, cultivation before sowing and stocking rate) on the amounts of ground cover at the end of the dry season were measured from 1985–1991 at two sites, Hillgrove and Cardigan, near Charters Towers, north-east Queensland. Ground cover levels varied significantly between years and were significantly affected by pasture management. Cover levels were curvilinearly related to pasture yields. Management options which increased pasture growth (tree killing, using sown pastures, applying superphosphate) or decreased pasture consumption (lower stocking rates) increased cover levels. Pasture treatments affected the shape of the relationship between pasture yield and cover. Cover levels were higher for oversown than native pastures at all levels of pasture yield. For pasture yields below 3000 kg/ha, cover levels increased with stocking rate but there was little difference in cover levels between stocking rates at higher pasture yields. The importance of managing stocking rates for the maintenance of ground cover is emphasised.

Introduction

Extensive beef cattle grazing is the main land use in the semi-arid woodlands that occupy much of northern Australia. These woodlands have an open tree layer (usually of *Eucalyptus* species) and an herbaceous layer dominated by tall, perennial tussock grasses. There is increasing concern about stability and sustainability of these woodlands (Gardener *et al*. 1990). In a survey conducted in 1991, Tothill and Gillies (1992) found 44% had suffered some change, of which 12% was badly affected with severe soil erosion and dominance of undesirable species. There have been no comparable surveys since 1991 but the overall situation is unlikely to have changed (Scanlan and McIvor 2002).

The importance of ground cover for reducing runoff and soil loss is well recognised (see review by Gifford 1985): it intercepts and absorbs the energy of falling raindrops; it impedes the flow of runoff water, increasing infiltration; and it resists the erosive force of flowing water (Osborn 1952). In addition to protecting the soil surface, cover also provides a favourable habitat and food source for microorganisms and improves the physical condition of the soil surface (Thurow 1991). Monitoring ground cover levels is useful for managing runoff and soil loss (McIvor *et al.* 1995) and for predicting the success of regeneration after pasture degradation (McIvor 2001a).

Herbage, and the litter derived from it, are major contributors to ground cover and much of the variation in ground cover in grazed pastures can be related to changes in pasture growth and utilisation. If cover levels are to be managed, we need to know how they are affected both by environmental variation and by management practices. The ECOSSAT (Ecological Studies in the Semi-arid Tropics) project was established in 1981 to examine a range of pasture systems (from native woodland to fully developed pastures) on 2 soils of different fertility in the Charters Towers district of north Queensland. In this paper, the effects of a range of pasture treatments on ground cover levels of pastures over the period 1985–1991 are presented. The impacts of these treatments on cover:yield relationships are also examined.

Materials and methods

Sites

The experimental sites were at Hillgrove (80 km north-west of Charters Towers) and Cardigan

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(40 km south-east of Charters Towers). Detailed descriptions of the sites are given in McIvor and Gardener (1991) and McIvor *et al.* (1991). Both sites have a subhumid tropical climate with an average growing season of 14 weeks. The vegetation at both sites is an open woodland with *Eucalyptus crebra* (Hillgrove), *E. drepanophylla* (Cardigan) and *E. erythrophloia* (both sites) the dominant trees. The herbaceous layer is dominated by perennial tussock grasses; the most important species are *Bothriochloa ewartiana*, *Heteropogon contortus* and *Chrysopogon fallax*. The soil at Hillgrove is a euchrozem (Gn3.12, Northcote 1979; eutrophic red ferrosol, Isbell 1996) derived from basalt and the soil at Cardigan is a neutral red duplex (Dr 2.12; eutrophic red chromosol) derived from granodiorite.

Treatments

At each site, the experimental plots consisted of 9 unreplicated pasture systems each grazed at 4 stocking rates (McIvor and Gardener 1995). Eight of the pasture systems (Systems 1–8) were a 2 × 2 × 2 factorial of pastures, timber treatment and fertiliser application (Table 1). The ninth system was a fertilised sown pasture established after clearing the trees and cultivating the soil before sowing.

Table 1. Pasture treatments and stocking rates (steers/ha) on the 36 experimental plots at each site: –, no treatment; +, treatment applied. System 9 was cleared of trees and the soil cultivated before sowing.

Pasture system	Sown species	Timber treatment	Fertiliser
	Stocking rates: 0.1, 0.2, 0.33, 0.5 steers/ha		
1	—	—	—
2	—	+	—
3	—	—	+
4	—	+	+
	Stocking rates: 0.2, 0.33, 0.5, 1.0 steers/ha		
5	+	—	—
6	+	+	—
7	+	—	+
8	+	+	+
9	+	+	+

Pastures. The *native* pastures consisted of the existing native and naturalised species with no intentionally sown species. The *oversown* pastures were sown with a mixture of 4 legumes: *Macroptilium atropurpureum* cv. Siratro, *Stylosanthes guianensis* cv. Graham, *S. hamata* cv. Verano and *S. scabra* cv. Seca (2 kg/ha of each); and 4 grasses: *Bothriochloa insculpta* cv. Hatch, *Chloris gayana* cv. Callide, *Cenchrus ciliaris* cv. American and *Urochloa mosambicensis* CPI 46876 (1 kg/ha of each). Seed was spread on the soil surface at the start of the growing season after the existing herbage had been burnt; Hillgrove was sown in December 1981 and Cardigan in January 1985. Additional seed was spread at the start of the following growing season.

Timber treatment. Trees on the *live* plots were not treated. All trees on the *killed* plots were killed by stem injection with arboricide. The trees were treated at Hillgrove in April 1982 and at Cardigan in January 1985.

Fertiliser application. The *nil* plots received no fertiliser. The *superphosphate* plots received 100 kg/ha of superphosphate at sowing and again each year during the late dry season.

Tree clearing and cultivation. The trees were removed mechanically and the soil cultivated with discs before sowing.

The *stocking rates* were 0.1, 0.2, 0.33 and 0.5 steers/ha on the native pastures (Systems 1–4) and 0.2, 0.33, 0.5 and 1.0 steers/ha on the sown pastures (Systems 5–9). This range would be considered light to very heavy in commercial practice. Stocking rates were applied by varying plot sizes. Plots grazed at 0.1, 0.2, 0.33, 0.5 and 1.0 steers/ha had areas of 2.5, 1.25, 0.75, 0.5 and 0.5 ha, respectively. The plots were grazed with single steers (1–2-year-old, 200–350 kg) in a similar manner to studies by Jones *et al*. (1980) and McIvor (1985), except for plots grazed at 1 steer/ha where 2 steers were used. Steers were moved between plots twice-weekly so that each plot was grazed for 25% of the time.

Plot management

Grazing commenced at Hillgrove in June 1984 and at Cardigan in September 1986. Each plot was grazed throughout the experimental period except when it carried insufficient feed to support an animal. When this occurred, the plot was omitted from the rotation until herbage regrew sufficiently to recommence grazing. At Hillgrove in April 1988, 20 plots had insufficient feed and the site was destocked until October 1988. The native pasture plots were burnt at the start of the growing season in 1986, 1987 and 1989 at Hillgrove and in 1990 at Cardigan. This is consistent with commercial practice where burning to remove accumulated dry herbage is common when seasonal conditions and stocking rates permit such accumulation.

Measurements

The presentation yield of each plot was estimated at the end of the dry season (November) using the BOTANAL technique (Tothill *et al*. 1992). At the same time, the amount of ground cover (standing herbage, litter, tree leaves and twigs, animal dung, rocks, stones) was estimated using the techniques described by McIvor *et al.* (1995). Estimates were made in 50 quadrats in each plot.

Statistical analyses

Cover levels for Systems 1–8 for each year were analysed using factorial analysis of variance. The data were transformed (arcsine square root) before analysis. All main effects (pastures, fertiliser, timber treatment and stocking rate) and 2-factor interactions were fitted. All 3-way interactions and the 4-way interaction were combined to form the error sum of squares. Residuals were calculated, plotted using stem-leaf plots and normal quantile-quantile plots, and tested using the Shapiro-Wilks statistic (Royston 1982) to check the normality and constancy of variance. Results over more than one year were analysed using a multivariate repeated measures approach (Crowder and Hand 1990). This approach produces a between-plots analysis, and a within-plots analysis. The between-plots analysis is equivalent to an analysis of the results for each plot meaned over years. This analysis produces univariate *F* tests for the effects concerned. The within-plots analysis tests the year main effect and all interactions with year based on the multivariate test statistic, Wilks Lambda.

Pasture Systems 8 and 9 differed only in treatment before sowing — System 9 plots were cleared mechanically and the soil cultivated whereas on the System 8 plots, the trees were killed and there was no cultivation. The results from the 2 systems have been compared to assess the effects of clearing and cultivation. The data were analysed by analysis of variance using the pasture system × stocking rate interaction as the error term.

When the cover levels were plotted against pasture yields, the relationships were clearly asymptotic with rapid increases in cover as pasture yield increased at low levels. The following equation was fitted using Genstat 5 (Payne *et al.* 1988):

$$\%C = a + be^{cY}$$

where %C is ground cover,
Y is pasture yield,
and a, b and c are constants.

Results

Rainfall and growing conditions

Over the long-term, January–March is the wettest quarter. However, during the experiment, rainfall during this quarter was below average in 9 of the 11 years at Hillgrove, and 7 of the 8 years at Cardigan including all years when cover was measured except 1991. Mean rainfalls during the other quarters were similar to or above the long-term average values. The variable rainfall produced widely varying growing conditions with the length of the growing seasons during the period cover was measured varying from 4–17 weeks at Hillgrove and from 4–25 weeks at Cardigan (estimated using the methods of McCown 1973).

Treatment effects on ground cover levels

Ground cover levels varied significantly between years and were significantly affected by all treatments except fertiliser application (Table 2).

Table 2. The effect of management on ground cover (%) at the end of the dry season: means over treatments and years. *The pasture values are for plots stocked at 0.2, 0.33 and 0.5 steers/ha.

	Hillgrove		Cardigan	
Year	P<0.001		P<0.001	
1985	78.8		—	
1986	77.7		78.3	
1987	61.0		55.3	
1988	45.7		52.4	
1989	72.2		81.7	
1990	76.8		81.8	
1991	90.0		88.9	
Pasture*	P = 0.355		P<0.001	
Native	72.9		67.7	
Oversown	74.7		79.4	
Trees	P<0.001		P<0.001	
Live	64.9		69.7	
Killed	78.6		76.5	
Fertiliser	P = 0.661		P = 0.097	
Nil	71.1		72.1	
Superphosphate	72.4		74.0	
Cultivation	P = 0.698		P = 0.012	
System 8	78.5		81.5	
System 9	75.1		69.3	
Stocking rate (steers/ha)	P<0.001		P = 0.006	
	Native	Oversown	Native	Oversown
0.1	76.7	—	69.0	—
0.2	78.4	81.1	69.9	80.3
0.33	75.6	76.9	68.9	79.3
0.5	64.5	66.0	59.0	79.0
1.0	—	54.8	—	71.0

Cover levels were higher where the trees were killed and declined as stocking rate increased at both sites. Oversown pastures had higher cover levels than native pastures at Cardigan but there were no significant differences between pastures at Hillgrove. Similarly, the oversown plots (System 8) had significantly higher cover levels than pastures developed after cultivation (System 9) at Cardigan but not at Hillgrove.

There were significant interactions between treatment and year for trees and stocking rate at both sites and also for pastures at Cardigan. Cover levels were similar for native and oversown pastures at Cardigan in 1986, but in all following years they were higher on the oversown plots (Figure 1).

Plots with killed trees had higher cover levels than plots with live trees during the early and middle years but the differences were not significant in the final year at Hillgrove or the final 3 years at Cardigan (Figure 2).

The interaction of stocking rate with year was more complex. For the native pastures at Hillgrove, in 1991 there was no change in cover level with stocking rate, but in all other years, cover declined as stocking rate rose (Figure 3). On the oversown plots, cover levels declined with stocking rate in all years although the rate of decline was least in 1991. At Cardigan, there was no change in cover level with change in stocking rate for either pasture type in 1986, 1987, 1990 and 1991. In 1988 and 1989, there were large decreases in ground cover as stocking rate increased for both pastures.

Cover: pasture yield relationships

The general relationship between ground cover and pasture yield is shown in Figure 4 which displays the total set of estimates for Hillgrove. The general asymptotic relationship is clear but there is considerable variation in cover level for any pasture yield. Individual equations were fitted for the different treatments.

There were no differences in the relationships between the two sites or between the tree and fertiliser treatments but there were for the other treatments. The native pastures had lower cover levels at all pasture yields than the oversown

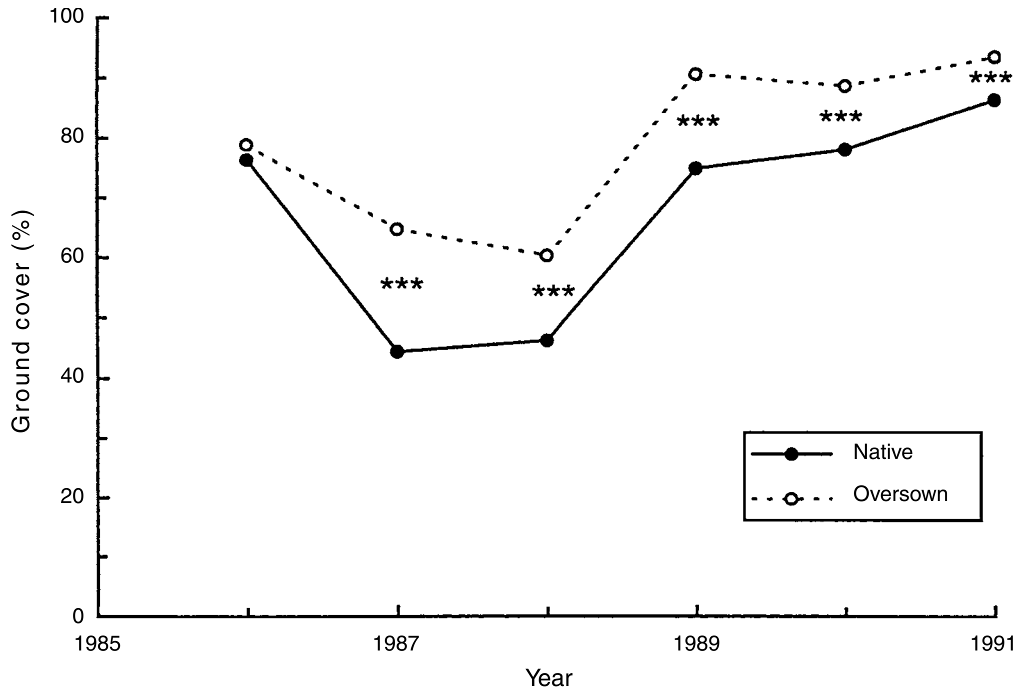

Figure 1. Changes in ground cover levels for native and oversown pastures at Cardigan. Significant differences: P = 0.001. Values for plots stocked at 0.2, 0.33 and 0.5 steers/ha only.

pastures but there were no differences between oversown plots with low legume contents (<25%) and those with higher legume contents (>25%) (Figure 5a). At high pasture yields, there were no differences in cover levels between the stocking rates but at lower yields cover levels increased as stocking rate increased (Figure 5b). The System 8 plots had higher cover levels at low pasture yields than the System 9 plots but there were no differences between these 2 systems at high yields (Figure 5c).

Discussion

There was a wide range in cover levels (18–100%) across treatments and years which can largely be explained by 3 factors — pasture yield, tree litter and differences in the shape of the cover:yield relationships. Most of the variation can be attributed to differences in pasture yield — a simple linear regression of the mean cover levels in Table 2 on equivalent pasture yields explained more than 50% of the variance.

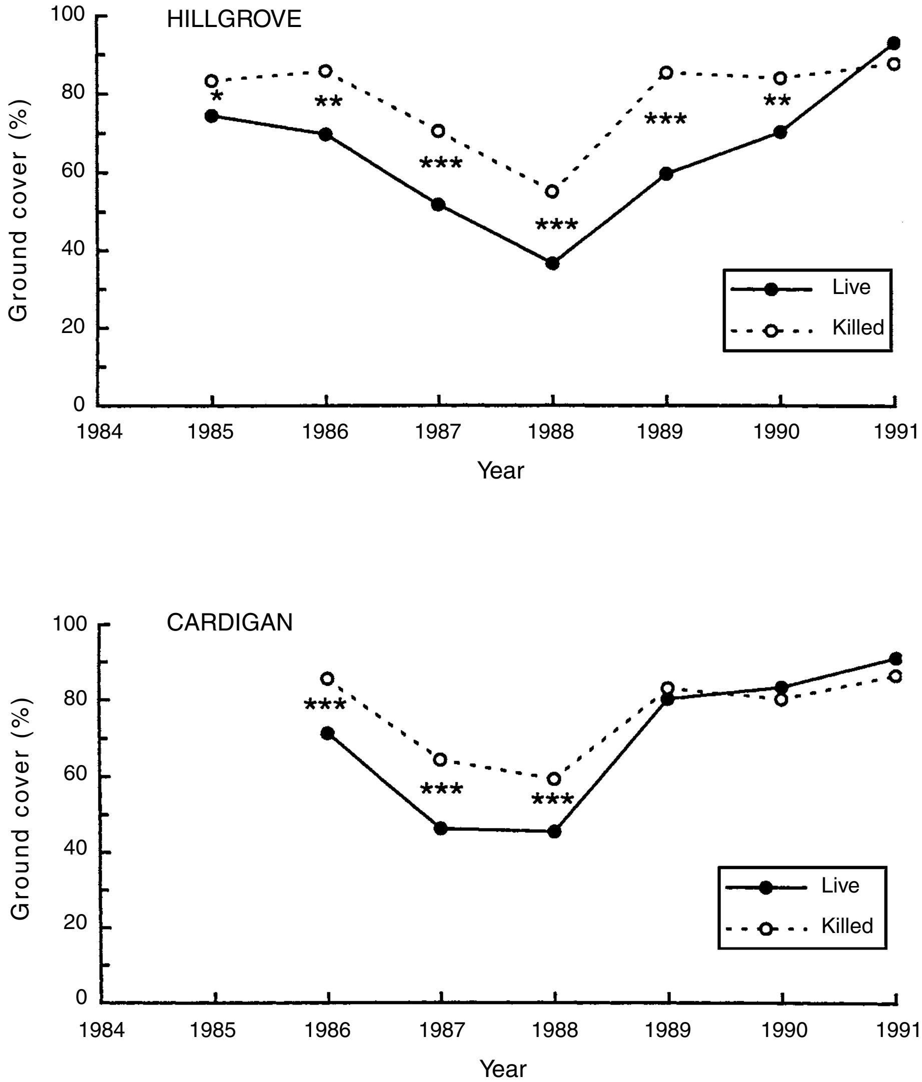

Figure 2. Changes in ground cover levels of plots with live or killed trees at Hillgrove and Cardigan. Significant differences: *, P = 0.05; **, P = 0.01; ***, P = 0.001.

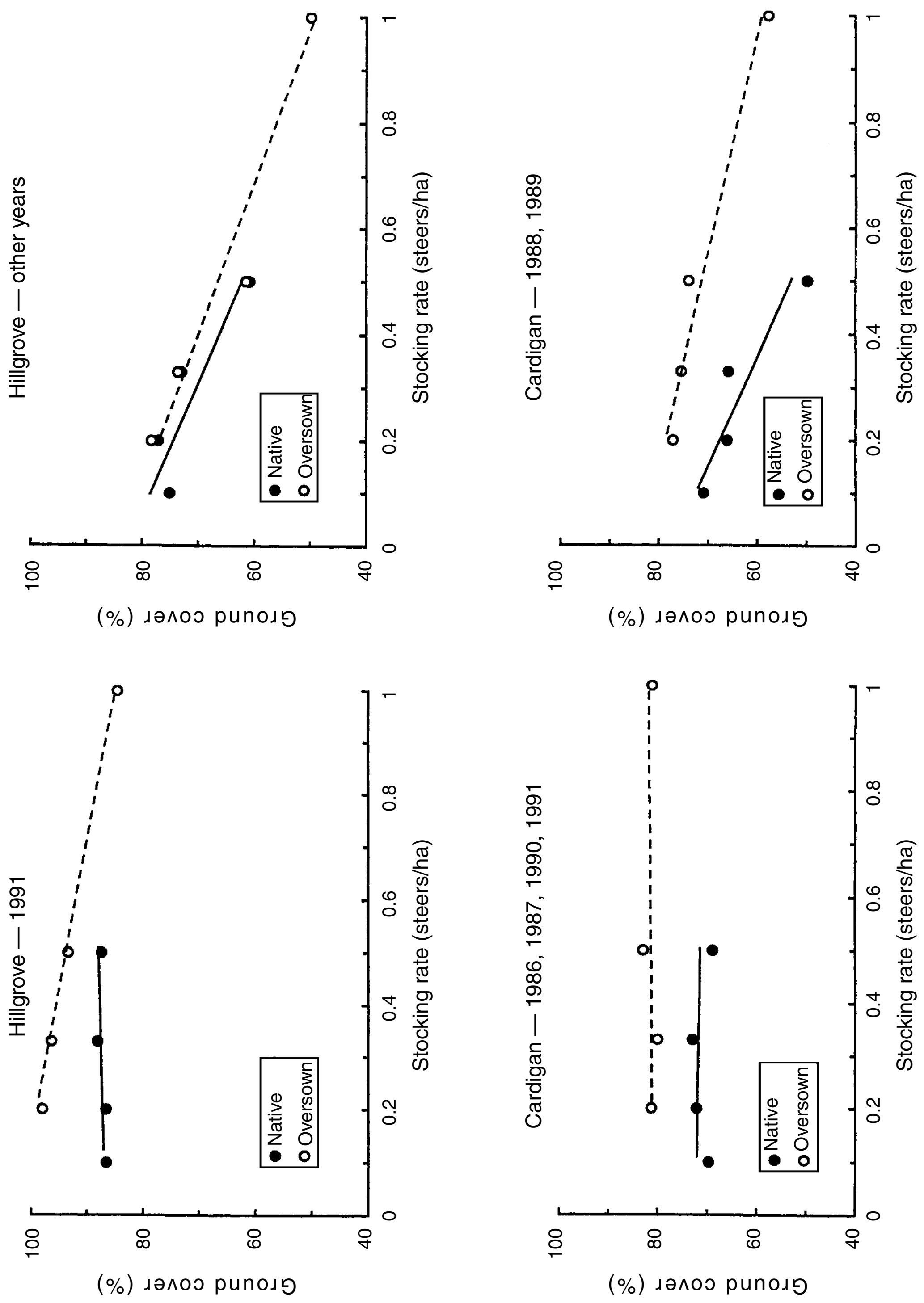

Figure 3. Changes in ground cover levels with stocking rate for different groups of years at Hillgrove and Cardigan. The lines are linear regression lines.

The treatment effects on pasture yields reflected treatments that increase pasture growth (tree killing at both sites, sown species and superphosphate application at Cardigan) and decreases in yield as stocking rates increase (McIvor and Gardener 1995).

A second factor is the contribution of tree litter. The live trees at these sites shed an average of 1270 and 720 kg/ha of litter annually at Hillgrove and Cardigan, respectively (McIvor 2001b). These values are a third to a half of the pasture yields at the end of the growing season and tree litter is likely to take longer to break down than pasture litter. For plots where the trees were killed prior to cover measurements commencing, the trees would still have contributed woody litter. The absence of tree litter probably explains the lower cover levels for the System 9 plots (no trees following mechanical clearing) compared with the System 8 plots (dead trees) at low pasture yields (Figure 5c). All the yield:cover relationships had cover values greater than zero at zero pasture yield reflecting the other components (herbaceous litter, rocks, stones, cattle dung) that contributed to cover.

A third factor in the variation in cover levels was the different shapes of the yield:cover relationships (Figure 5), particularly at low yields. Cover levels were higher for oversown pastures than native pastures at all levels of yield. The differences between stocking rates are partly due to the 0.1 an/ha plots being native pasture only and the 1.0 an/ha plots being oversown pasture only, but also are probably due to changes in species composition, *e.g.* an increase in prostrate and/or stoloniferous grasses with an increase in stocking rate (Scanlan and McIvor 1993) and altered morphology and increased litter due to greater trampling and detachment at the higher stocking rates.

A number of studies have shown that, when cover levels drop below about 40%, there is a sharp increase in runoff and soil movement (*e.g.* Elwell and Stocking 1976; Snyman and van Rensburg 1986; Lawrence and Cowie 1992; Silburn *et al.* 1992; Zobisch 1993; McIvor *et al.* 1995; Scanlan *et al.* 1996). It is desirable that ground cover be maintained above at least this level and these results show that pasture management can make a major contribution. Since cover levels are closely related to pasture yield, the amount of cover provided by a pasture depends on the balance between production and consumption. Cover can be increased by improving pasture production (*e.g.* by tree killing, using sown pastures, applying superphosphate) and/or

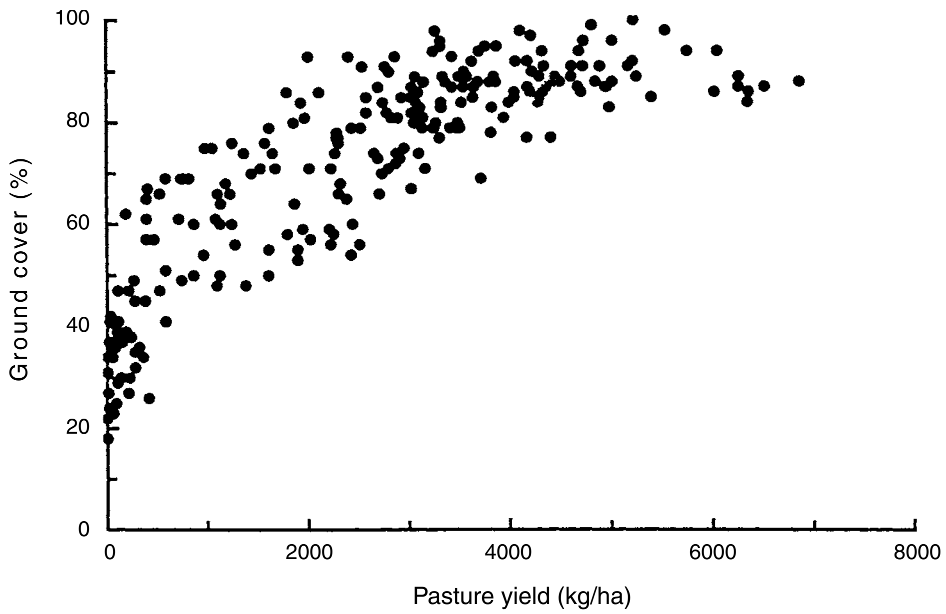

Figure 4. Ground cover levels in relation to pasture yields at the end of the dry season at Hillgrove (all plots in all years).

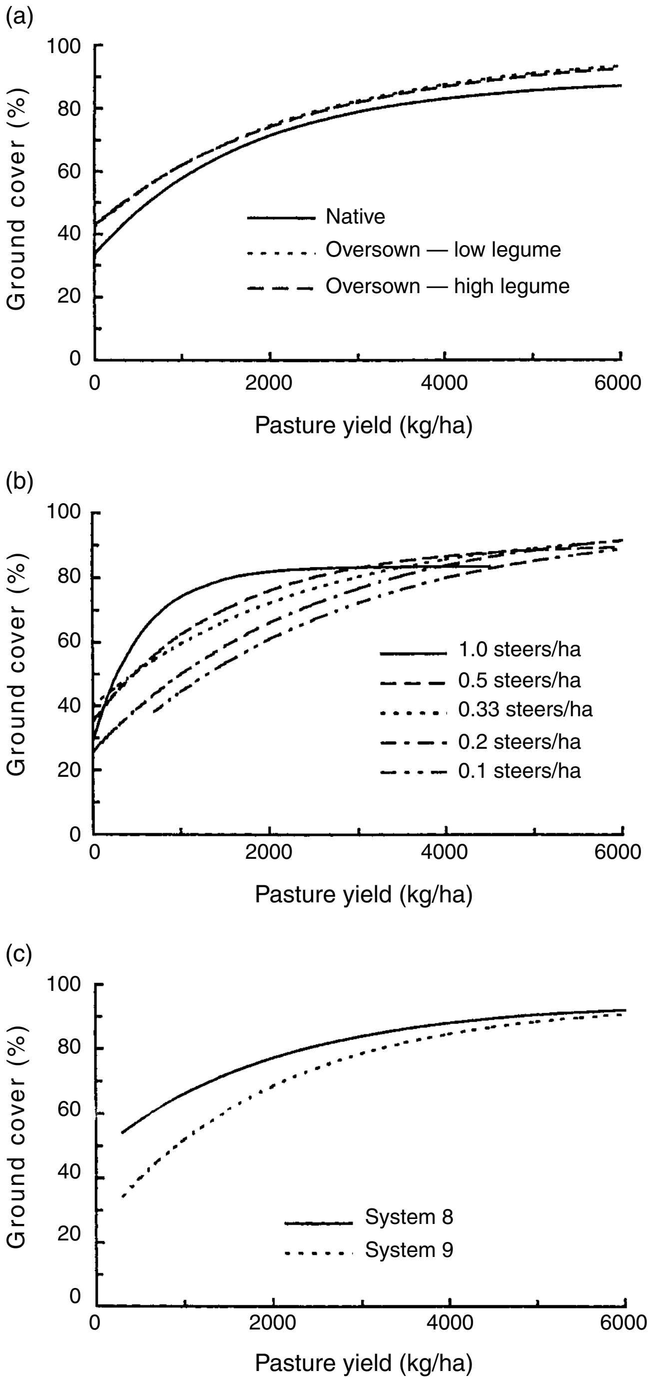

Figure 5. Ground cover levels in relation to pasture yields at the end of the dry season at Hillgrove and Cardigan: (a) Native pastures, and oversown pastures with low (<25%) and high (>25%) legume content. Values for plots stocked at 0.2, 0.33 and 0.5 steers/ha only. (b) Comparison of stocking rates. Plots at 0.1 steers/ha are native pasture only and the plots at 1.0 steer/ha are oversown pastures only while the remaining stocking rates are a mix of the two pastures. (c) Comparison of System 8 (trees killed, oversown pasture) and System 9 (trees cleared mechanically, pasture sown on a cultivated seedbed).

by decreasing pasture consumption (lower stocking rates). In the short term, pasture production is largely controlled by current weather conditions and control of cover provided by pasture plants depends on managing animal numbers. At Hillgrove, cover levels were below 40% for 29% of the plot-year combinations at the highest stocking rates but did not drop below 40% at the lowest stocking rates; the equivalent values at Cardigan were 15% and 6%.

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