CHAPTER EIGHT

Synthesis and future directions

Redgrass (*Bothriochloa macra*) dominated ground-storey vegetation, near Armidale, NSW

8.1 INTRODUCTION

This study investigated the agricultural management determinants of ground-storey vegetation on the Northern Tablelands, NSW. The intensification of agricultural management regimes in production-dominated landscapes of the Northern Tablelands has generally been shown to lead to a decline in native species richness and to strongly influence species composition. This chapter presents a synthesis of the results of this study and their relationship with conservation and agricultural management, their importance to general ecology, and discusses future directions for research. The objectives are to:

1. identify native species associated with different land tenures/uses (production, private remnant or public) and the effects of land tenures/uses on native and exotic species richness;
2. compare numbers of native species unique to each management type (grazing, fertiliser and cultivation);
3. identify native, locally rare species;
4. discuss use of evenness indices;
5. develop a state and transition model for ground-storey vegetation;
6. discuss verification of management trends; and
7. discuss further analysis of seasonal and survey data.

8.2 IMPORTANCE OF RESULTS TO CONSERVATION AND AGRICULTURAL MANAGEMENT

Native ground-storey vegetation is an important component in the overall conservation of biodiversity, and this has been formally recognised by the NSW State Government with the introduction of the *Native Vegetation Conservation Act 1997*. The Act defined plant ground cover in which native species comprise more than 50% of the cover as native vegetation, which requires a permit for clearing outside specified exemptions. Similar provisions have been adopted in the *Native Vegetation Act 2003*, which replaces the *Native Vegetation Conservation Act* 1997. Attention has thereby been focussed on management and conservation of the native ground-storey vegetation that has been utilised by the agricultural sector since European settlement.

8.2.1 Land tenure/use

The original vegetation composition and structure on the Northern Tablelands, varied from forests with a grassy under-storey to natural grasslands, which have been altered by the thinning or removal of woody vegetation and by the sowing of improved pastures. An estimated 80% of the region has been altered by European settlement and development (Morgan and Terry 1990), but large amounts of native ground-storey vegetation remain. Landholders are managing small grassy areas for conservation with added benefits such as better stock management, reserves for feed for drought periods and aesthetics.

Methods

The responses of native and exotic species richness to land tenure (production, public and private remnant) were analysed using a one-way analysis of variance (ANOVA) and means were compared using Tukeys Honestly Significant Difference ($\alpha = 0.05$) using the statistical package Statview (Analytical Software 2000). Data was tested for normality, no transformations were necessary, and no outliers were found.

Results

Private remnant areas managed for conservation and public areas have significantly higher native species richness than comparable areas managed for production (Table 8.1), in contrast with ecological theory that diversity will decline during long intervals without disturbances (Connell 1978). These areas also had lower exotic species richness than production areas. Some 78% of the ground-storey taxa recorded in private remnants were native (130 taxa), with a similar percentage in public areas (76% or 143 taxa). Production areas had a lower percentage of natives (66% or 189 taxa) (Appendix 8.1).

Table 8.1 Native and exotic species richness (mean ± SEM) in 6 x 5 m plots surveyed on public land and in private remnant areas and production areas on private properties. Different superscripts indicate that means differ significantly (Tukey's test, $p \leq 0.05$).

	Private remnant areas managed for conservation	Production areas not managed for conservation	Public areas	F	Df	p
Number of sites	27	302	44			
Native species richness	18.78[a] (± 1.22)	12.45[b] (± 0.30)	18.30[a] (± 0.89)	35.60	2, 370	< 0.001
Exotic species richness	5.04[a] (± 0.52)	6.86[b] (± 0.18)	5.02[a] (± 0.44)	9.96	2, 370	< 0.001

Public and private remnant land tenures had higher native species richness than production, and the reverse was true for exotic species richness. These results are comparable with the land use categories of McIntyre and Lavorel (1994b). The species richness means from McIntyre and Lavorels' study were estimated from figures in their paper (Figure 4 in McIntyre and Lavorel 1994b) and are therefore approximations. The mean native species richness for grazed pasture in the study by McIntyre and Lavorel (1994b) (~ 12 native species) and production in this study are very similar, although the mean exotic species richness in their study is higher (~9 exotic species) than here. The difference may be due to the fact that McIntyre *et al.* (1993) sampled generally heavy and chronic grazing (McIntyre *et al.* 1993), whereas a range of grazing pressures was sampled in this study. Comparisons can also be drawn between the public areas and stock routes sampled in this study and by McIntyre and Lavorel (1994b). Higher numbers of native (~ 23.5 species) and exotic (~ 7.5) species were recorded in their study. The difference in native species richness may be attributed to the higher proportion of ungrazed sites and the higher exotic species richness to the presence of soil disturbance in 23% of sites in their study. Native and exotic species richness in private remnants in this study was lower than the average of 24 and 6 species respectively in reserves in the study of McIntyre and Lavorel (1994b). The differences may be attributed to the episodic grazing that occurs in private remnant areas in this study.

The Northern Tablelands remains dominated by native ground-storey vegetation, despite the impacts of cultivation, fertilisers, grazing and other forms of disturbance (McIntyre and Lavorel 1994a). Public reserves, cemeteries, travelling stock reserves and routes, and on-farm remnants are important areas in the agricultural landscape of the Northern Tablelands of NSW. These areas have higher native and lower exotic species richness than comparable areas managed for production. Such areas have been acknowledged as important for conservation in south-eastern Australia (Williams and Metcalfe 1991; McIntyre *et al.* 1993; Prober *et al.* 2001; Austen 2002; Prober *et al.* 2002a), similar to ditch banks in the Netherlands and field margins in Europe. In the Netherlands, ditch banks are recognised for their role in the conservation of ground-storey diversity and are included in agri-environmental management (Blomqvist *et al.* 2003). Ditch banks are showing decline in diversity, and therefore management of these areas is important. Similar studies are uncommon in Australia, because such small areas are not regarded as a priority in overall conservation goals (Prober and Thiele 1995). They are regarded as poor investments for conservation dollars in some quarters (Bridgewater *et al.* 1991). However, recognition of their value is increasing (Williams and Metcalfe 1991; Austen 2002).

8.2.2 Conservation of native ground-storey vegetation

It is important for current and future generations that areas of ground-storey vegetation are protected from the ongoing influences from agriculture, which has already led to a reduction in species richness and a significant shift in floristic composition. The changes may not be static, and additional loss of species could occur if present management continues. Recent and future changes in management, such as planned rest grazing, may lead to the loss of further species. Native species sensitive to continuous grazing may have already disappeared from the landscape due to grazing pressure. Under some grazing regimes, palatable species decline in abundance while unpalatable ones increase. Sites with planned rest grazing have recently undergone changes in grazing management from continuous grazing to planned rest. Species absent under continuous grazing therefore, are also likely to be absent from planned rest sites unless they have been able to recolonise in the last few years (Reseigh *et al.* 2003). Native species present under continuous grazing may be intolerant of the new planned rest regime. However, changes in management may have the opposite effect, an increase in species richness, as species are able to invade or recolonise and become established in the new regime.

Comparisons of ground-storey native species associated with land use/tenure (Appendix 8.1) indicated that despite lower native species richness in production areas, 46 native ground storey species were found only in production sites (Table 8.2). Nine native species were found only on private remnant sites, and 18 native species only on public land sites (Tables 8.3 and 8.4, respectively). The proportion of species to site was calculated (e.g. 46 native species were sampled at 302 production sites, therefore the ratio of species/site was 0.15), and these ratios illustrate that production areas sustain lower numbers of unique native species per site (0.15) than private remnant (0.35) and public (0.35) lands.

Nevertheless, production sites play an important role in the conservation of native ground-storey species on the Northern Tablelands of NSW, as do small areas such as cemeteries, on-farm remnants and travelling stock reserves and routes. Many of these areas are too small to be conserved in the formal reserve system, but they have an important role in the conservation of species not found in production areas and this role should be recognised and maintained (Morgan and Terry 1999). Therefore it is important that different elements of the landscape be managed in different ways to ensure that native ground-storey vegetation is both optimally conserved and productively utilised.

Table 8.2 Sample frequency of native ground-storey taxa recorded only in production sites (n = 302).

Native taxa	Frequency	Native taxa	Frequency
Acacia dealbata	0.005	*Dipodium punctatum*	0.003
Alternanthera species *A*	0.013	*Echinopogon mckiei*	0.011
Aristida calycina var. *calycina*	0.024	*Eleocharis acuta*	0.003
Aristida warburgii	0.003	*Eleocharis pusilla*	0.003
Austrodanthonia induta	0.005	*Enneapogon nigricans*	0.003
Austrostipa ramosissima	0.005	*Epilobium hirtigerum*	0.005
Austrostipa rudis subsp. *nervosa*	0.003	*Eragrostis molybdea*	0.038
Bulbostylis densa	0.003	*Eriochilus cuniculatus*	0.005
Cassinia laevis	0.003	*Euchiton involucratum/sphaericum*	0.008
Chamaesyce dallachyana	0.005	*Eulalia aurea*	0.013
Chenopodium pumilio	0.021	*Hemarthria uncinata* var. *uncinata*	0.005
Crassula colorata var. *acuminata*	0.003	*Hydrocotyle peduncularis*	0.013
Crassula sieberana	0.003	*Isolepis hookeriana*	0.005
Cynoglossum australe	0.008	*Leucochrysum albicans ssp albicans* var. *albicans*	0.003
Cyperus gracilis	0.011	*Murdannia graminea*	0.005
Cyperus sphaeroideus	0.019	*Paspalum distichum*	0.005
Daucus glochidiatus	0.008	*Portulaca oleracea*	0.013
Deyeuxia quadriseta	0.003	*Rorippa gigantea*	0.003
Dichelachne rara	0.019	*Solenogyne bellioides*	0.027
Digitaria diffusa	0.003	*Solenogyne dominii*	0.005
Digitaria ternata	0.011	*Solenogyne gunnii*	0.013
Dillwynia juniperina	0.003	*Stellaria angustifolia*	0.003
Dillwynia sieberi	0.003	*Wahlenbergia planiflora* subsp. *longifolia*	0.005

Table 8.3 Sample frequency of native ground-storey taxa recorded only in private remnant sites (n = 27).

Native taxa	Frequency
Austrodanthonia richardsonii	0.003
Einadia hastata	0.003
Einadia nutans subsp. *Linifolia*	0.003
Epilobium gunnianum	0.003
Goodenia bellidifolia	0.003
Hibbertia acicularis	0.003
Hibbertia linearis	0.003
Imperata cylindrica	0.003
Trachymene incisa	0.003

Table 8.4 Sample frequency of native ground-storey taxa recorded only in public sites[1] (n = 44).

Native taxa	Frequency
Arthropodium species	0.003
Austrodanthonia eriantha	0.003
Brachyloma daphnoides	0.003
Dianella tasmanica	0.003
Dichelachne inaequiglumis	0.003
Euphrasia orthocheila subsp. *orthocheila*[1]	0.003
Grevillea species	0.003
Hakea eriantha	0.003
Hakea microcarpa	0.003
Leiocarpa species *nov*	0.008
Lobelia gracilis	0.003
Oreomyrrhis eriopoda	0.003
Podolepis jaceoides	0.003
Pultenaea setulosa	0.005
Rhytidosporum procumbens	0.003
Stylidium graminifolium	0.003
Xanthorrhoea australis	0.003
Xanthorrhoea glauca subsp. *Glauca*	0.003

1 Classified as a herb (Royal Botanic Gardens Sydney 2002)

8.2.3 Sustainability of agricultural management

Generally increased intensification of agricultural production associated with commercial grazing, fertiliser application and cultivation on the Northern Tablelands leads to a decrease in native species richness and affects ground-storey vegetation composition, thereby significantly influencing the ground-storey diversity of the region. Despite this, many native species are found in areas used for agricultural production.

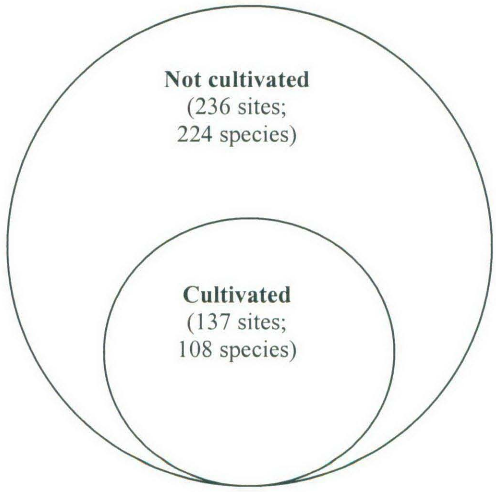
The influence of the agricultural management regime (grazing, fertiliser application and cultivation) on native species was assessed by computing the native species numbers associated with different kinds of management. This was done firstly with respect to the influence of cultivation (cultivated and not cultivated), secondly, fertiliser application (fertilised and not fertilised) excluding all cultivated sites, and finally, grazing (not grazed or episodically grazed and planned rest or continuous grazing) excluding all cultivated and fertilised sites.

Areas with a history of cultivation (108 species) contained no native species that were not found in uncultivated areas (224 species) (Figure 8.1a). At sites with no history of cultivation, a larger number of native species occurred in unfertilised (199 species) than fertilised (156 species) sites (Figure 8.1b). Similarly a larger number of native species was found at ungrazed or episodically grazed sites (171 species) with no history of cultivation or fertiliser application than in grazed sites (127 species) (Figure 8.1c).

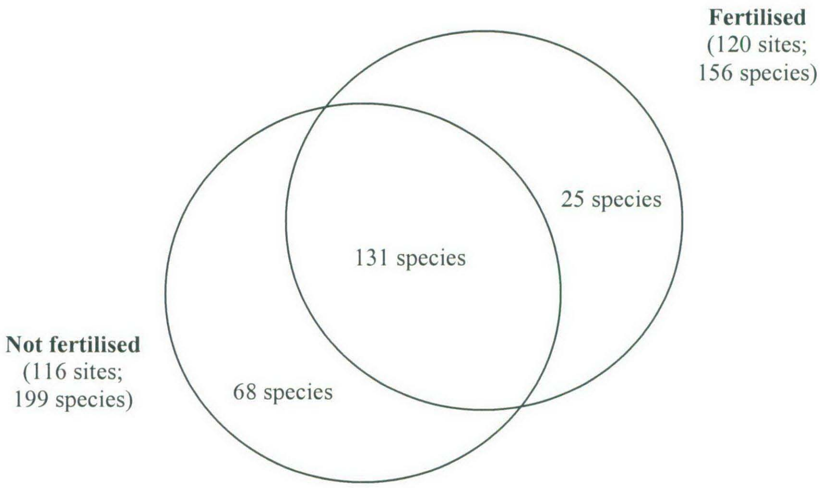
Some 72 native species in this study were always associated with an absence of intensive production (ungrazed or episodically grazed, not fertilised and no cultivation history). Therefore the grazing industries have an important role in managing 152 (68%) of the native species recorded in this study. Any widespread change in management and land use owing to economic pressures or perceived environmental benefit needs to be considered at a regional scale due to the influences that such a change may have on the conservation of native species in the region.

A diversity of management regimes (involving grazing, cultivation, fertiliser application and their absence) is important to conservation of the regional ground-storey vegetation. The species that make up this assemblage are conserved to varying degrees in the landscape at sites managed for production or in areas that have been set aside on private property for conservation or in public areas. All these areas have an ongoing role in the conservation and management of native ground-storey vegetation on the Northern Tablelands of NSW.

(a)



(b)



(c)

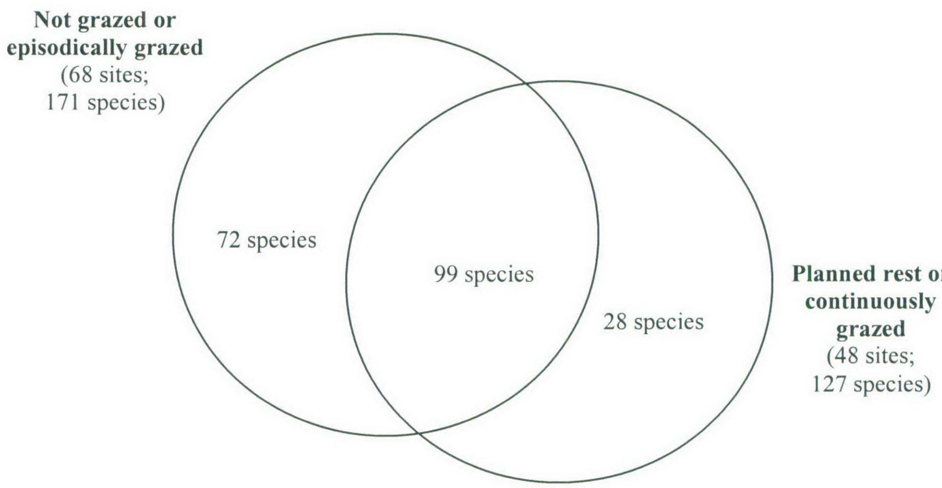


Figure 8.1 Influences of agricultural management on native species of the ground-storey flora data set. (a) Influence of cultivation on native species diversity (n = 373 sites); (b) influence of fertiliser history in uncultivated sites (n = 236); (c) influence of grazing regime in unfertilised sites (n = 116).

8.2.4 Regional flora

Rarity of regional flora

Plant conservation of rare species typically involves identifying such species, and research and development of a recovery plan. McIntyre *et al.* (1993) stated that few species from grasslands are listed as rare or threatened species in NSW according to Briggs and Leigh (1988) and the same is true in analysis of lists compiled by NSW Scientific Committee (2003). McIntyre *et al.* (1993) devised a measure of rarity based on the low frequency of occurrence in plots. Due to the threats from increasing agricultural management identified in this study and others (e.g. Stuwe and Parsons 1977; Lunt 1991; McIntyre and Lavorel 1994a; Morgan and Terry 1999; Clarke 2003), there is a need for the identification of species at risk (McIntyre *et al.* 1993). The apparent rarity (sample frequency < 3%) of many of the species of ground-storey vegetation on the Northern Tablelands has been discussed and reviewed by McIntyre *et al.* (1993), McIntyre and Lavorel (1994b) and Waters (2001).

Rarity in this study was assessed by methods similar to McIntyre *et al.* (1993). A species was potentially considered locally rare if its sample frequency of occurrence was < 3% (n = 373). Species were then removed if they were (McIntyre *et al.* 1993):

1. exotic: the conservation status of exotic species is of little interest;
2. species with a short season of growth or only apparent between May and December (outside the sampling time frames of the regional study), as they may have been simply under-represented; and
3. tree species, as this study did not aim to sample the tree stratum which is accordingly under-represented.

It must be remembered that sites were allocated within the habitats defined by the stratification variables. Further restrictions on sampling were also imposed. The following sites were avoided (after McIntyre *et al.* 1993):

1. areas with slopes > 18°;
2. areas of significant outcropping rock;
3. wetlands and water courses;
4. recently cultivated and planted areas (within the last 10 years);
5. stock camps or areas within 200 m of stock camps; and

6. areas where management had changed recently (within the last 7-10 years).

In the present study, 86 (27%) taxa were considered rare in the landscapes sampled (Appendix 8.2). *Thesium australe* and *Euphrasia orthocheila* subsp. *orthocheila* were the only recognised (NSW Scientific Committee 2003) rare or vulnerable species in the present study. Taxa listed as locally rare include the native grass, *Joycea pallida,* that is considered regionally significant (Murray, S., pers. comm. September 2003), and *Xanthorrhoea australis* and *X. glauca* subsp. *glauca* which are often not observed in the region due to clearing (pers. obs.).

The present study identified 50 native taxa (Table 8.5) as locally rare, in addition to those listed by McIntyre *et al.* (1993) and Waters (2001), including the shrub *Einadia hastata* and twiner, *E. nutans* subsp. *linifolia*. Twenty-nine taxa (Table 8.6) were common to those listed by McIntyre *et al.* (1993). Some 39 taxa listed in this study as locally rare occurred at frequencies lower than those observed by McIntyre *et al.* (1993) and therefore the classification of these taxa as locally rare must be regarded with caution. Reasons for the disparity in frequencies probably relate to the focus of each study. McIntyre *et al.* (1993) sampled public land predominantly while Waters (2001) confined her study to a small area east of Armidale. Some species may be rare in the grassy vegetation sampled in all these studies simply because they are more common in other systems that were not systematically sampled (e.g. forests and wetlands). Differences may also relate to the identification of specimens. Taxonomic uncertainties between the studies has not been resolved as voucher specimens lodged by McIntyre *et al.* (1993) are not readily accessible as they are not incorporated into the NE Herbarium. Differences may also be related to sampling in different years, and the possible effect of inter-annual differences in climate on large fluctuations in population abundance of some taxa.

Table 8.5 Sample frequency of native taxa identified as locally rare in this study (n = 373) that were not listed by McIntyre *et al.* (1993) or Waters (2001).

Taxa	Frequency (%)	Taxa	Frequency (%)
Alternanthera nana	0.5	*Epilobium gunnianum*	0.3
Alternanthera species *A*	1.3	*Eragrostis elongata*	0.5
Aristida calycina var. *calycina*	2.4	*Eriochilus cucullatus*	0.5
Aristida jerichoensis var. *subspinulifera*	2.4	*Euphrasia orthocheila* subsp. *orthocheila*	0.3
Aristida warburgii	0.3	*Grevillea* species	0.3
Austrostipa ramosissima	0.5	*Hakea eriantha*	0.3
Austrostipa rudis subsp. *rudis*	1.1	*Hemarthria uncinata* var. *uncinata*	0.5
Brachyloma daphnoides	0.3	*Imperata cylindrica*	0.3
Bulbostylis densa	0.3	*Isolepis hookeriana*	0.5
Calocephalus sp.	0.5	*Joycea pallida*	0.8
Cassinia laevis	0.3	*Lachnagrostis filiformis*	1.6
Chamaesyce dallachyana	0.5	*Leiocarpa* species *nov*	0.8
Convolvulus arvensis	0.8	*Lobelia gracilis*	0.3
Crassula colorata var. *acuminata*	0.3	*Opercularia aspera*	0.8
Dianella revoluta var. *revoluta*	2.9	*Panicum queenslandicum* var. *queenslandicum*	1.1
Dianella tasmanica	0.3	*Paspalum distichum*	0.5
Dichelachne inaequiglumis	0.3	*Pultenaea setulosa*	0.5
Dichelachne rara	1.9	*Rhytidosporum procumbens*	0.3
Dillwynia sieberi	0.3	*Rorippa gigantea*	0.3
Dipodium punctatum	0.3	*Solenogyne dominii*	0.5
Einadia hastata	0.3	*Solenogyne gunnii*	1.3
Einadia nutans subsp. *linifolia*	0.3	*Trachymene incisa*	0.3
Eleocharis acuta	0.3	*Wahlenbergia planiflora* subsp. *planiflora*	1.6
Eleocharis pusilla	0.3	*Xanthorrhoea australis*	0.3
Enneapogon nigricans	0.3	*Xanthorrhoea glauca* subsp. *glauca*	0.3

Table 8.6 Sample frequency of locally rare native taxa common to this study (n = 373) and that of McIntyre *et al.* (1993) (n = 120).

	Frequency this study (%)	Frequency McIntyre *et al.* (1993) (%)
Austrodanthonia induta	0.5	0.8
Calotis dentex	0.5	0.8
Convolvulus erubescens	2.4	0.8
Cynoglossum australe	0.8	2.5
Cyperus gracilis	1.1	1.7
Daviesia genistifolia	0.5	0.8
Desmodium brachypodum	1.1	0.8
Deyeuxia quadriseta	0.3	0.8
Digitaria diffusa	0.3	1.7
Digitaria parviflora	0.5	0.8
Echinopogon ovatus	1.1	0.8
Einadia nutans subsp. *nutans*	2.9	1.7
Epilobium hirtigerum	0.5	0.8
Eulalia aurea	1.3	1.7
Goodenia bellidifolia	0.3	2.5
Hakea microcarpa	0.3	0.8
Helichrysum scorpioides	0.8	0.8
Hibbertia riparia	0.5	0.8
Hypoxis hygrometrica var. *villosisepala*	2.4	2.5
Lachnagrostis aemula	2.7	2.5
Leucochrysum albicans subsp. *albicans* var. *albicans*	0.3	1.7
Leucopogon species affinity *fraseri*	2.9	2.5
Murdannia graminea	0.5	0.8
Pimelea linifolia	2.1	1.7
Spiranthes sinensis subsp. *australis*	1.9	1.7
Stackhousia monogyna	0.8	1.7
Stellaria angustifolia	0.3	1.7
Thesium australe	0.8	1.7
Urtica incisa	0.8	1.7

8.3 CONCEPTUAL IMPORTANCE OF RESULTS TO ECOLOGY

8.3.1 Evenness

Evenness of ground-storey vegetation, calculated using Smith and Wilson's index (Krebs 1999) applied to plant cover, was not explained by any of the measured management or environmental variables in this study. This measure of evenness is independent of species richness and is sensitive to both rare and the common species. Reasons for the absence of a relationship may be related to the explanatory variables measured. Management variables that invoke short-term change in plant cover are more likely to register changes in evenness than the longer-term responses to management (e.g. cultivation, fertiliser and grazing) sought in this study. Short-term impacts need to be considered in further studies investigating relationships between management and evenness of ground-storey vegetation.

8.3.2 State and transition models

State and transition models (Westoby *et al.* 1989) describe vegetation dynamics as changes (transitions) from one vegetation state to another over periods of time, possibly decades, although changes in vegetation states have been observed in shorter time frames (5-10 years) on the Northern Tablelands where vegetation has been fenced to remove grazing. There are several state and transitions in the ground-storey vegetation of the Northern Tablelands, NSW, but the conditions required for many transitions are generally undetermined (Whalley 1994). These conditions may be related to management or other external forces, and the possibility of such transitions occurring cannot be reliably predicted.

Alternative state and transition models for each of the three lithologies (basalt, granite and metasediment) (Figure 8.2 and Table 8.7) to those proposed by Whalley (1994) and Lodge and Whalley (1989) are presented. The models focus on statistically significant changes in the species composition of ground-storey vegetation based on the results of Chapter 6. These tables highlight character species that are indicators of the different states. The result is a model that incorporates not only native grasses but also the native herbs that contribute to species assemblages in the ground-storey vegetation of the Northern Tablelands. Native species from Tables 6.4-6.23 with a frequency of occurrence of > 50% and ≥ 30% more frequent than in contrasting management levels were included in relevant states. For example, the frequency of *Asperula conferta* (63%) under episodic grazing was ≥30% higher than under planned rest (17%) or continuous (10%) grazing on granite sites with no history of fertiliser or cultivation (Table 6.3). Therefore it was included in state 2 (not grazed or only episodically grazed) of the model. Transitions were attributed to the relevant management factors: grazing (episodic, continuous and planned rest), fertiliser application (unfertilised or fertilised) and cultivation (cultivated or uncultivated).

State 1 is the pre-European vegetation described by Lodge and Whalley (1989) in terms of dominant grasses (*Themeda australis* and *Sorghum leiocladum*). The contribution of herbs to the composition of pre-European vegetation is undescribed as early settlers typically described only the dominant grasses (see Chapter 2). The derivation of State 2 from State 1 can be attributed partly to episodic grazing in areas without a history of cultivation or fertiliser application. Other factors leading to these states are unknown from the pre-European situation. State 2 is characterised by *Bothriochloa macra* and *Sporobolus creber* on basalt, *Themeda australis* and *Sorghum leiocladum* on granite, and *Sporobolus creber* on metasediment.

States 3-5 are all associated with continuously grazed regimes. State 3 on basalt is characterised by the native grasses, *Bothriochloa macra* and *Sorghum leiocladum*, and by *Bothriochloa macra* and *Sporobolus creber* on granite soils. There are insufficient data for State 3 on metasediments. Grazing and the addition of superphosphate (Transition 3) leads to State 4. On basalt, species changes to *Microlaena stipoides* and *Austrodanthonia bipartita*, whereas *Bothriochloa macra* still characterises granite soils in addition to *Cynodon dactylon* and *Eragrostis leptostachya*. Metasediments are characterised by *Eragrostis trachycarpa* and *Eragrostis* species *A*. State 5 is derived from the pre-European situation by a history of continuous grazing with fertiliser application and cultivation (Transition 4). Under this regime, basalt parent materials are characterised by *Bothriochloa macra*, similar to State 3. *Chloris truncata*, *Eragrostis leptostachya* and *Bothriochloa macra* characterise granite, similar to States 3 and 4.

Planned rest grazing forms the basis for States 6-8, where these states are all based on States 2-5 as all sites were previously continuously grazed prior to the introduction of planned rest grazing (Transitions 5-7). Transition 5 to State 6 is associated with a change in grazing management, but insufficient data are available to describe State 6 for basalt parent materials. Granite sites are dominated by *Bothriochloa macra* and *Sporobolus creber,* the same as under continuous grazing, although the types of herbs associated with each grazing regime are different: *Fimbristylis dichotoma* and *Juncus filicaulis* under continuous grazing and *Cheilanthes sieberi* subsp. *sieberi* and *Oxalis exilis* under planned rest grazing.

Transition 6 to State 7 involves a change in grazing management to planned rest grazing with a history of fertiliser application. As a result, *Elymus scaber* var. *scaber* and *Panicum effusum* dominate on basalt compared to *Microlaena stipoides* and *Austrodanthonia bipartite* under continuous grazing with a history of fertiliser application. *Microlaena stipoides* and *Aristida vagans* dominate State 7 on granite, in contrast to *B. macra, Cynodon dactylon* and *Eragrostis leptostachya* under continuous grazing, although *Panicum effusum* remains in the species assemblage. Insufficient data are available for metasediments. Transition 7 to State 8 comprises a change in grazing management in areas with a history of superphosphate and cultivation. Very limited data are available, although *E. leptostachya* dominates planned rest as with continuous grazing in State 5 on basalt, and *Carex inversa* remains in the species assemblage. Species characterising State 8 on granite and metasediment are uncertain due to insufficient data.

Landholders can effect any of the numbered transitions (T2-T7) in Figure 8.2. Reverse transitions (unnumbered) may be possible by reducing management inputs such as intensity and timing of grazing, fertiliser application and cultivation. However, some of the backwards transitions may be effectively irreversible in cultivated areas, without assisted dispersal of taxa sensitive to soil disturbance. The transitions postulated here require experimental testing to determine if they can be duplicated.

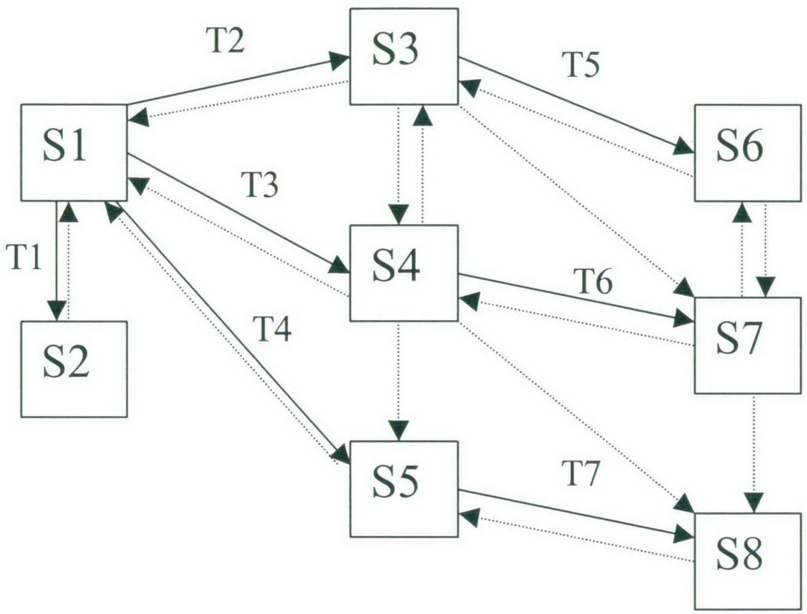


Figure 8.2 State (S) and transition (T) model for the regional ground-storey for all lithologies on the Northern Tablelands of NSW. Arrows indicate transitions produced by changes in management observed in this study (–); transitions supported by evidence are numbered. Arrows that are missing represent transitions that were not observed in this study. Transitions could be produced with intensive investment in management including changes in grazing, fertiliser application and cultivation and with capital investment such as reseeding but are not included for the sake of simplicity (……).

Table 8.7 Catalogues of (a) transitions and (b) states for regional ground-storey flora, Northern Tablelands of NSW.

(a) Catalogue of Transitions
Transition 1: Not grazed for least 10 years or episodic grazing, no fertiliser or cultivation history
Transition 2: Continuous grazing by sheep and cattle
Transition 3: Continuous grazing by sheep and cattle with a history of superphosphate application
Transition 4: Continuous grazing by sheep and cattle with a history of superphosphate application and cultivation
Transition 5: Planned rest grazing after a history of continuous grazing by sheep and cattle
Transition 6: Planned rest grazing after a history of continuous grazing by sheep and cattle and superphosphate application
Transition 7: Planned rest grazing after a history of continuous grazing by sheep and cattle, superphosphate application and cultivation

Table 8.7 cont.

(b) Catalogue of states
State 1: **Pre-European vegetation on all lithologies** *Aristida ramosa, Austrodanthonia* species, *Bothriochloa macra, Cymbopogon refractus, Poa sieberiana, Sorghum leiocladum, Themeda australis* and herb species
State 2 - Not grazed or episodically grazed **Basalt:** *Bothriochloa macra, Fimbristylis dichotoma, Sporobolus creber* **Granite:** *Asperula conferta, Austrodanthonia ramosa* var. *racemosa, Gonocarpus tetragynus, Sorghum leiocladum, Themeda australis,* **Metasediment:** *Dichelachne micrantha, Sporobolus creber*
State 3 – Continuously grazed by livestock **Basalt:** *Acaena agnipila / ovina, Bothriochloa macra, Desmodium varians, Sorghum leiocladum* **Granite:** *Bothriochloa macra, Oxalis exilis, Sporobolus creber* **Metasediment:** *Rumex brownii,* insufficient data
State 4 - Continuously grazed by livestock with a history of fertiliser application **Basalt:** *Acaena agnipila / ovina, Austrodanthonia bipartita, Epilobium billardierianum* subsp. *hydrophilum, Microlaena stipoides, Oxalis exilis, Vittadinia cuneata* var. *cuneata* **Granite:** *Bothriochloa macra, Chloris truncata, Cynodon dactylon, Elymus scaber* subsp. *scaber, Eragrostis leptostachya*, *Eragrostis trachycarpa, Fimbristylis dichotoma, Juncus filicaulis, Panicum effusum, Pennisetum alopecuroides* **Metasediment:** *Eragrostis brownii, Eragrostis* sp. *A*, *Eragrostis trachycarpa, Panicum effusum, Rumex brownii*
State 5 - Continuously grazed by livestock with a history of fertiliser application and cultivation **Basalt:** *Asperula conferta, Bothriochloa macra*, *Carex inversa, Chloris truncata, Dichondra repens*, *Elymus scaber* var. *scaber*, *Eragrostis leptostachya, Geranium solanderi* var. *solanderi, Sporobolus creber* **Granite:** *Austrodanthonia ramosa* var. *racemosa, Bothriochloa macra*, *Eragrostis leptostachya*, **Metasediment:** Insufficient data
State 6 - Planned rest grazing after a history of continuous grazing **Basalt:** Insufficient data **Granite:** *Bothriochloa macra, Cheilanthes sieberi* subsp. *sieberi, Juncus usitatus, Oxalis exilis, Sporobolus creber,* **Metasediment:** Insufficient data
State 7 - Planned rest grazing after a history of continuous grazing by livestock and fertiliser application **Basalt:** *Elymus scaber* var. *scaber, Panicum effusum* **Granite:** *Aristida vagans*, *Eragrostis brownii, Microlaena stipoides*, *Panicum effusum,* **Metasediment:** Insufficient data
State 8 - Planned rest grazing after a history of continuous grazing by livestock, fertiliser application and cultivation **Basalt:** *Carex inversa, Eragrostis leptostachya* **Granite:** *Juncus usitatus* **Metasediment:** Insufficient data

8.4 FUTURE RESEARCH

8.4.1 Confirmation of influences of management trends

This study has provided information regarding the influences of agricultural management on individual species, species richness and composition. However, detailed understanding of the responses of species to agricultural management (grazing, fertiliser and cultivation) needs considerably more information about how specific aspects of management interact with the species traits of plant taxa to influence their persistence and abundance under different management regimes. This may require experiments at a small plot or paddock scale. It is important that these experiments be conducted on farms where management has been relatively constant, rather than in newly developed areas so as to minimise the influences of succession and ensure realism of the results. If not, the results may be confounded with the changes due to altered management. Revisiting the planned rest grazed sites may provide valuable insights into the time required for these relatively new systems to stabilise, which will provide important information for state and transition models. The effect of grazing by native herbivores requires further research, as many landholders claim that kangaroos significantly impact on their livestock carrying capacity, but their effect on diversity is unclear.

The results of low native species richness under planned rest grazing contradict exponents' claims of increased native species richness (Earl and Jones 1996). Therefore further experimental studies are required to confirm or refute the conclusions reached in this study. The results in this study might be an artefact of planned rest grazing being established on pastures that have previously been heavily continuously grazed, fertilised and cultivated, and thus already depleted of native species prior to the commencement of planned rest grazing.

8.4.2 Further analysis of data set

The seasonal ground-storey flora data set has provided an initial insight into how ground-storey vegetation varies through time. Subsequent measurements in the periods of peak native species richness have been made since the seasonal experiment ended in May 2002, and therefore there exists an opportunity to analyse 3 years of incidence and cover data in relation to year to year variation as well as the influence of events such as the 2003 drought and further changes in agricultural management. Furthermore, there is now comprehensive information regarding the vegetation matrix that characterises the 15 sites. These sites could be sampled yearly to provide important continuing data on species richness and composition through time.

The study of the regional ground-storey flora set has produced an extensive data set, containing records of the incidence and cover of over 300 species and subspecies, and some 131 environmental and management variables including soil nutrient data. The soil nutrient data can be related to agricultural management, providing information about the influence of management on soil nutrient levels. The data set has further potential for use in the analysis of the relationship between environmental and management variables and plant functional traits, rare species and ecological behaviour of key species such as *Themeda australis* and *Sorghum leiocladum* that were once the dominant grasses in the region. Cover data were only used to compute evenness in this study, but the potential for these data to be analysed in relation to the influence of different types of agricultural management exists and should provide further insight into the effects of management on species abundance.

Prior to this study, production landscapes were assumed to conserve native ground-storey vegetation, by the employment of different agricultural management practices (Kemp *et al.* 2003a) and exclusion of grazing from private remnants (Trèmont and Whalley 1995; Morsley and Trèmont 2000). This study has quantified the diversity of native ground-storey vegetation in production, private remnants and public land tenures. Production landscapes, especially those with on-farm remnants, have an important role in the conservation and management of ground-storey vegetation on the Northern Tablelands, NSW.

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