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Retaining trees in a grazing landscape: impacts on ground cover in sheep-grazing agro-ecosystems in southern Queensland

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Abstract

In low-input, low-productivity grazing systems, the modification of natural woodlands through overstorey tree and woody regrowth removal are management options used by graziers to increase native grass production for livestock grazing. This paper describes studies that determine if vegetation management by graziers affect floristic composition and plant cover in the Traprock wool-producing region of southern Queensland. Forty-seven sites in the region were sampled according to vegetation type (ironbark/gum woodland and box woodland), density of mature trees (low: 6 trees/ha, medium: 6-20 trees/ha, and high: >20 trees/ha), and the presence or absence of woody regrowth in the understorey to determine vegetation patterns. A subset of 18 sites was selected to establish grazing exclusion experiments in both vegetation types under varying mature tree densities. Here we describe the general patterns in vegetation under differing mature tree densities and provide some preliminary results of the 4-year grazing exclusion experiment. While grass production is low under high overstorey tree densities, no differences between medium tree densities and open paddock areas is apparent, suggesting retaining trees in a low-input, low-productivity grazing system can provide biodiversity benefits without adversely impacting upon production.

Introduction

An increasing body of research is recognising the value of biodiversity within production landscapes (e.g. McIntyre and Lavorel, 1994; Kirkpatrick *et al.,* 2005). However, ecological studies examining whether different grazing management strategies enhance biodiversity conservation while maintaining long-term productivity are limited (Dorrough *et al.*, 2004). In contrast, the negative effects of grazing have been well documented. Grazing alters the composition of understorey species (Prober and Thiele, 1995; Clarke, 2003), prevents seedling recruitment (McIntyre and Lavorel, 1994), contributes to soil erosion and compaction (Yates and Hobbs, 1997) and enhances the invasion of exotic species (Prober and Thiele, 1995; Clarke, 2003).

Trees have traditionally been viewed as having negative impacts on grass production in grazing landscapes, by competing for water, soil nutrients, light or a combination of these factors (Scholes and Archer, 1997). A number of studies (e.g. McIvor and Gardener, 1995; McIvor, 2001) have shown tree density is inversely related to pasture yield in many woodland communities. However, retaining trees on grazing lands can provide shelter and shade for stock (Walpole, 1999), reduce salinity and land deterioration (McIvor and McIntyre, 2002), enhance soil nutrients (Gibbs *et al.*, 1999) and potentially improve the quality of grasses for livestock (Jackson and Ash, 2001). In spite of these benefits, the clearing of remnant vegetation and re-clearing of woody regrowth in grazing landscapes has resulted in the loss and severe modification of large areas of woodlands in eastern Australia (McIvor and McIntyre, 2002). In addition, pastoral land management in many grazing systems often involves removing or reducing the tree layer in remaining wooded areas to increase native grass production for livestock grazing (McIvor and McIntyre, 2002).

Exclosure studies have been widely utilised to assess the effects of livestock grazing in relation to groundcover composition and abundance, but have produced mixed results (Pettit & Frond, 2007; Spooner et al., 2002). Lunt *et al*. (2007), for example, implemented grazing exclusion in a *Eucalyptus camalulensis* forest in the Gulpa Island State Forest in South East Australia. The results, over a 12 year period, indicated grazing exclusion had very little impact on understorey composition and structure (Lunt *et al*., 2007). Lunt & Morgan (1999), in contrast, saw an increase in species richness over a 10 year period in a *Themeda triandra* grassland reserve in south-east Australia. These studies demonstrate vegetative responses to grazing exclusion may be largely influenced by environmental factors as well as grazing history and exclusion duration.

Potentially, there are both biodiversity and production benefits if trees are retained in grazing landscapes. However, there is little empirical information to suggest what overstorey tree density may be appropriate so that both production and conservation goals may be achieved in these agricultural systems. In our study, overstorey (mature) tree density and the presence/absence of woody regrowth in the understorey were used as broad surrogates of vegetation management practices for livestock grazing in the Traprock wool-producing region of southern Queensland, Australia. The objective of this study was to determine the effects of vegetation management for grazing (altered tree density and woody regrowth) on floristic composition and cover of two woodland communities which previously dominated the landscape. Specifically, we examined the following questions: is there a difference in floristic composition and understorey cover across overstorey tree density classes? What is the response of the understorey to grazing exclusion?

Methods

Study area

The study was undertaken in the Traprock wool-growing region in southern Queensland, an area recognised for the production of fine gauge wool fibres by predominantly un-improved native pasture grazing. The original vegetation of the region had been subjected to clearing by ring-barking some 80 years ago and many sites were periodically re-cleared (until about 30 years ago) to control woody regrowth (Le Brocque *et al.,* 2008). The remaining vegetation is predominately grassy eucalypt woodland comprised of narrow-leaved ironbark (*Eucalyptus crebra*), tumbledown gum (*E. dealbata*), white box (*E. albens*) (Queensland Herbarium RE type 13.11.3, Sattler and Williams, 1999) on the upper slopes and ridges and, on the lower slopes, yellow box (*E. melliodora*), greybox (*Eucalyptus microcarpa*) or gum topped box (*Eucalyptus moluccana*) (RE type 13.11.8, Sattler and Williams, 1999), interspersed with grazing paddocks. The region supports approximately 300 000 hectares of grazing land, stocked at a nominal rate of about 1-2 DSE (dry sheep equivalents) per hectare.

Composition and understorey cover across overstorey tree densities

Survey sites were stratified across vegetation type (ironbark/gum woodland vs. box woodland), density of overstorey trees (low (<6 trees/ha), medium (6-20 trees/ha) and high (>20 trees/ha)), and presence/absence of woody regrowth in the understorey. Sites within each of these treatment combinations were sampled from patches at least 5 ha in size. A total of 47 sites were sampled, including 4 reference sites (Figure 1; Table 1). Reference sites were chosen to represent woodlands with minimal grazing impact; however, they have been subjected to modification from light grazing, altered fire regimes and some selective logging, in the past.

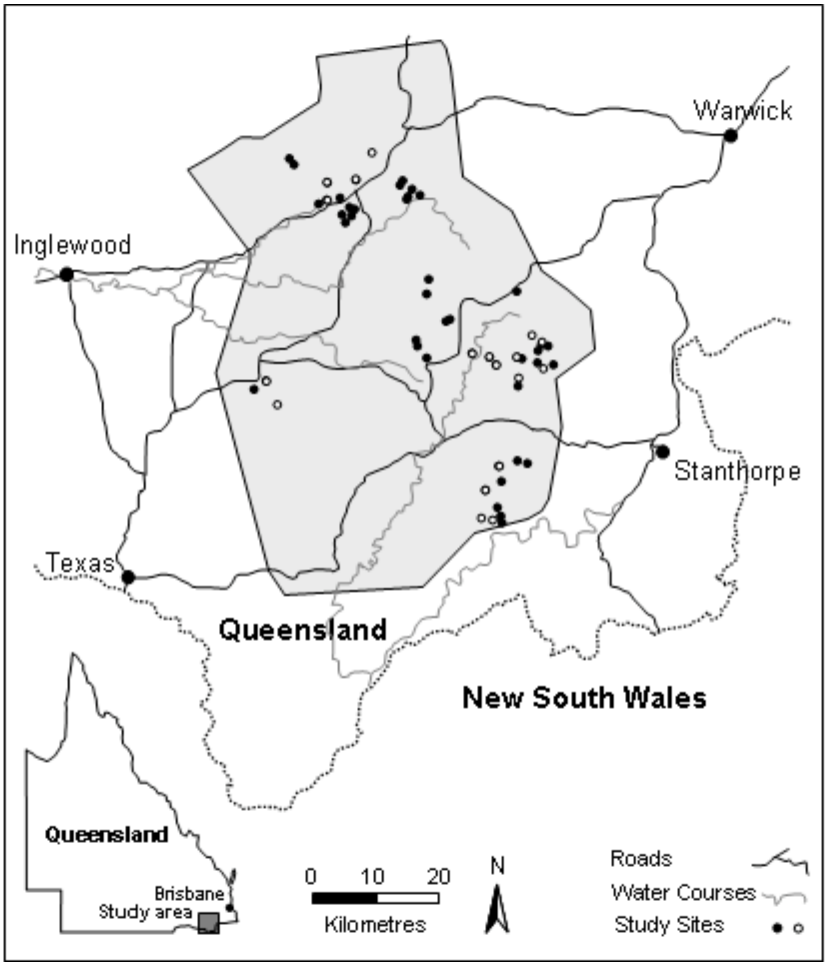

Figure 1. Map of Traprock wool-growing region (shaded) showing location of study sites. Open site symbols represent both survey and exclosure sites.

At each survey site, a 500 m² quadrat was randomly established and the composition and frequency of plant species was determined (after Morrison *et al.*, 1995). Site stand structure was determined using the modified Specht (1981) structural classification scheme (after Le Brocque and Buckney, 1997). Based on the vegetation of the study area, six strata were pre-defined: trees 10-30 m, trees <10 m, shrubs >2 m, shrubs <2 m, forbs/herbs/other (non-woody species), and graminoids (including grasses, sedges and others). The percentage foliage cover of each stratum was estimated within the 500 m² quadrat. Data were pooled across some strata to derive total tree cover and total shrub cover.

Table 1. Description of survey sites, abbreviated description (label), and number (n) of replicates for each treatment combination and site numbers. * Subset of study sites included in grazing exclusion study.

Site description	Label	n	Site numbers
Low density; no regrowth; ironbark/gum woodland	LNU	5	1*, 2*, 3*, 4, 5
Low density; regrowth; ironbark/gum woodland	LRU	5	6, 7, 8, 9, 10
Low density; no regrowth; box woodland	LNL	5	11*, 12, 13*, 14, 15*
Low density; regrowth; box woodland	LRL	4	16, 17, 18, 19
Medium density; no regrowth, ironbark/gum woodland	MNU	4	20, 21*, 22*, 23*
Medium density; regrowth, ironbark/gum woodland	MRU	4	24, 25, 26, 27
Medium density; no regrowth, box woodland	MNL	3	28*, 29*, 30*
High density; no regrowth; ironbark/gum woodland	HNU	4	31*, 32, 33*, 34*
High density; regrowth; ironbark/gum woodland	HRU	2	35, 36
High density; pole stage regrowth; ironbark/gum woodland	HORU	4	37, 38, 39, 40
High density; no regrowth; box woodland	HNL	3	41*, 42*, 43*
Reference; ironbark/gum woodland	REFU	2	44, 45
Reference; box woodland	REFL	2	46, 47

Understorey response to grazing exclusion

Across both vegetation types, a subset of 18 sites that were free of woody regrowth in the understorey was selected for grazing exclusion (Figure 1). At each site, three 6 x 6 metre plots were established in areas representing the corresponding vegetation type and overstorey tree density. Exclosures consisted of a control or open site marked by four corner pegs allowing animal grazing; a partial exclosure plot comprising of a 1.5m fence to exclude sheep grazing; and a complete exclosure with a 2.5m fence to prevent grazing from sheep and other large herbivores (Figure 2).

Exclosures were sampled in April 2005 (two months after establishment), February 2006 (12 months after exclosure establishment), February 2007 (2 years after exclosure establishment), and in February 2008 (3 years after exclosure establishment). Within each 6 x 6 metre exclosure plot, a central 2 x 2 metre quadrat was sampled for ground cover and vascular plant species composition.

Ground cover was determined by subjectively estimating the percent cover of all species within each 2 x 2 metre quadrat. The above-ground vegetation was clipped in a separate 0.25 m² quadrat within each 6 x 6 m exclosure plot using hand sheers. Plant biomass (gm/0.25m²) was determined as dry weight by after oven drying (50-60 ºC) for 3 to 4 days.

Figure 2. Complete exclosure set up in a low overstorey tree density (open paddock) site. Photo: A. Le Brocque, 2006.

Statistical Methods

Non-metric multidimensional scaling (nMDS) was performed on Bray-Curtis similarities calculated from the frequency data (survey) and plant cover data (exclosure study) using the Primer v.5.2.9 for Windows program (Primer-E Ltd, 2001). Analysis of similarity (ANOSIM) was performed on the frequency data to determine if there were differences in similarlity between *a priori* groups (Clarke and Gorley, 2001). One-way analysis of variance was used to determine if there were differences in grass cover or forb/herb cover between treatments. All cover data were arc-sine transformed prior to analysis, while Levene's statistic and residual plots were used to test for homogeneity of variances. In addition, Spearman-rank correlations were performed to determine whether cover variables (e.g. tree and grass cover) were related.

A two-way crossed analysis of similarity (ANOSIM) was performed on plant cover data to determine if there were differences between treatments in terms of exclosure and overstorey tree densities. A Two-way ANOVA for each vegetation type was also undertaken, analysing the 2008 (3 years following exclusion) biomass data with respect to exclosure treatment and mature tree density and the interaction between these factors. The homogeneity of variances assumption (Levene's test; $p>0.05$) was met for both vegetation types.

Results

Composition and understorey cover across overstorey tree densities

A total of 202 plant taxa from 53 families was recorded in the study (Le Brocque *et al.*, 2008). A plot of centroids from the nMDS ordination of frequency data (Figure 3) indicates a general gradient of increasing mature tree density from left to right across the diagram. Low tree density no regrowth sample centroids (LNU and LNL) were well separated from low density regrowth and medium density woodlands (LRL, LRU, MRU, MNL, MNU) and high tree density box woodlands (HNL, RefL), towards the centre of the ordination and high density ironbark/gum woodlands (HNU, HRU, HoRU, RefU) on the right (Figure 3). Analysis of similarity showed no significant differences in floristic composition between low density no regrowth ironbark/gum woodlands (LNU) and low density no regrowth box woodlands (LNL) ($R = 0.176$; Table 2). With a few exceptions, such as low tree density no regrowth samples (LNL, LNU), ANOSIM results reveal significant differences in floristic composition between box woodlands and ironbark/gum woodlands within any mature tree density or regrowth/no regrowth treatments (Table 2).

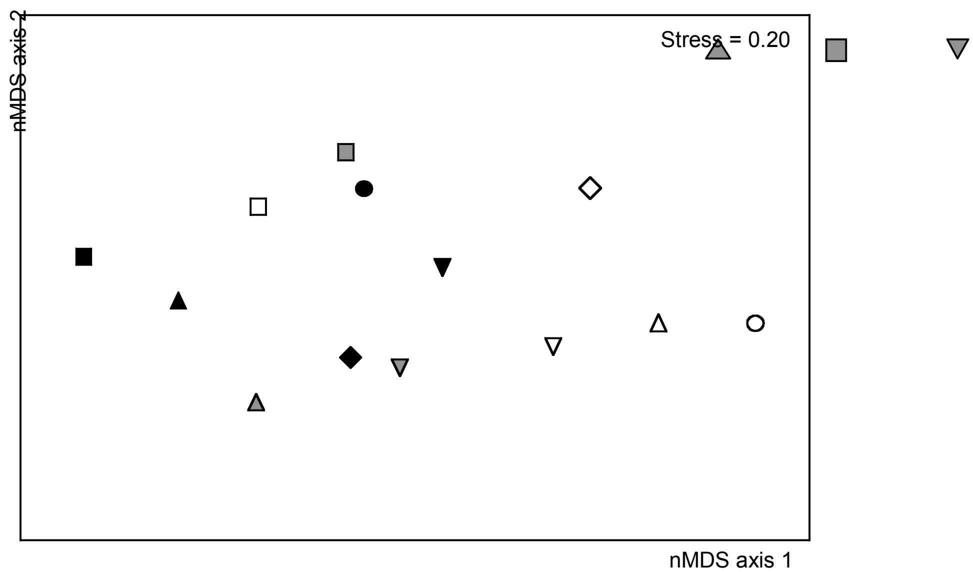

Figure 3. Centroids plot of non-metric multidimensional scaling ordination of floristic composition data (frequency) across all sites: LNU (▲), LNL (■), LRU (▼), LRL (◆), MNU ( ), MNL ( ), MRU ( ), HNU (△), HNL (□), HRU (▽), HoRU (◇), RefL (●), RefU (○).

Table 2. Summary of results from analysis of similarity (ANOSIM) of floristic composition (plant frequency) across overstorey tree densities.

Summary of Pairwise comparisons (R values): (R values are significant at † 0.05<p<0.01; †† p<0.01)

	LNU	LRU	LNL	LRL	MNU	MRU	MNL	HNU	HRU	HORU	HNL	REFU
LRU	0.46††											
LNL	0.18	0.86††										
LRL	0.29	0.31	0.87††									
MNU	0.23	0.51††	0.54††	0.28								
MRU	0.31	0.11	0.74††	0.02	-0.05							
MNL	0.49†	0.29†	0.85†	0.20	0.28	0.32						
HNU	0.77††	0.50††	0.93††	0.62†	0.54†	0.28	0.35					
HRU	0.64†	0.46	1.00†	0.43	0.36	-0.21	0.50	-0.04				
HORU	0.65†	0.34	0.91††	0.63†	0.67†	0.46	0.48	0.10	0.46			
HNL	0.40†	0.59†	0.87†	0.61†	0.22	0.41	0.15	0.37	0.92	0.72		
REFU	0.89†	0.78†	1.00†	0.96	0.96	0.93	1.00	-0.25	0.50	0.68	1.00	
REFL	0.64†	0.44	0.89†	0.32	0.07	<0.01	<0.01	0.18	0.50	0.61	0.67	1.00

Mean grass cover ranged between 3% (RefU) and 71% (LNL) across treatments (Figure 4a). Low density no regrowth box woodland (LNL) had a significantly higher grass cover than most other woodlands ($p<0.05$), except for low density no regrowth ironbark/gum woodland (LNU) and medium density no regrowth woodlands (MNU and MNL) (Figure 4a). Forb cover was generally low across all treatments ranging from 2% (REFL) to 15% (LNU) and was generally higher in no regrowth woodlands (Figure 4b). Grass cover declined significantly with increasing total tree cover ($r_s = -0.510$; $p<0.001$; Figure 5a). Similarly, forb and herb cover declined with increasing total tree cover ($r_s = -0.489$; $p<0.001$; Figure 5b).

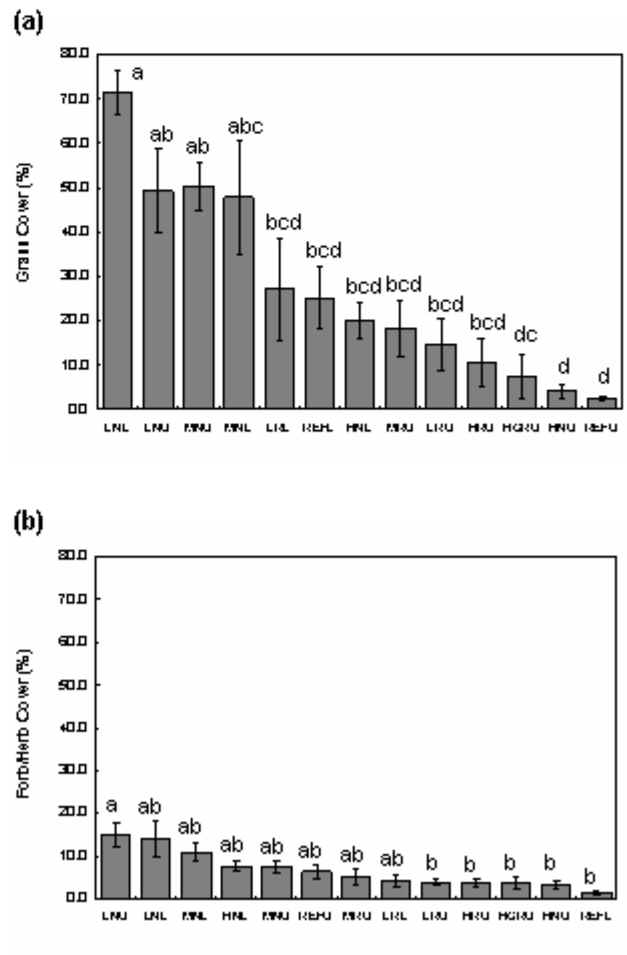

Figure 4. Mean foliage projective cover (%) of (a) grasses (df = 12, 34; F = 8.90) and (b) herbs/forbs (df = 12, 34; F = 3.47) across treatments. Treatments with same letter are not significantly different (Tukey's test, $p>0.05$). Error bars are standard errors.

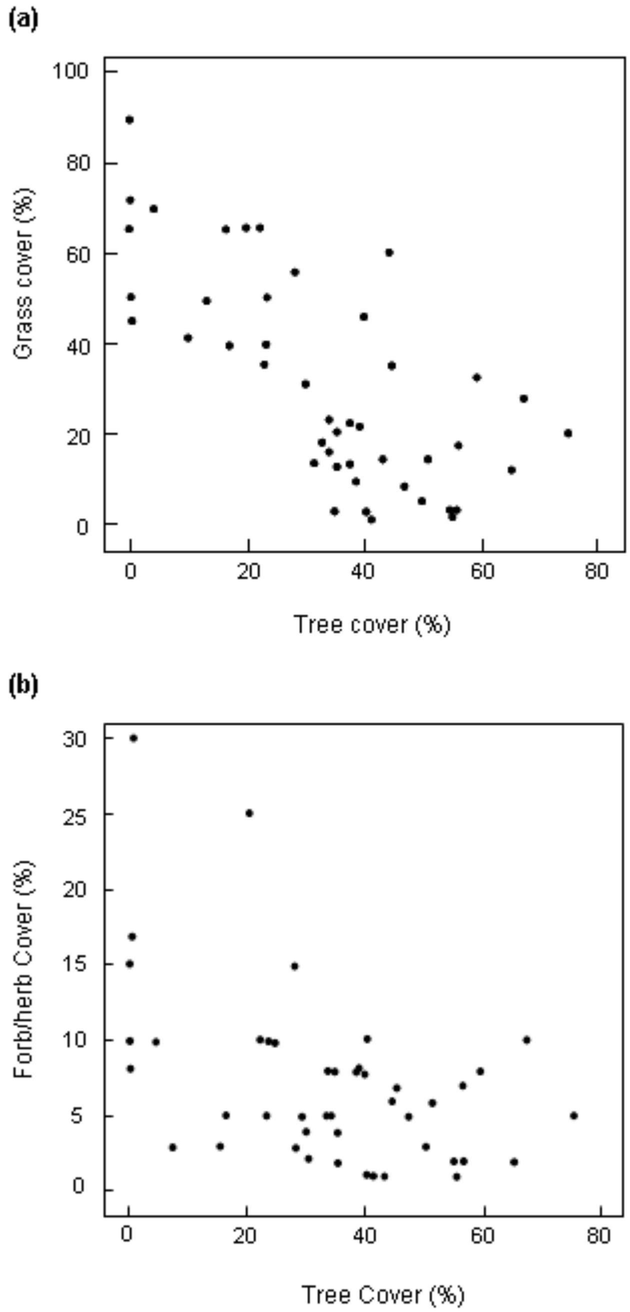

Figure 5. Scatterplot showing relationship between (a) grass and tree cover, and (b) forb/herb cover and total tree cover.

Understorey response to grazing exclusion

A total of 151 plant taxa (135 native, 16 exotic) were recorded across the exclosure and overstorey tree density treatments in the two vegetation types. The two-way crossed ANOSIM of plant cover data for both vegetation types following three years of exclusion (Table 3) shows that differences between mature tree densities were significant for both ironbark/gum woodlands (p=0.007) and box woodlands (p=0.037). Exclosure treatments were not significant (p>0.05) across either vegetation type (Table 3). In ironbark/gum woodlands, high mature tree density sites were significantly different in floristic composition to low and medium tree density sites. In box woodlands, high mature tree density sites were significantly different in floristic composition to low tree density sites. Medium density box woodland sites were not significantly different in floristic composition to either high or low tree density sites.

Table 3. Summary of results from analysis of similarity (ANOSIM) of plant cover data across treatments following three years of exclusion. Global R value and significance level shown; treatments sharing the same superscript are not significantly different (p>0.05).

Effects	R value	Significance	Pairwise tests		
Ironbark/gum woodland					
Overstorey Tree Density	0.262	0.007*	Low[a]	Medium[a]	High[b]
Exclosure	-0.192	0.953	Complete[a]	Partial[a]	Open[a]
Box woodland					
Overstorey Tree Density	0.193	0.037*	Low[a]	Medium[ab]	High[b]
Exclosure	-0.147	0.894	Complete[a]	Partial[a]	Open[a]

Mean biomass data for exclosure treatments for both vegetation types across all years is shown in Figure 6. High heterogeneity across all treatments precluded any meaningful statistical analysis of biomass data with respect to time. Generally low density treatments show a stronger response in terms of increasing biomass than either medium or high tree density treatments across both vegetation types (Figure 6). An increase in mean above-ground biomass from 2005 to 2008 was generally indicated for low tree density treatments for both vegetation types. High density ironbark/gum woodland sites also exhibited a marked increase in biomass in 2008. In the low density treatments, the most notable increase in mean above-ground biomass was in the complete exclosures (Figures 6a & 6d). A highly variable response is noted for medium and high density box woodland samples. No pattern is evident for medium density ironbark/gum woodland samples.

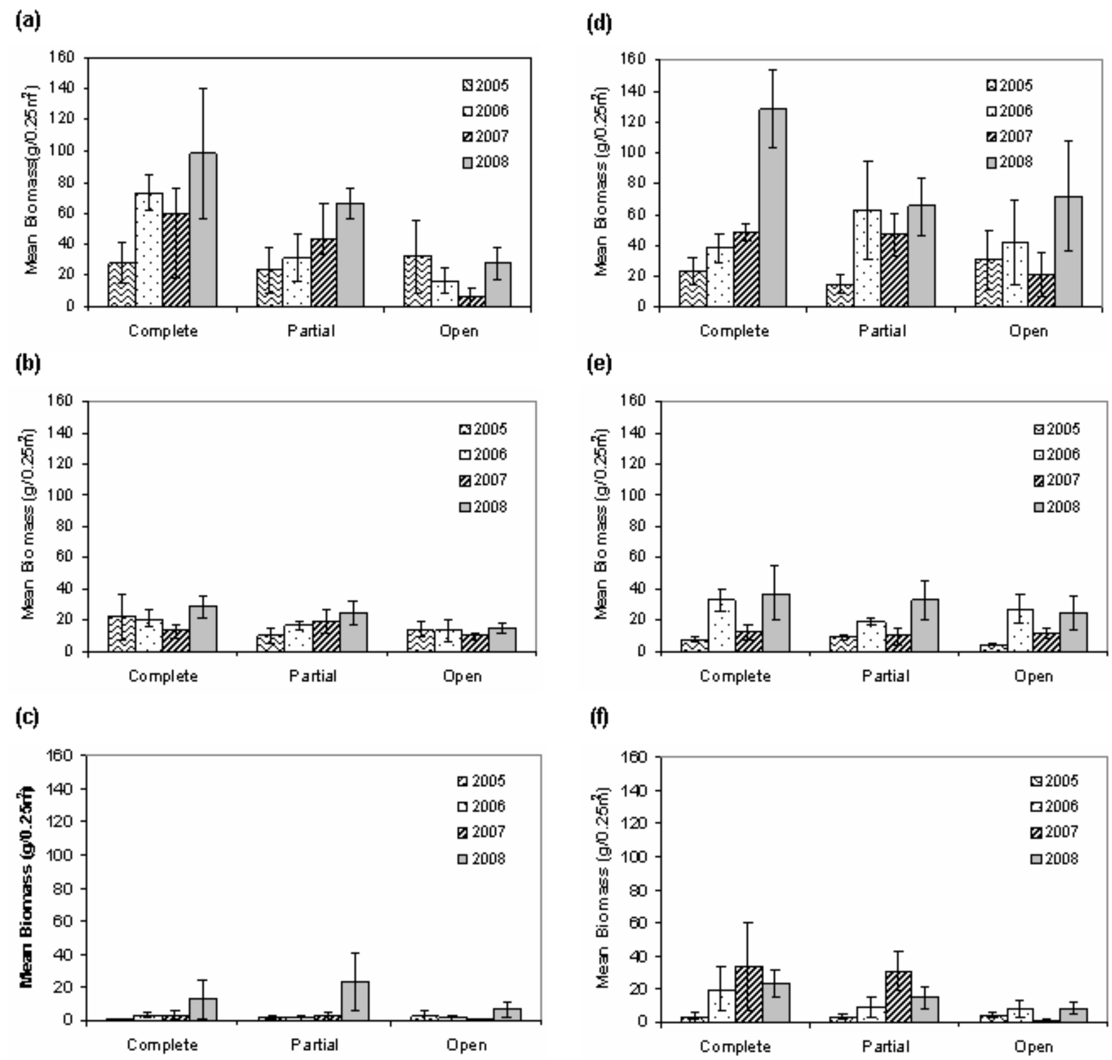

Figure 6. Mean above-ground plant biomass (gm/0.25m^2) across treatments for (a) low (b) medium and (c) high density ironbark/gum woodland, and (d) low (e) medium and (f) high density box woodland for successive years. Error bars are standard errors.

Overstorey tree density showed significant differences in terms of above-ground biomass for both vegetation types ($p < 0.05$; Table 4). Low overstorey tree density sites were significantly higher in above-ground biomass in 2008 than medium and high overstorey density sites. Exclosure type and the interaction term were not significant ($p > 0.05$; Table 4).

Table 4. Two-way ANOVA of above-ground biomass in 2008 for each vegetation type. Tukey's post hoc tests show mean biomass per $0.25m^2$ (± standard error): means sharing same superscript are not significantly different (p>0.05).

Woodland	Factor	F-score (df)	P-value	Post Hoc Tests		
Ironbark/gum Woodland	Overstorey Tree Density	13.30 (2)	0.000	Low 63.9^{a} (16.2)	Med. 22.6^{b} (3.6)	High 14.0^{b} (6.7)
	Exclosure	2.15 (2)	0.146	not significant		
	Density * Exclosure Interaction	0.87 (4)	0.499	not significant		
Box Woodland	Overstorey Tree Density	7.72 (2)	0.004	Low 88.3^{a} (17.0)	Med. 31.4^{b} (7.1)	High 15.3^{b} (4.0)
	Exclosure	2.60 (2)	0.102	not significant		
	Density * Exclosure Interaction	1.16 (4)	0.361	not significant		

Discussion

Composition and understorey cover across overstorey tree densities

The results indicate that no differences in species composition (frequency) or ground cover are evident between low density no regrowth woodlands (LNU and LNL); however, these woodlands were generally different to other woodlands in terms of species composition. These open paddock areas are structurally very simple systems, with an absence of shrub and tree strata. The resultant ground cover of grasses and herbs/forbs essentially form a 'paddock' community that show little similarity to pre-European vegetation types. At medium and high overstorey tree densities, differences in species composition between the vegetation types became more evident. In particular, medium overstorey tree density woodlands show similarity to higher overstorey tree density woodlands and the reference (relatively undisturbed) woodlands within the two vegetation types. This suggests that medium overstorey tree densities (6-20 trees/ha) provide for an increased diversity of plant species closer in composition to less disturbed elements of the grazing landscape.

However, ground (grass and herb/forb) cover showed no differences between open paddock areas and medium overstorey tree densities, particularly where there was an absence of woody regrowth in the understorey, despite significant negative relationships observed between ground cover and tree cover. Indeed, the relationship exhibited for grass cover and tree cover indicates that at lower tree cover (less than approx. 20%), grass cover shows little decline. These results suggest that medium overstorey tree densities do not necessarily adversely affect ground forage (at least in terms of cover) for this system.

Chilcott *et al.* (1997) suggested that an overstorey of mature trees at a medium density may facilitate the re-establishment of native plant species. Retaining mature trees on grazing lands can also provide a range of other ecosystem benefits including: shelter and shade for stock (Walpole, 1999); prevention of land deterioration (McIvor and McIntyre, 2002); enhancement of soil nutrients (Gibbs *et al.*, 1999); and potential improvement in the quality of grasses for livestock (Jackson and Ash, 2001).

Understorey response to grazing exclusion

While very much a preliminary analysis of data gathered from the grazing exclusion study, some general trends are notable. Overstorey tree density was a significant factor accounting for differences in both species composition and above-ground biomass for 2008 data (three years following exclusion). However, the results are somewhat contradictory. Overall ground cover species composition (in terms of similarity) was not different between low and medium overstorey tree densities in both vegetation types, consistent with the broader survey. The box woodland also shows a significant difference between low overstorey tree density sites and high overstorey tree density sites, with medium overstorey tree density sites not different to either. On the other hand, low overstorey tree density sites exhibited greater increases in mean biomass over the experimental period in comparison to medium and high density samples. In particular, medium overstorey tree density sites showed a highly variable pattern over the four sampling sessions and may reflect the effects of other factors, such as possible climate influences. Lunt *et al.* (2007) similarly found rainfall to have a greater influence on plant responses than grazing exclusion in *E. camaldulensis* forests in southeast Australia.

Competition for resources, particularly soil water and light, can greatly influence plant survival and reproduction with dense tree stands likely to decrease resource levels available to small herbaceous vegetation and grasses (Jackson & Ash, 2001; McIvor, 2001; Scanlan, 2002; Lunt *et al.*, 2007). Low overstorey tree density sites would, as a result of reduced resource competition, exhibit a greater in crease in above-ground biomass than those with higher overstorey densities.

More significantly, exclosure type (complete, partial or open) showed no consistent differences in composition or above-ground biomass after three years of grazing exclusion. This result is somewhat surprising as, particularly in open paddock areas, it was expected that biomass would be much higher in the complete grazing exclosure than the open grazed plots within sites. While some trend reflecting this expectation appears to exist in relation to the 2008 biomass data, high variability within samples overshadows any significant differences. Species composition may also take longer to exhibit differences between exclosure treatments, due to a lag in assemblage changes within plots.

The effects of grazing within differing vegetation communities can be species specific (Hobbs & Huenneke, 1992), with the exclusion of livestock grazing resulting in increased biomass production of grazing-sensitive plant species (Lunt *et al.*, 2007). Spooner & Briggs (2008) examined fenced and unfenced sites in grazing woodlands in southern New South Wales over a 5 year period and found significant differences in plant species. Fenced sites exhibited considerable decreases in perennial grasses, both native and exotic, between 2000 and 2005 and notable increases in exotic annual grasses (Spooner & Briggs, 2008). Hence, mean biomass may not show significant differences between grazing exclusion and open plots, but may show marked differences in species composition and abundance.

Longer implementation of exclosure treatments may be required before differences may be realised. Compared with other exclosure studies, the duration of this investigation in the Traprock region is relatively short. Pettit & Froend (2001) studied grazing exclosure in *E. marginata* woodlands in southwest Western Australia for 7 years. Spooner & Briggs (2008) analysed data over a 5 year period. Lunt & Morgan (1999) carried out treatments in a grassland reserve in southeast Australia for 10 years. Lunt *et al.* (2007) examined *E. camaldulensis* forests in southeast Australia for 12 years and produced only minor impacts on understorey composition and structure.

Management and conservation significance

Vegetation management practices within the Traprock region have influenced the floristic composition and richness of woodland communities. Maintaining a medium density of mature trees in these woodlands can potentially satisfy both production (in terms of grass cover) and biodiversity (floristic composition) goals in this modified grazing landscape. In both vegetation types examined here, a medium density of trees would be adequate to ensure a similar floristic composition to that of high mature tree density areas is maintained. This is significant for land management practices in the Traprock region in that while there is no significant increase in grass production in the very open areas compared to medium mature tree density areas, there is a significant decline in biodiversity value, at least in terms of floristic composition, and potentially other ecosystem services provided by more structurally complex vegetation.

Three years of grazing exclusion has failed to show differences in above-ground biomass between the three exclosure types (complete, partial, open). This, in part, may be due to high inter-annual variability, or may indicate a longer study is required. However, both compositional and biomass differences were evident between overstorey tree densities, confirming results from the broader survey. A further analysis of species composition and functional types within plots may provide more conclusive evidence for assessing differences between exclosure types. Longer-term monitoring of exclosure plots would seem necessary in determining the biodiversity ‘potential’ of the woodland and paddock elements of this production landscape.

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