

Effects of recent changes in grazing and fertiliser management on the species richness of native ground-storey vegetation, Northern Tablelands, New South Wales

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Abstract

Despite major land use changes, much of the ground-layer vegetation on the Northern Tablelands of New South Wales is still dominated by native grasses. The native grassy ecosystems of the region were studied to determine the impacts of grazing, fertilising and cultivation history on vascular plant species richness. Sampling was stratified on the basis of management. The incidence of all plant species in 30 m² quadrats was recorded at 373 sites within a 60 km radius of Armidale. Sites with a history of cultivation were found not to contribute any additional native species to the total number of native species found in uncultivated sites. In sites with no history of cultivation or fertiliser, the never grazed and infrequently grazed sites had significantly higher native species richness than grazed sites. The combined effects of increasing grazing intensity and fertiliser inputs significantly reduced native species richness and increased exotic species richness.

Keywords

exotic species, fertiliser, grasses, grazing, native species

Introduction

The landscape of south-eastern Australia was once characterised by ecosystems with a grassy understorey, ranging from forests to natural grasslands. Woodlands dominated much of the vegetation west of the Great Dividing Range (Sivertsen and Clarke 1999, Hamilton 2001), but there were significant areas of natural grassland on the tablelands, slopes and plains of New South Wales, the plains and Wimmera district of Victoria, south-eastern South Australia and the Tasmanian Midlands (Eddy et al. 1998; Hamilton 2001). The nature of the vegetation has progressively changed since European settlement. Woody vegetation has been thinned or removed from extensive areas to facilitate pasture and crop production. The ground-layer vegetation has also been altered, and in Victoria and southern New South Wales most remaining native grasslands are highly fragmented and modified, and are among Australia's most threatened and poorly conserved ecosystems (Eddy et al. 1998, Kemp 2002). However, in some areas where grazing is the predominant land use, particularly in northern and western New South Wales, the ground-layer vegetation remains dominated by native grasses (Lodge et al. 1984). These grasslands, which have often been derived by the removal of trees (Benson 1996), are extensive but usually floristically and structurally different from the original vegetation (Lunt 1997). Native grassy ecosystems continue to be affected by clearing and cultivation, the application of fertilisers, livestock grazing, invasion of exotic species and other forms of disturbance (McIntyre and Lavorel 1994a).

This paper presents preliminary results of a study of the effects of management on the ground-layer plant diversity of grassy ecosystems on the Northern Tablelands. The project was initiated to determine the management requirements of native herbaceous vegetation on the Northern Tablelands, as it is uncertain how tree clearing, fertiliser history, cultivation history

and the intensity and timing of grazing influence the diversity of native herbaceous vegetation. It is therefore important to clarify the impacts of management on the conservation value of native grassy vegetation, for the benefit of land managers, land administrators and conservationists alike. While there have been previous studies of the composition of grasslands in the region (including McIntyre et al. 1993, McIntyre and Martin 2001), this paper focuses on the impact of changes in grazing management on the species richness of native herbaceous vegetation.

Management history of the Northern Tablelands

The grazing industry on the Northern Tablelands is similar to that of many grazing regions in south-eastern Australia, but native and natural pastures (as defined by Lodge and Whalley 1989) are more prominent than in areas further south. The Northern Tablelands covers about 38 000 km² of temperate highlands above 800 m altitude. Rainfall is greatest during summer but fairly uniformly distributed throughout the rest of the year, and frosts are severe in winter. Before the arrival of Europeans, the Tablelands consisted of rolling hills and plains, with open grassy woodland in the valleys and denser open forests on the ridges (Oxley 1820). There were also smaller areas of natural grassland and wetlands. Tussock grasses dominated the grassy layer. Early accounts indicate that the dominant species often included Kangaroo Grass (*Themeda australis*), Native Sorghum (*Sorghum leiocladum*) and Poa Tussock (*Poa sieberiana*) on fine soils; or Kangaroo Grass, Wire Grass (*Aristida ramosa*) and Barbed-wire Grass (*Cymbopogon refractus*) on coarser soils (Lodge and Whalley 1989).*

Europeans arrived on the Northern Tablelands in the 1830s, and the grazing industry developed rapidly (Nadolny 1998). Extensive clearing, draining of swamps and other developments were carried out. Eucalypt regrowth was usually dense and had to be repeatedly cleared, and many pastures were regularly burnt. Livestock numbers reached a peak around 1910 and were not exceeded for another 40 years. It is likely that, after 1910, pasture quality declined and the relative abundance of desirable plants such as *Austrodanthonia* spp. diminished, while undesirable plants such as *Aristida* spp. increased by the 1940s (Lodge and Whalley 1989). The original native legumes, which were usually either twiners or shrubs, also declined as a result of continuous grazing (Nadolny 1998). During the 1950s, the spreading of superphosphate and clover seeds, often by aircraft, became an established practice. This resulted in a dramatic increase in stocking rates, from about 2–3 sheep/ha to 8–12 sheep/ha (Cook and Malecky 1974). Further intensification was achieved through the sowing of exotic pasture grasses, such as Phalaris, Fescue and Cocksfoot.

Eucalypt dieback, associated with severe defoliation by various native insects, became severe in the 1970s (Heatwole and Lowman 1986). It provided a warning that the new agricultural regime was unsustainable (Reid et al. 1997). The enhanced nutrient status of soils under trees, partly resulting from the camping habits of livestock (Taylor et al. 1984), was one of several factors that appeared to contribute to the build-up of insect populations (Landsberg et al. 1990, Nadolny 2002). Other problems with the new 'improved' pastures began to emerge. These included sensitivity to drought, lack of regeneration of trees and shrubs, loss of natural controls for pasture pests, an increase in exotic weeds, and an increased risk of land degradation, especially if intensification was attempted on marginal country (Nadolny 1998). In contrast to more southern areas, exotic pastures were often short-lived and were progressively invaded by summer-active native grasses such as *Bothriochloa macra* and *Sporobolus creber*. By the late 1980s some graziers were questioning the 'sown pasture' philosophy because the expected increases in production had not been sustained.

Following the collapse of wool prices in the early 1990s many farmers lowered their inputs, and some experimented with 'new' approaches to management. The cost of inputs such as superphosphate continued to increase, while the returns from the sale of wool and livestock declined (Connell et al. 1996). Hence, the benefits of lower input systems utilising native pastures became more apparent (Lodge 1994, Jones 1995). An approach to grazing management

* Nomenclature follows Wheeler et al. (2002).

that involved planned rests, generally called rotational or cell grazing, also became popular. This usually involves keeping livestock in relatively large mobs that are sequentially allowed to graze a large number of small paddocks for short periods, with the pastures being given a long period of rest in between (Savory 1988, Earl and Jones 1996). The 'planned rest' approach became intertwined with a philosophy of utilising existing resources, minimising inputs, and learning more about grazing systems and native pastures in particular (Wright and Wright 2000). However, improvements in knowledge about managing pastures were not confined to this movement; parallel developments included enhancing direct drilling technology, understanding drought management strategies for maintaining sown pastures (Boschma and Scott 2000) and the extension of robust techniques for estimating pasture biomass.

The Landcare movement involved another revolution in thinking in which landholders assumed greater responsibility for improving their local environment (Curtis et al. 1995). One new notion was that areas of bushland on farms had to be specifically managed to encourage the regeneration of trees and shrubs and to protect other plants that were sensitive to grazing pressure (Davidson and Davidson 1992). The fencing of remnants has been encouraged by various incentive schemes funded through the Natural Heritage Trust, its Commonwealth predecessors, and the Department of Land and Water Conservation (NSW).

The *Native Vegetation Conservation Act 1997* (NSW) has also resulted in a more explicit consideration of the conservation of native vegetation in land use decisions, and is intended in part to protect native vegetation that has a high conservation value. The Act defines ground cover in which native species comprised more than 50% of the cover as 'native vegetation', and requires a permit for any clearing outside of specified exemptions. This has focused attention on the conservation values of native grasslands used by the grazing industries since European settlement, and on the impact of grazing and associated management.

Methods

Survey area

The study was confined to the Northern Tablelands of New South Wales, within 60 km of Armidale. Within this area the altitude ranges from about 850 m to over 1300 m above sea level, and mean precipitation varies from about 700 to 1000 mm per annum.

Four main parent materials underlie the region: sediments and metasediments, basic volcanic rocks (basalt), acidic volcanic rocks, and acidic igneous rocks (granite). The intensification of agriculture is concentrated on basalt-derived soils of moderate to high fertility (Morgan and Terry 1990). Pasture intensification has also occurred on soils derived from granites and metasediments, but these soils are of lower fertility and so development has been less intense because of the higher inputs required.

Survey design

Sampling was stratified on the basis of three management variables: cultivation (two levels — not cultivated, cultivated), grazing (four levels — not grazed by ungulates, episodically grazed, planned rest, continuous grazing) and fertiliser application (2 levels — never fertilised, fertilised). Within each of these variables, sites were further stratified by lithology (basalt, metasediment, granite). The analysis of differences resulting from lithology will be reported elsewhere. A total of 108 combinations were possible, but because of the absence of various combinations in the landscape and limited time only 32 combinations were sampled. These combinations were selected to enable a sufficient replication of the desired management variables, and for specific comparisons to be made between grazing, fertilisation and cultivation regimes on different lithologies. The various combinations of management variables can therefore be selected for comparison.

Within the general habitats defined above, further restrictions on sampling were imposed. The following sites were avoided (after McIntyre et al. 1993):

- 1 areas with slopes greater than 18°
- 2 areas with significant rock outcrops
- 3 wetlands and water courses

- 4 recently cultivated and planted areas (within the last 10 years)
- 5 properties that had changed their management practices recently (within the last 6 years)
- 6 stock camps or areas in the vicinity of stock camps.

At each site, a single quadrat of 30 m² (5 × 6 m: McIntyre and Lavorel 1994b) was laid out using a technique based on that of McIntyre, Huang and Smith (1993), and the incidence of all higher plant species was recorded. Sampling extended from January to April (mid-summer to mid-autumn) in both 2001 and 2002, which enabled reproductive material of species to be collected for adequate identification. Several plant species that could not be differentiated in a vegetative state were combined.

Statistical methods

Analysis of variance (ANOVA) was used to examine the differences between native and exotic species richness with different responses to grazing regimes. An unbalanced two-way ANOVA with the most parsimonious model was used to examine native and exotic species richness under different grazing and fertiliser regimes. The 'ungrazed' regime was excluded from this analysis.

Results

A total of 373 sites (Figure 1) were sampled, recording a total of 321 species and subspecies (224 native and 97 exotic). Only four taxa occurred in greater than 50% of sites. *Hypochaeris radicata* and/or *H. glabra*, both perennial exotic Asteraceae, were the most frequently occurring taxa (86%). The next most frequent species were the perennial native grasses, *Bothriochloa macra* (69%), *Sporobolus creber* (65%) and *Poa sieberiana* (60%). Over 60 species were found only once during the survey, including the rare plant *Euphrasia orthochelia* subsp. *orthochelia*. Seven life forms (forbs, grasses, shrubs, trees, twiners, other monocots and ferns) were recorded. Forbs were the most common life form recorded, and included *Hypochaeris glabra/radicata* and *Euchiton sphaericus*. Grasses were the second most common life form, and ferns were the least frequent. Only two fern species were recorded: *Cheilanthes sieberi* subsp. *sieberi* and *Pteridium esculentum*.

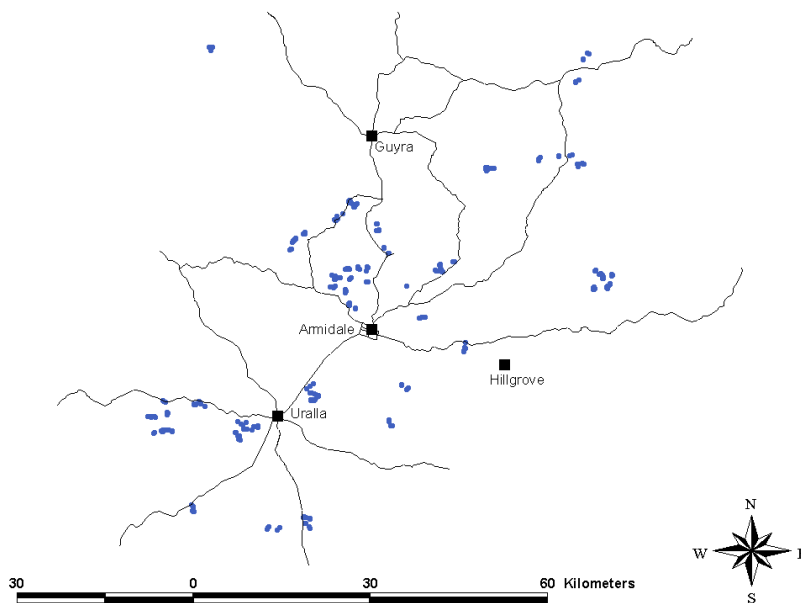


Figure 1 The study area, showing locations of sites surveyed for herbaceous vegetation on the Northern Tablelands, NSW.

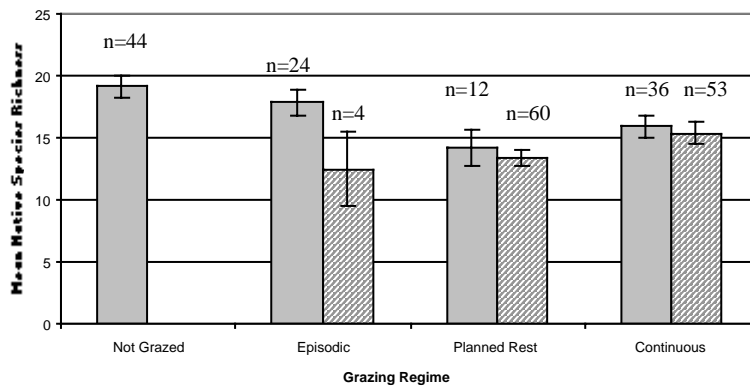
Effects of cultivation on native species richness

The 137 sites with a history of cultivation supported a total of 108 native species (10.1 native species per site, ± 0.3 SEM), whereas 236 uncultivated sites contained 224 native species (16.1 native species per site, ± 0.4 SEM). All species recorded at sites with a history of cultivation were also recorded in uncultivated pastures. Therefore the majority of native ground-layer diversity was found in uncultivated sites, which are the focus of the remainder of this paper.

Effects of grazing and fertiliser on species richness

In sites with no history of cultivation or fertilisation there was a significant difference in the mean native species richness between (a) sites that were not grazed or episodically grazed, and (b) planned rest and continuously grazed sites ($P = 0.01$, $F = 3.85$, $df = 115$) (Figure 2A). Mean exotic species richness was not significantly different between grazing regimes ($P = 0.14$, $F = 1.85$, $df = 115$) (Figure 2B). A direct comparison of all fertilised and unfertilised sites is difficult to interpret because the grazing regime is a confounding factor — fertilised paddocks are generally grazed more intensely than unfertilised paddocks.

(A)



(B)

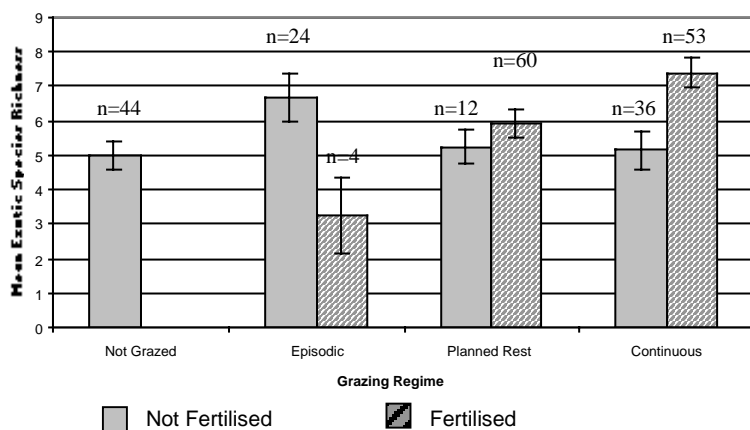


Figure 2 Mean (a) native and (b) exotic species richness (± 1 SEM) in 30 m² quadrats at 233 sites with no history of cultivation.

Considering the interaction of grazing and fertiliser, in the 236 sites with no history of cultivation (three were excluded due to inconsistencies in fertiliser and grazing management), the grazing and fertiliser interaction had no significant effect on mean native species richness (two-way ANOVA, $P = 0.30$, $F = 1.22$, $df = 2$) (Figure 2A, Table 1A). Within the same grazing

regime, mean native species richness was consistently lower in fertilised sites compared to unfertilised sites, but these differences were not significant. This variation was most noticeable in sites with an episodic regime of grazing but because of the small sample size for unfertilised areas this needs to be regarded with caution.

The grazing and fertiliser interaction had a significant effect on mean exotic species richness (two-way ANOVA, $P < 0.01$, $F = 5.05$, $df = 2$) (Figure 2B, Table 1B). Planned rest and continuously grazed sites had a larger number of exotic species if they were fertilised. In some areas there was a tendency for exotic pasture seed to be spread with superphosphate, and the presence of a few species could be attributed to this practice. However, this practice was not generally part of routine agricultural management in this study, and fewer than 6% of sites had seed added with fertiliser. A high number of exotic species was also found in episodically grazed, unfertilised sites (Figure 2B).

Table 1 ANOVA table for the effects of grazing and fertiliser on (a) native and (b) exotic species richness.

	Effect	DF	F-value	P-value
(A)	Grazing	2	5.25	< 0.01
	Fertiliser	1	1.38	0.24
	Grazing : fertiliser	2	1.22	0.30
	Error	183		
(B)	Grazing	2	0.97	0.38
	Fertiliser	1	5.36	0.02
	Grazing : fertiliser	2	5.05	< 0.01
	Error	183		

Discussion

The results indicate that native species richness was greater in sites that are seldom grazed than in those grazed by a continuous or planned rest regime. This is consistent with the results of McIntyre and Lavorel (1994b) who found that on the Northern Tablelands of New South Wales, plots in areas managed for production have fewer native species than reserves and stock routes, and the converse for exotic species. The findings of our study also agree with those of Lunt and Morgan (1999), who found that in Victorian grasslands most native species were resilient to a range of management regimes, including the long-term absence of biomass removal. In contrast, previous studies have emphasised the sensitivity of many native grassland species to long inter-fire periods, and the potential of many species to disappear irreversibly after lengthy periods beneath a closed grass sward (Scarlett and Parsons 1990, Morgan 1997, Morgan 1998). Overseas studies (Puerto et al. 1990, Montalvo et al. 1993, Noy-Meir 1995) have also found that grazed sites tend to have higher total species richness and diversity than adjacent sites protected from grazing but in these studies species were not segregated into native and exotic.

It is thought that native species sensitive to continuous grazing may have disappeared from the landscape due to grazing pressure. Under some grazing regimes, palatable species decline in abundance while unpalatable ones increase. It is possible that the grazing impacts have been underestimated, because sheep or cattle have grazed many ungrazed sites sometime in the past 50 years and livestock have been excluded from many ungrazed sites only recently (in the last 8–10 years). This may not have been sufficient time for changes to become obvious, particularly for species that live for more than 10 years (Lunt and Morgan 1999). Records from early explorers and settlers do not provide sufficiently detailed descriptions to clearly characterise the matrix of species in these grassy woodlands and grasslands in the 18th and 19th centuries.

Unfertilised sites grazed according to a planned rest regime had a similar native species richness (14.3 species \pm 1.4 SEM) to sites that were continuously grazed (15.9 species \pm 0.9 SEM). Sites with planned rest grazing have recently (last 6–10 years) undergone changes in grazing management from continuous grazing to planned rest grazing. Species absent under

continuous grazing therefore, are also likely to be absent from planned rest grazed sites, unless they have been able to recolonise in the last few years.

This study found no significant difference in exotic species richness in relation to grazing intensity, which is consistent with the findings of McIntyre and Lavorel (1994b) and Fensham (1998). The high species richness of exotic plants on the episodically grazed sites is most likely explained by the mechanical disturbance and water accumulation that are prevalent on travelling stock routes that comprise the majority of these episodically grazed sites, rather than the impact of grazing. Among sites that were fertilised, planned rest sites had significantly lower exotic species richness (5.9 species \pm 0.4 SEM) than sites that were grazed continuously (7.4 species \pm 0.5 SEM). This same trend was evident in native species richness. This could be due to the planned rest pattern of grazing, which may permit native grass basal area to increase in response to increased fertility, potentially excluding interstitial herbs (Earl and Jones 1996).

It is impossible in a natural experiment such as this to study the effects of fertiliser alone on species richness, as the application of fertiliser is usually associated with increased stocking. Few studies have documented the impact of fertiliser and the associated increase in stocking on native or natural pastures. Studies have generally investigated the impacts of fertiliser on species in glasshouse or small plot trials (Robinson and Dowling 1976; Taylor et al. 1985). Lodge and Whalley (1989) described the changes in pasture composition and dominant species produced by heavy continuous grazing with fertiliser, from pastures dominated by tall, warm season perennials such as *Themeda australis*, *Sorghum leiocladum* and *Cymbopogon refractus*, to pastures dominated by short, warm season perennials such as *Bothriochloa macra* and *Sporobolus creber*. Conversely, if fertilised pastures are grazed heavily in summer, the tall warm-season perennials such as *T. australis*, *S. leiocladum* and *C. refractus* may be replaced by native, year-long green perennials such as *Austroanthonia* spp., *Dichelachne* spp. and *Microlaena stipoides*.

This study highlights the important role of production areas in the conservation of native species in grassy vegetation on the Northern Tablelands of New South Wales, as well as the role of areas managed for conservation that exclude or restrict stock grazing and other forms of development. It would appear that the landscape needs to be managed in different ways to ensure that native grassy vegetation is both optimally conserved and productively utilised. Further investigations of the dataset reported here will focus on the impact of grazing and associated management and pasture development on the composition of the native vegetation.

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