Grazing management and environmental determinants of the diversity and composition of ground-storey vegetation on the Northern Tablelands, NSW

Volume II - APPENDICES

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LIST OF APPENDICES

APPENDIX 1 RESEIGH *ET AL.* (2003)

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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 m^2 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 km^2 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 m^2 (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*.

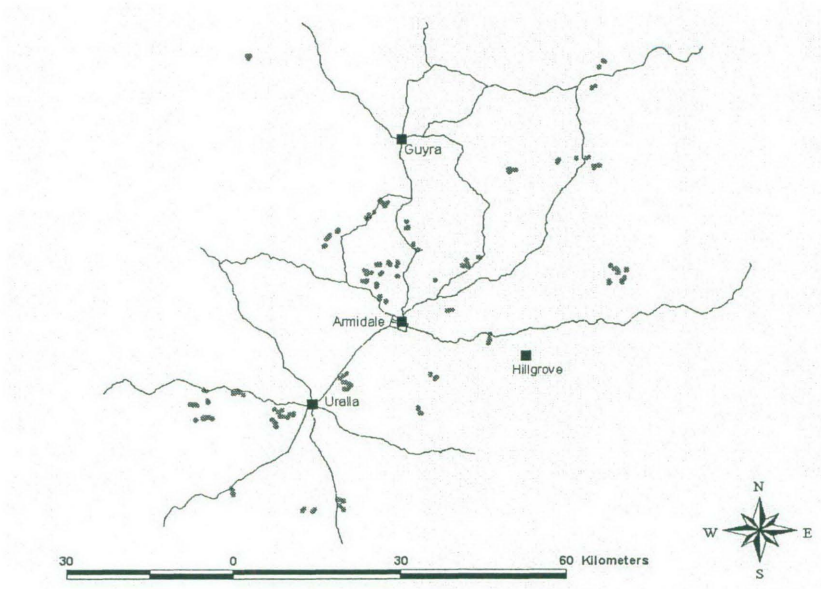


Figure 1 The study area, showing locations of sites surveyed for herbaceous vegetation on the Northern Tablelands, NSW.

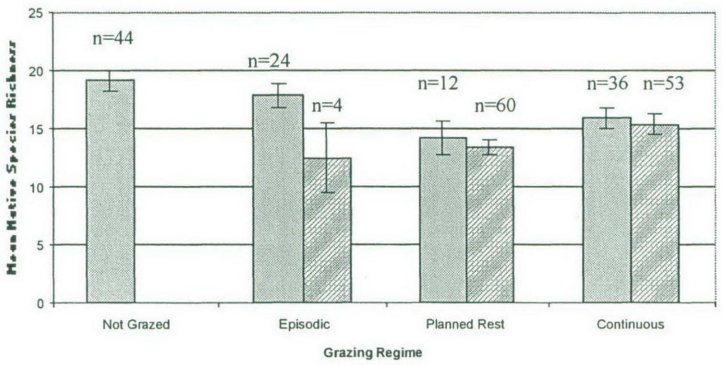
Effects of cultivation on native species richness

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)

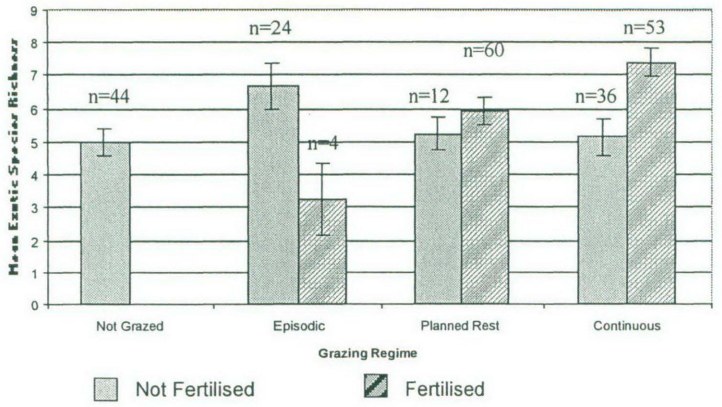


Figure 2 Mean (a) native and (b) exotic species richness (±1 SEM) In 30 m^2 quadrats at 233 sites with no history of cultivation.

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 ±1.4 SEM) to sites that were continuously grazed (15.9 species ±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 ±0.4 SEM) than sites that were grazed continuously (7.4 species ±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 *Austrodanthonia* 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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APPENDIX 2 RESEIGH AND NADOLNY (2002)

Conference paper published in the Proceedings of the Seventeenth Annual Conference of the Grassland Society of NSW.

Managing grassy native vegetation for conservation on the Northern Tablelands, NSW.

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Introduction

The nature of the vegetation in New South Wales has been altered since European settlement. Grazing pressure is a major cause of decline in the condition of native vegetation, leading to major reductions in the abundance of some species and to local extinctions of plant species that are particularly sensitive to grazing (Benson 1991). On the Northern Tablelands of NSW, many landholders are managing small grassy areas for conservation with added benefits including more efficient stock management, reserves of feed for drought periods, aesthetics, wildlife corridors, and seed collection for regeneration. These privately managed reserves have important roles in conserving species at a local scale.

Methods

A total of 329 sites on private land was surveyed over two years from January to April in 2001 and 2002. All plant species within a 6 x 5 m plot were recorded. Twenty-seven sites had a grazing regime managed for conservation. These areas were either destocked or episodically grazed. All other sites were grazed with the primary purpose of commercial livestock production, with regimes varying from set stocking to rotational.

Results

There was significantly higher average native species richness in sites managed for conservation compared to sites managed for production (Table 1). Conversely, there was significantly lower average exotic species richness in sites managed for conservation than sites managed for production. A total of 130 native plant species was recorded in sites managed for conservation, including 36 grasses, 10 twiners, 62 other herbs and 15 shrubs. Of these, 19 species were only found in sites managed for conservation. Some 185 native species were recorded in the 302 sites managed for commercial production.

Table 1. Average native and exotic species richness in 6 x 5 m plots surveyed on private properties.

	Managed for Conservation	Not managed for conservation	Significance
Number of sites	27	302	
Average Native Species Richness (± SE Mean)	18.78 (± 1.22)	12.45 (± 0.30)	$P < 0.001$
Average Exotic Species Richness (± SE Mean)	5.04 (± 0.52)	6.86 (± 0.18)	$P = 0.004$

Conclusions

Grassy remnants managed for conservation are richer in native species, contain fewer exotic species and contain species not found in areas managed for commercial grazing. This illustrates the important role these small areas play in the conservation of native vegetation on the Northern Tablelands.

Reference
Benson J. (1991) The effect of 200 years of European settlement on the vegetation and flora of New South Wales. *Cunninghamia.* **2,** 343-370.

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APPENDIX 3.1 GROUND-STOREY VEGETATION SPECIES LIST FOR SEASONAL GROUND-STOREY DATA SET.

Table 1 Species recorded in the seasonal ground-storey study, Northern Tablelands, NSW. Nomenclature follows Harden (1993a,b, 2000, 2002) and Wheeler *et al.* (2002) except where indicated. Nomenclature based on advice from L. Copeland, University of New England, indicated with #. Sample frequency based on n = 15 sites.

Species	Origin	Life form	Frequency (%)
Acaena agnipila / ovina	Native	forb	38.3
Acetosella vulgaris	Exotic	forb	30.0
Agrostis aemula	Native	grass	0.8
Aira cupaniana	Exotic	grass	9.2
Ajuga australis	Native	forb	4.2
Alternanthera nana	Native	forb	3.3
Anagallis arvensis	Exotic	forb	0.8
Andropogon virginicus	Exotic	grass	1.7
Anthoxanthum odoratum	Exotic	grass	27.5
Aristida jerichoensis var. *subspinulifera*	Native	grass	6.7
Aristida ramosa	Native	grass	26.7
Aristida vagans	Native	grass	20.8
Aristida warburgii	Native	grass	20.0
Asperula conferta	Native	forb	59.2
Austodanthonia bipartita	Native	grass	26.3
Austrodanthonia racemosa var. *racemosa*	Native	grass	29.6
Axonopus compressus	Native	grass	13.3
Bothriochloa macra	Native	grass	51.7
Bracteantha bracteata	Native	forb	3.3
Briza maxima	Exotic	grass	1.7
Briza minor	Exotic	grass	15.4
Bromus racemosus	Exotic	grass	17.1
Bulbine bulbosa	Native	forb	6.3
Carex inversa	Native	monocot	51.3
Centaurium tenuiflorum	Exotic	forb	12.9
Cerastium glomeratum	Exotic	forb	0.4
Chloris truncata	Native	grass	17.5
Chrysocephalum apiculatum	Native	forb	2.9
Ciclospermum leptophyllum	Native	forb	6.7
Cirsium vulgare	Exotic	forb	47.5
Convolvulus erubescens	Native	twiner	12.1
Conyza albida	Exotic	forb	22.1
Cymbonotus lawsonianus	Native	forb	30.4
Cymbopogon refractus	Native	grass	16.7
Cynodon dactylon	Native	grass	9.2
Dactylis glomerata	Exotic	grass	0.4
Daucus glochidiatus	Native	grass	2.9
Desmodium varians	Native	twiner	20.8
Dianella longifolia	Native	monocot	6.7

Species	Origin	Life form	Frequency (%)
Dianthus armeria	Exotic	forb	24.6
Dichanthium setosum	Native	grass	5.8
Dichelachne crinita	Native	grass	4.2
Dichelachne micrantha	Native	grass	11.3
Dichondra repens	Native	forb	37.5
Dichopogon fimbriatus	Native	monocot	13.8
Digitaria brownii	Native	grass	1.7
Drosera peltata	Native	forb	4.2
Echinopogon ovatus	Native	grass	3.3
Einadia nutans	Native	twiner	10.4
Eleusine tristachya	Exotic	grass	5.4
Elymus scaber	Native	grass	42.1
Epilobium billardierianum	Native	forb	27.1
Epilobium species	Native	forb	7.1
Eragrostis benthamii	Native	grass	3.3
Eragrostis brownii	Native	grass	20.4
Eragrostis leptostachya	Native	grass	30.8
Eragrostis species *A*	Exotic	grass	14.2
Eragrostis trachycarpa	Native	grass	39.6
Eriochilus cucullatus	Native	monocot	0.4
Eucalyptus bridgesiana	Native	tree	6.7
Euchiton sphaericus	Native	forb	37.1
Eulalia aurea	Native	grass	3.8
Fimbristylis dichotoma	Native	monocot	44.2
Geranium solanderi var. *solanderi*	Native	forb	31.3
Glycine clandestina	Native	twiner	29.6
Glycine tabacina	Native	twiner	1.3
Gonocarpus tetragynus	Native	forb	6.7
Haloragis heterophylla	Native	forb	40.0
Helichrysum scorpioides	Native	forb	6.3
Holcus lanatus	Exotic	grass	37.1
Hovea linearis	Native	shrub	5.8
Hydrocotyle laxiflora	Native	forb	17.5
Hypericum gramineum	Native	forb	47.1
Hypochaeris glabra/radicata	Exotic	forb	90.4
Hypoxis hygrometrica var. *villosisepala*	Native	monocot	2.5
Imperata cylindrica	Native	grass	7.5
Juncus filicaulis	Native	monocot	44.6
Juncus usitatus	Native	monocot	12.1
Juncus vaginatus	Native	monocot	13.3
Lagenifera gracilis	Native	forb	9.6
Leptorhynchos squamatus	Native	forb	0.8
Lespedeza juncea	Native	shrub	5.0
Leucopogon species affinity *fraseri*[#] (not described in Harden	Native	shrub	16.7
Lissanthe strigosa	Native	shrub	6.7
Lolium perenne	Exotic	grass	4.2
Lomandra filiformis	Native	monocot	9.6

Species	Origin	Life form	Frequency (%)
Luzula flaccida	Native	forb	17.9
Medicago species	Exotic	forb	0.8
Medicago laciniata	Exotic	forb	2.5
Melichrus urceolatus	Native	shrub	6.7
Mentha satureioides	Native	forb	9.6
Microlaena stipoides	Native	grass	8.8
Modiola caroliniana	Exotic	forb	5.0
Oxalis exilis	Native	forb	62.9
Panicum effusum	Native	grass	32.5
Paronychia brasiliana	Exotic	forb	23.8
Paspalum dilatatum	Exotic	grass	11.7
Pennisetum alopecuroides	Native	grass	5.4
Petrorhagia nanteuilii	Exotic	forb	1.7
Phalaris aquatica	Exotic	grass	17.1
Phyllanthus gunnii	Native	forb	9.2
Pimelea curviflora	Native	shrub	40.0
Pimelea linifolia	Native	shrub	6.7
Plantago debilis / varia	Native	forb	10.8
Plantago gaudichaudii	Native	forb	0.8
Plantago lanceolata	Exotic	forb	67.1
Poa sieberiana	Native	grass	78.8
Polygonum aviculare	Exotic	forb	0.8
Richardia stellaris	Native	forb	5.8
Rubus fruticosus	Exotic	twiner	5.4
Rumex brownii	Native	forb	39.6
Schoenus apogon	Native	monocot	1.3
Scleranthus biflorus	Native	forb	9.2
Setaria gracilis	Exotic	grass	9.6
Sorghum leiocladum	Native	grass	37.5
Spiranthes sinensis subsp. *australis*	Native	monocot	0.4
Sporobolus creber	Native	grass	60.8
Swainsona species	Native	twiner	0.8
Taraxacum officinale	Exotic	forb	1.3
Themeda australis	Native	grass	41.7
Tricoryne elatior	Native	monocot	1.3
Trifolium arvense	Exotic	forb	5.8
Trifolium campestre	Exotic	forb	62.1
Trifolium glomeratum	Exotic	forb	0.8
Trifolium repens	Exotic	forb	63.8
Verbascum thapsus	Exotic	forb	0.8
Vicia sativa subsp. *angustifolia*	Exotic	twiner	1.3
Vittadinia cuneata var. *cuneata*	Native	forb	10.4
Vulpia bromoides / muralis / myuros	Exotic	grass	47.9
Wahlenbergia luteola	Native	forb	37.1
Wahlenbergia planiflora subsp..*planiflora*	Native	forb	9.6
Zornia dyctiocarpa var. *dyctiocarpa*	Native	twiner	0.8

APPENDIX 4.1 SITE STRATIFICATION FOR SHADING ILLUSTRATES COMBINATIONS THAT WERE NOT FULLY SAMPLED.

Table 1 Site stratification combinations in the regional ground-storey vegetation data set, and number of sites within each cell. Shading indicates combinations not fully sampled.

Management									
Grazing	Not Grazed	Not Grazed	Not Grazed	Not Grazed	Not Grazed	Not Grazed	Not Grazed	Not Grazed	Not Grazed
Fertiliser	Never	Low	High	Never	Low	High	Never	Low	High
Cultivation	Never	Never	Never	10-20 ya	10-20 ya	10-20 ya	>21 ya	>21 ya	>21 ya
Lithology									
Granite	9								
Basalt	18	1							
Metasediment	17	2							

Management									
Grazing	Episodic	Episodic	Episodic	Episodic	Episodic	Episodic	Episodic	Episodic	Episodic
Fertiliser	Never	Low	High	Never	Low	High	Never	Low	High
Cultivation	Never	Never	Never	10-20 ya	10-20 ya	10-20 ya	>21 ya	>21 ya	>21 ya
Lithology									
Granite	8								
Basalt	8								
Metasediment	8								

Management									
Grazing	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned	Planned
Fertiliser	Never	Low	High	Never	Low	High	Never	Low	High
Cultivation	Never	Never	Never	10-20 ya	10-20 ya	10-20 ya	>21 ya	>21 ya	>21 ya
Lithology									
Granite	12	8	13			11		4	12
Basalt		7	12			11		2	11
Metasediment		9	11			8		4	4

Management									
Grazing	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Fertiliser	Never	Low	High	Never	Low	High	Never	Low	High
Cultivation	Never	Never	Never	10-20 ya	10-20 ya	10-20 ya	>21 ya	>21 ya	>21 ya
Lithology									
Granite	20	9	8			11	0		12
Basalt	8	12	8			16	0	3	8
Metasediment	8	8	8			2	1	3	14

APPENDIX 4.2 GROUND-STOREY VEGETATION SPECIES LIST FOR NORTHERN TABLELANDS, NSW.

Table 1 Ground-storey vegetation species list, Northern Tablelands, NSW. Nomenclature and life form classification follows Harden (1993a, b, 2000, 2002) and Wheeler *et al.* (2002) except where indicated. Nomenclature based on advice from L. Copeland, University of New England, indicated with #. Synonym as in Harden (1993a, b, 2000, 2002) indicated in parenthesis. Sample frequency based on n = 373 sites.

NB. A number of species surveyed in this study have not yet been formally described or the genera require revision to enable accurate identification of field samples. Species include *Leiocarpa* sp. *nov.*, *Leucopogon* sp. affin. *fraseri* and *Pultenaea setulosa*, and many of the species of Asteraceae, particularly the genus *Chrysocephalum.*

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Acacia dealbata	Native	tree	0.5	<0.1
Acacia filicifolia	Native	tree	0.5	<0.1
Acacia implexa	Native	tree	1.3	<0.1
Acaena agnipila / ovina	Native	forb	20.9	0.2
Acaena novae-zelandiae	Native	forb	1.3	<0.1
Acetosella vulgaris	Exotic	forb	32.4	0.9
Agrostis capillaris	Exotic	grass	0.3	<0.1
Aira cupaniana	Exotic	grass	1.9	<0.1
Ajuga australis	Native	forb	1.1	<0.1
Alternanthera nana	Native	forb	0.5	<0.1
Alternanthera pungens	Exotic	forb	0.5	<0.1
Alternanthera species *A*	Native	forb	1.3	<0.1
Amaranthus hybridus	Exotic	forb	1.3	<0.1
Ammi majus	Exotic	forb	0.3	<0.1
Ammobium alatum	Native	forb	6.7	0.1
Anagallis arvensis	Exotic	forb	0.5	<0.1
Angophora floribunda	Native	forb	1.3	0.1
Anthoxanthum odoratum	Exotic	grass	17.7	1.3
Arthropodium species	Native	monocot	0.3	<0.1
Arctotheca calendula	Exotic	forb	2.7	<0.1
Aristida calycina var. *calycina*	Native	grass	2.4	0.5
Aristida jerichoensis var. *subspinulifera*	Native	grass	2.4	0.3
Aristida personata	Native	grass	12.3	1.5
Aristida vagans	Native	grass	4.3	0.8

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Aristida warburgii	Native	grass	0.3	0.1
Asperula conferta	Native	forb	33.8	0.7
Austrodanthonia bipartita	Native	grass	7.0	<0.1
Austrodanthonia caespitosa	Native	grass	0.5	0.3
Austrodanthonia eriantha	Native	grass	0.3	<0.1
Austrodanthonia induta	Native	grass	0.5	<0.1
Austrodanthonia laevis	Native	grass	1.3	<0.1
Austrodanthonia racemosa var. *obtusata*	Native	grass	0.8	<0.1
Austrodanthonia racemosa var. *racemosa*	Native	grass	35.9	1.3
Austrodanthonia richardsonii	Native	grass	0.3	<0.1
Austrodanthonia tenuior	Native	grass	0.8	<0.1
Austrostipa ramosissima	Native	grass	0.5	<0.1
Austrostipa rudis subsp. *nervosa*	Native	grass	0.3	<0.1
Austrostipa rudis subsp. *rudis*	Native	grass	1.1	<0.1
Austrostipa scabra subsp. *scabra*	Native	grass	3.5	0.1
Avena barbata	Exotic	grass	1.1	0.1
Axonopus compressus	Exotic	grass	0.8	<0.1
Bidens subalternans	Exotic	forb	1.1	<0.1
Bothriochloa macra	Native	grass	69.4	9.7
Brachyloma daphnoides	Native	shrub	0.3	<0.1
Bracteantha bracteata	Native	forb	2.1	<0.1
Brassica juncea	Exotic	forb	0.3	<0.1
Briza minor	Exotic	grass	4.0	<0.1
Bromus brevis	Exotic	grass	3.5	<0.1
Bromus cartharticus	Exotic	grass	2.7	<0.1
Bromus racemosus	Exotic	grass	35.9	1.2
Bulbostylis densa	Native	monocot	0.3	<0.1
Bursaria spinosa	Native	shrub	1.3	<0.1
Calocephalus species	Native	forb	0.5	<0.1
Calotis cuneifolia	Native	forb	3.5	0.1
Calotis dentex	Native	shrub	0.5	<0.1
Capsella bursa-pastoris	Exotic	forb	0.3	<0.1
Carex inversa	Native	monocot	38.9	0.7

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Carthamus lanatus	Exotic	forb	1.1	<0.1
Cassinia laevis	Native	shrub	0.3	<0.1
Centaurium erythraea	Exotic	forb	0.3	<0.1
Centaurium tenuiflorum	Exotic	forb	8.0	0.1
Cerastium glomeratum	Exotic	forb	0.8	<0.1
Chamaesyce dallachyana	Native	forb	0.5	<0.1
Cheilanthes sieberi subsp. *sieberi*	Native	fern	8.6	0.3
Chenopodium pumilio	Native	forb	2.1	<0.1
Chloris truncata	Native	grass	18.2	1.4
Chrysocephalum apiculatum	Native	forb	8.0	0.2
Chrysocephalum semipapposum	Native	forb	3.8	0.1
Ciclospermum leptophyllum	Exotic	forb	3.8	<0.1
Cirsium vulgare	Exotic	forb	31.4	0.5
Conium maculatum	Exotic	forb	0.3	<0.1
Convolvulus arvensis	Native	twiner	0.8	<0.1
Convolvulus erubescens	Native	twiner	2.4	<0.1
Conyza albida	Exotic	forb	8.3	0.1
Conyza bonariensis	Exotic	forb	3.5	<0.1
Conyza parva	Exotic	forb	0.3	<0.1
Cotoneaster species	Exotic	tree	0.3	<0.1
Crassula colorata var. *acuminata*	Native	forb	0.3	<0.1
Crassula sieberana	Native	forb	0.3	<0.1
Crepis capillaris	Exotic	forb	2.7	<0.1
Cymbonotus lawsonianus	Native	forb	9.4	0.1
Cymbopogon refractus	Native	grass	4.3	0.4
Cynodon dactylon	Native	grass	22.8	2.2
Cynoglossum australe	Native	forb	0.8	<0.1
Cyperus brevifolius	Exotic	monocot	0.3	<0.1
Cyperus eragrostis	Exotic	monocot	1.9	<0.1
Cyperus gracilis	Native	monocot	1.1	<0.1
Cyperus sphaeroideus	Native	monocot	1.9	0.1
Dactylis glomerata	Exotic	grass	8.0	0.6
Daucus carota	Exotic	forb	0.3	<0.1

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Daucus glochidiatus	Native	forb	0.8	<0.1
Daviesia genistifolia	Native	shrub	0.5	<0.1
Desmodium brachypodum	Native	twiner	1.1	<0.1
Desmodium varians	Native	twiner	24.9	0.4
Deyeuxia quadriseta	Native	grass	0.3	<0.1
Dianella longifolia var. *longifolia*	Native	monocot	3.5	0.1
Dianella revoluta var. *revoluta*	Native	monocot	2.9	0.2
Dianella tasmanica	Native	monocot	0.3	<0.1
Dianthus armeria	Exotic	forb	11.3	0.1
Dichanthium setosum	Native	grass	3.2	0.2
Dichelachne crinita	Native	grass	3.2	0.1
Dichelachne inaequiglumis	Native	grass	0.3	<0.1
Dichelachne micrantha	Native	grass	22.0	1.0
Dichelachne rara	Native	grass	1.9	0.1
Dichondra repens	Native	forb	18.0	0.5
Dichopogon fimbriatus	Native	monocot	1.6	<0.1
Digitaria brownii	Native	grass	1.3	<0.1
Digitaria diffusa	Native	grass	0.3	<0.1
Digitaria parviflora	Native	grass	0.5	<0.1
Digitaria ternata	Exotic	grass	1.1	0.1
Dillwynia juniperina	Native	shrub	0.3	<0.1
Dillwynia sieberi	Native	shrub	0.3	<0.1
Dipodium punctatum	Native	monocot	0.3	<0.1
Echinopogon intermedius	Native	grass	1.1	<0.1
Echinopogon mckiei	Native	grass	1.1	<0.1
Echinopogon ovatus	Native	grass	1.1	<0.1
Echium plantagineum	Exotic	forb	0.5	<0.1
Einadia hastata	Native	shrub	0.3	<0.1
Einadia nutans subsp. *linifolia*	Native	twiner	0.3	<0.1
Einadia nutans subsp. *nutans*	Native	twiner	2.9	0.1
Eleocharis acuta	Native	forb	0.3	<0.1
Eleocharis pusilla	Native	forb	0.3	<0.1
Eleusine tristachya	Exotic	grass	24.4	1.6

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Elymus scaber var. *scaber*	Native	grass	38.9	1.1
Enneapogon nigricans	Native	grass	0.3	<0.1
Epilobium billardierianum subsp. *cinereum*	Native	forb	14.2	0.2
Epilobium billardierianum subsp. *hydrophilum*	Native	forb	4.3	<0.1
Epilobium gunnianum	Native	forb	0.3	<0.1
Epilobium hirtigerum	Native	forb	0.5	<0.1
Eragrostis benthamii	Native	grass	12.9	0.5
Eragrostis brownii	Native	grass	9.9	0.4
Eragrostis curvula	Exotic	grass	0.5	0.1
Eragrostis elongata	Native	grass	0.5	<0.1
Eragrostis leptostachya	Native	grass	39.9	3.8
Eragrostis molybdea	Native	grass	3.8	0.9
Eragrostis species *A*	Exotic	grass	3.5	0.1
Eragrostis trachycarpa	Native	grass	36.2	1.6
Eriochilus cucullatus	Native	monocot	0.5	<0.1
Eucalyptus banksii	Native	tree	0.3	<0.1
Eucalyptus blakelyi	Native	tree	0.8	<0.1
Eucalyptus bridgesiana	Native	tree	0.3	<0.1
Eucalyptus caliginosa	Native	tree	4.8	0.2
Eucalyptus dalrympleana	Native	tree	0.3	<0.1
Eucalyptus laevopinea	Native	tree	1.1	<0.1
Eucalyptus melliodora	Native	tree	2.1	<0.1
Eucalyptus nova-anglica	Native	tree	0.5	<0.1
Eucalyptus pauciflora	Native	tree	0.3	<0.1
Eucalyptus viminalis	Native	tree	2.9	0.2
Eucalyptus youmanii	Native	tree	0.3	<0.1
Euchiton involucratum / sphaericum	Native	forb	0.8	<0.1
Euchiton involucratum	Native	forb	6.7	0.1
Euchiton sphaericum	Native	forb	27.6	0.3
Eulalia aurea	Native	grass	1.3	0.2
Euphrasia orthocheila subsp. *orthocheila*	Native	forb	0.3	<0.1
Festuca pratensis	Exotic	grass	8.3	1.0
Fimbristylis dichotoma	Native	monocot	39.1	0.6

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Gamochaeta spicata	Exotic	forb	2.1	<0.1
Geranium solanderi var. *solanderi*	Native	forb	24.1	0.3
Glycine clandestina	Native	twiner	12.9	0.2
Glycine tabacina	Native	twiner	15.0	0.2
Gnaphalium americanum	Exotic	forb	0.5	<0.1
Gnaphalium coarctatum	Exotic	forb	7.5	0.1
Gonocarpus tetragynus	Native	forb	3.2	0.1
Goodenia bellidifolia	Native	forb	0.3	<0.1
Goodenia hederacea subsp. *hederacea*	Native	forb	0.8	<0.1
Grevillea species	Native	shrub	0.3	<0.1
Hakea eriantha	Native	shrub	0.3	<0.1
Hakea microcarpa	Native	shrub	0.3	<0.1
Haloragis heterophylla	Native	forb	32.2	0.4
Hardenbergia violacea	Native	twiner	0.5	<0.1
Helichrysum scorpioides	Native	forb	0.8	<0.1
Hemarthria uncinata var. *uncinata*	Native	grass	0.5	<0.1
Hibbertia acicularis	Native	shrub	0.3	<0.1
Hibbertia linearis	Native	shrub	0.3	<0.1
Hibbertia obtusifolia	Native	shrub	3.5	0.1
Hibbertia riparia	Native	shrub	0.5	<0.1
Holcus lanatus	Exotic	grass	18.0	1.1
Hordeum leporinum	Exotic	grass	0.3	<0.1
Hovea linearis	Native	shrub	1.1	<0.1
Hydrocotyle laxiflora	Native	forb	12.9	0.2
Hydrocotyle peduncularis	Native	forb	1.3	<0.1
Hypericum gramineum	Native	forb	20.9	0.3
Hypochaeris glabra / radicata	Exotic	forb	85.8	2.6
Hypoxis hygrometrica var. *villosisepala*	Native	monocot	2.4	<0.1
Imperata cylindrica	Native	grass	0.3	<0.1
Isolepis hookeriana	Native	monocot	0.5	<0.1
Joycea pallida	Native	grass	0.8	0.1
Juncus filicaulis	Native	monocot	25.5	0.4
Juncus usitatus	Native	monocot	11.8	0.2

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Juncus vaginatus	Native	monocot	12.9	0.4
Lachnagrostis aemula	Native	grass	2.7	<0.1
Lachnagrostis filiformis	Native	grass	1.6	<0.1
Lactuca saligna	Exotic	forb	0.8	<0.1
Lactuca serriola	Exotic	forb	0.3	<0.1
Lagenifera gracilis	Native	forb	3.5	<0.1
Leiocarpa sp. *nov*[#] [formally described as *Leptorhynchos squamatus* subsp. *A*]	Native	forb	0.8	<0.1
Lepidium bonariense	Exotic	forb	1.6	<0.1
Lepidium virginicum	Exotic	forb	0.8	<0.1
Leptorhynchos squamatus subsp. *A*	Native	forb	6.7	0.1
Lespedeza juncea subsp. *sericea*	Native	shrub	4.3	0.1
Leucochrysum albicans ssp albicans var. *albicans*	Native	forb	0.3	<0.1
Leucopogon sp. aff. *fraseri*[#] [not listed in Harden (1993a, 1993b, 2000, 2002)]	Native	shrub	2.9	<0.1
Lissanthe strigosa	Native	shrub	3.5	0.1
Lobelia gracilis	Native	forb	0.3	<0.1
Lolium perenne	Exotic	grass	14.7	1.2
Lomandra filiformis	Native	monocot	8.0	0.1
Lomandra longifolia	Native	monocot	2.9	0.1
Lomandra multiflora subsp. *multiflora*	Native	monocot	2.1	<0.1
Malus x domestica	Exotic	tree	0.5	<0.1
Marrubium vulgare	Exotic	forb	1.1	<0.1
Medicago laciniata	Exotic	forb	5.6	0.1
Medicago lupulina	Exotic	forb	0.5	<0.1
Medicago minima	Exotic	forb	1.1	<0.1
Medicago polymorpha	Exotic	forb	0.3	<0.1
Medicago sativa	Exotic	forb	0.3	<0.1
Medicago species	Exotic	forb	5.6	0.1
Melichrus urceolatus	Native	shrub	1.6	<0.1
Mentha satureioides	Native	forb	7.5	0.1
Microlaena stipoides	Native	grass	29.8	3.6
Microseris lanceolata	Native	forb	1.3	<0.1
Modiola caroliniana	Exotic	forb	5.6	0.1
Murdannia graminea	Native	monocot	0.5	<0.1

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Opercularia aspera	Native	forb	0.8	<0.1
Oreomyrrhis eriopoda	Native	forb	0.3	<0.1
Ornithopus species.	Exotic	twiner	0.8	<0.1
Oxalis exilis	Native	forb	43.7	0.5
Oxalis radicosa	Native	forb	0.8	<0.1
Panicum effusum	Native	grass	28.2	1.0
Panicum gilvum	Exotic	grass	0.3	<0.1
Panicum maximum var. *maximum*	Exotic	grass	0.3	<0.1
Panicum queenslandicum var. *queenslandicum*	Native	grass	1.1	<0.1
Paronychia brasiliana	Exotic	forb	31.6	0.5
Paspalum dilatatum	Exotic	grass	37.5	3.1
Paspalum distichum	Native	grass	0.5	<0.1
Pennisetum alopecuroides	Native	grass	10.7	0.7
Persicaria prostrata	Native	forb	2.1	<0.1
Petrorhagia nanteuilii	Exotic	forb	8.8	0.1
Phalaris aquatica	Exotic	grass	19.6	2.4
Phyllanthus gunnii	Native	forb	2.4	<0.1
Phyllanthus virgatus	Native	forb	5.9	0.1
Pimelea curviflora var. *divergens*	Native	shrub	12.1	0.1
Pimelea linifolia	Native	shrub	2.1	0.1
Pinus radiata	Exotic	tree	0.3	<0.1
Plantago debilis	Native	forb	3.5	0.1
Plantago gaudichaudii	Native	forb	5.9	0.1
Plantago lanceolata	Exotic	forb	47.2	1.0
Poa pratensis	Exotic	grass	0.8	<0.1
Poa sieberiana	Native	grass	59.8	10.3
Podolepis jaceoides	Native	forb	0.3	<0.1
Polygala japonica	Native	forb	1.3	<0.1
Polygonum aviculare	Exotic	forb	5.4	<0.1
Poranthera microphylla	Native	forb	2.1	<0.1
Portulaca oleracea	Native	forb	1.3	<0.1
Pteridium esculentum	Native	fern	1.6	<0.1
Pultenaea microphylla	Native	shrub	2.4	0.1

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Pultenaea [Weston and de Kok] *setulose*[#] [formally regarded as a form of *P. setulosa* Benth.]	Native	shrub	0.5	<0.1
Pyracantha species	Exotic	tree	0.3	<0.1
Ranunculus lappaceus	Native	forb	1.9	<0.1
Rhytidosporum procumbens	Native	shrub	0.3	<0.1
Richardia stellaris	Native	forb	0.5	<0.1
Rorippa gigantea	Native	forb	0.3	<0.1
Rosa rubiginosa	Exotic	shrub	3.8	<0.1
Rubus fruticosus aggregate	Exotic	twiner	1.6	<0.1
Rubus parvifolius	Native	twiner	2.7	0.1
Rumex brownii	Native	forb	47.2	0.5
Schkuhria pinnata var. *abrotanoides*	Exotic	forb	4.0	0.1
Schoenus apogon	Native	monocot	2.4	<0.1
Scleranthus biflorus	Native	forb	11.5	0.3
Senecio diaschides	Native	forb	0.8	<0.1
Senecio species *E*	Native	forb	1.1	<0.1
Setaria gracilis	Exotic	grass	11.3	0.5
Setaria pumila	Exotic	grass	5.9	0.3
Setaria viridis	Exotic	grass	0.5	<0.1
Sisymbrium orientale	Exotic	forb	0.5	<0.1
Solanum chenopodioides	Exotic	forb	0.3	<0.1
Solanum nigrum	Native	forb	0.8	<0.1
Solenogyne bellioides	Native	forb	2.7	<0.1
Solenogyne dominii	Native	forb	0.5	<0.1
Solenogyne gunnii	Native	forb	1.3	<0.1
Sonchus asper subsp. *glaucescens*	Exotic	forb	0.8	<0.1
Sonchus oleraceus	Exotic	forb	0.5	<0.1
Sorghum leiocladum	Native	grass	24.7	1.9
Spergularia rubra	Exotic	forb	0.3	<0.1
Spiranthes sinensis subsp. *australis*	Native	monocot	1.9	<0.1
Sporobolus creber	Native	grass	64.9	6.9
Stackhousia monogyna	Native	forb	0.8	<0.1
Stellaria angustifolia	Native	forb	0.3	<0.1
Stellaria media	Exotic	forb	0.5	<0.1

Taxa	Origin	Life form	Frequency (%)	Mean cover (%)
Stylidium graminifolium	Native	forb	0.3	<0.1
Taraxacum officinale	Exotic	forb	7.2	0.1
Themeda australis	Native	grass	19.3	3.4
Thesium australe	Native	forb	0.8	<0.1
Tolpis umbellata	Exotic	forb	0.3	<0.1
Trachymene incisa	Native	forb	0.3	<0.1
Tricoryne elatior	Native	monocot	4.0	<0.1
Trifolium arvense	Exotic	forb	9.1	0.2
Trifolium campestre	Exotic	forb	6.4	0.1
Trifolium fragiferum	Exotic	forb	2.7	<0.1
Trifolium glomeratum	Exotic	forb	1.3	<0.1
Trifolium repens	Exotic	forb	48.5	1.3
Trifolium subterraneum	Exotic	forb	0.3	<0.1
Urtica incisa	Native	forb	0.8	<0.1
Verbascum thapsus	Exotic	forb	1.3	0.1
Verbena bonariensis	Exotic	forb	2.7	<0.1
Veronica calycina	Native	forb	2.4	<0.1
Veronica plebeia	Native	forb	1.9	<0.1
Vicia sativa	Exotic	twiner	0.5	<0.1
Viola betonicifolia subsp. *betonicifolia*	Native	forb	5.1	<0.1
Vittadinia cuneata var. *cuneata*	Native	forb	4.8	0.1
Vittadinia muelleri	Native	forb	3.2	<0.1
Vulpia bromoides / muralis / myuros	Exotic	grass	31.6	1.3
Wahlenbergia communis	Native	forb	15.5	0.2
Wahlenbergia gracilis	Native	forb	1.3	<0.1
Wahlenbergia luteola	Native	forb	7.0	0.1
Wahlenbergia planiflora subsp. *longifolia*	Native	forb	0.5	<0.1
Wahlenbergia planiflora subsp. *planiflora*	Native	forb	1.6	<0.1
Wahlenbergia species	Native	forb	2.4	<0.1
Wahlenbergia stricta subsp. *stricta*	Native	forb	2.1	<0.1
Xanthorrhoea australis	Native	shrub	0.3	<0.1
Xanthorrhoea glauca subsp. *glauca*	Native	shrub	0.3	<0.1
Zornia dyctiocarpa var. *dyctiocarpa*	Native	twiner	0.8	<0.1

APPENDIX 4.3 RELATIONSHIP BETWEEN EASTING AND SUMMER AND WINTER PRECIPITATION AVERAGES

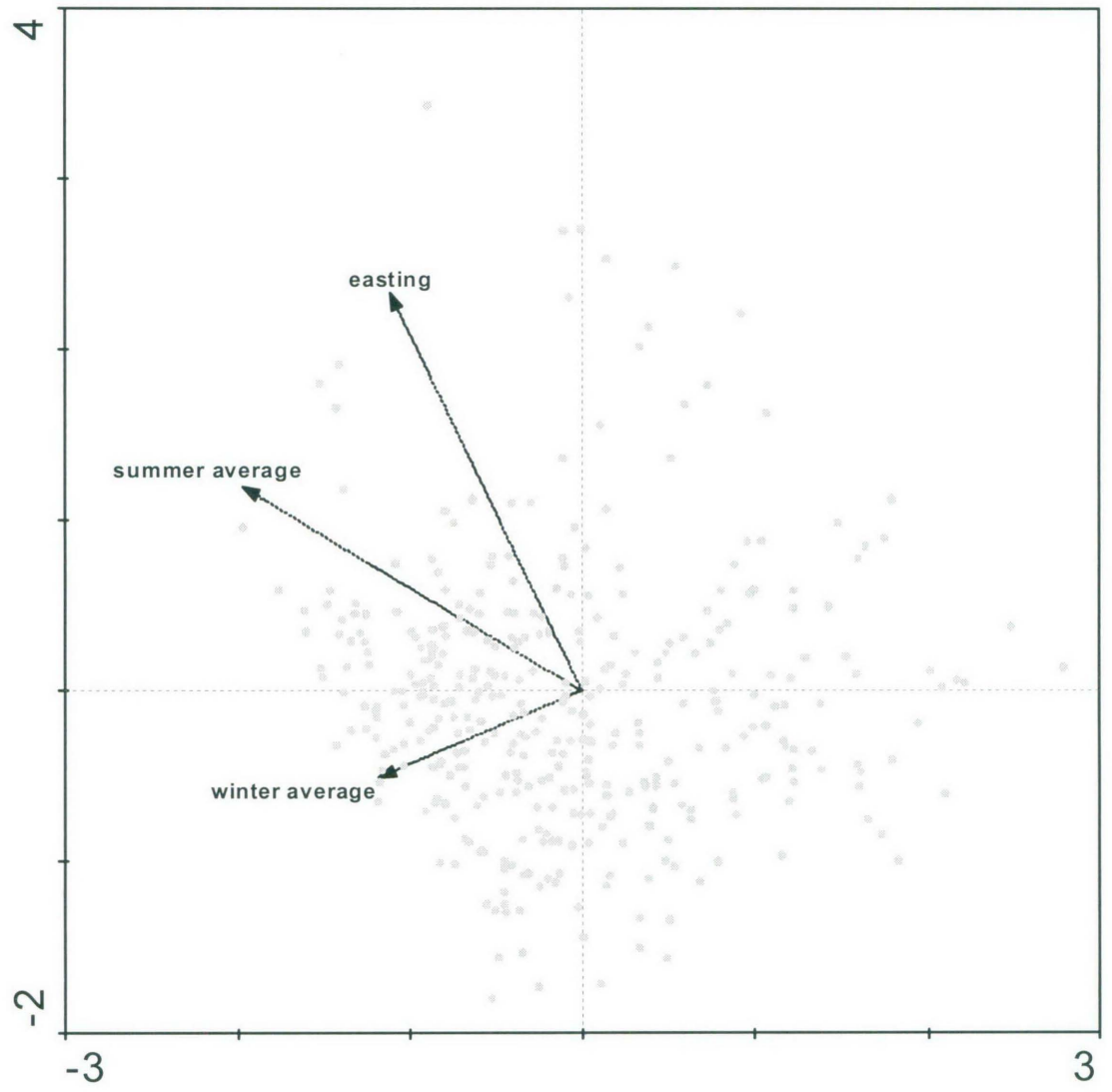

Figure 1 CCA ordination biplot illustrating relationship between easting and summer and winter precipitation averages. Sites; ◦, environmental variables represented by vectors.

APPENDIX 5.1 PRIORITISATION OF GROUP VARIABLES

Table 1. Prioritisation of grazing variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. Columns blank indicate no priority given to the variable. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
Paddock size	1		2	Correlated with NSR (r = 0.305), evenness (r = 0.185); Literature: Waters (2001)
Dry sheep equivalents	2		1	Correlated with NSR (r = 0.245), evenness (r = -0.254); Literature: (Sustainable Grazing Systems 2001)
Number of rests from grazing per year		1		Correlated with ESR (r = -0.150);
Number of months grazed per year		2		Correlated with ESR (r = 0.072)
Type of stock grazed				Literature from arid zone research Tiver and Andrew (1997) and Reseigh (1999)

Table 2. Prioritisation of fertiliser variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
Number of years fertiliser applied	1	2	2	Correlated with NSR (r = 0.411), ESR (r = 0.430) and evenness (r = - 0.139),
Time since fertiliser application				
Seed added to fertiliser				
Species added to fertiliser				Secondary importance, more influence on composition
Type of fertiliser applied				
Weight of fertiliser applied	2	2	1	Highly correlated with NSR (r = 0.379), ESR (r = 0.205), evenness (r = -0.179)
Fertiliser frequency				

Table 3. Prioritisation of cultivation variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
Time since cultivation				Taken into account in stratification analysis
Number of times cultivated	1	1	1	Correlation with NSR (r = 0.313), ESR (r = 0.216), evenness (r = -0.194); Literature: Waters (2001)
Cultivation frequency	2	2	2	
Species sown				Secondary importance, more influence on composition

Table 4. Prioritisation of other management variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
Land tenure				
Structural formation	1	1	1	Literature: Gibbs (1999)
Kangaroo grazing				
Rabbit grazing				

Table 5. Prioritisation of rainfall variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
January				
February				
March				
April		1		Correlation with ESR (r = 0.259)
May	1			Correlation with NSR (r = -0.285)
June		2		Correlation with ESR (r = 0.300)
July	2		1	Correlation with NSR (r = -0.250), evenness (r = -0.246)
August			2	Correlation with evenness (r = -0.207)
September				
October				
November				
December				
Mean annual				
Winter average				
Summer average				

Table 6. Prioritisation of temperature variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Minimum Temperature Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
January				
February				
March				
April				
May			1	Correlation with evenness (r = 0.214)
June				
July	1		2	Correlation with NSR (r = -0.236), evenness (r = 0.203)
August				
September	2			Correlation with NSR (r = -0.212)
October				
November				
December				
Mean annual				
Winter average				
Summer average				

Maximum Temperature Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				
Mean annual				
Winter average		2		Correlation with ESR (r = -0.173)
Summer average		1		Correlation with ESR (r = -0.212)

Table 7. Prioritisation of moisture Index variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
January				
February				
March				
April		2		Correlation with ESR (r = 0.289)
May	1			Correlation with NSR (r = -0.248)
June		1		Correlation with ESR (r = 0.347)
July	2		1	Correlation with NSR (r = -0.231), evenness (r = -0.195)
August			2	Correlation with evenness (r = -0.173)
September				
October				
November				
December				
Mean annual				
Winter average				
Summer average				

Table 8. Prioritisation of radiation variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
January				
February				
March				
April		2		Correlation with ESR (r = -0.226)
May	1		1	Correlation with NSR (r = 0.317), evenness (r = 0.214)
June				
July			2	Correlation with evenness (r = 0.198)
August				
September				
October				
November		1		Correlation with ESR (r = -0.261)
December				
Mean annual	2			Correlation with NSR (r = 0.271)
Winter average				
Summer average				

Table 9. Prioritisation of soil variables Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
Bulk density				
Total Nitrogen (mg/kg)				
Organic Carbon (%C)		1		Correlation with ESR (r = 0.268)
pH_{H2O}			1	Correlation with evenness (r = 0.233),
pH_{CaCl2}	1		2	Correlation with NSR (r = 0.296), evenness (r= 0.220)
Phosphorus (Colwell) (mg/kg)		2		Correlation with ESR (r = 0.235)
Sulphur (KCl40) (mg/kg)	2			Correlation with NSR (r = 0.212)

Table 10. Prioritisation of geographical variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
Geographical position – Easting		1		Correlation with ESR (r = 0.238) Literature: Waters (2001)
Geographical position – Northing				Correlation with NSR (r = 0.119)
Altitude		2		Correlation with ESR (r = 0.200)
Slope	2		2	Correlation with NSR (r = 0.21), evenness (r = 0.229)
Percentage of site under tree canopy	1		1	Correlation with NSR (r = 0.103), evenness (r = 0.268); Literature: Gibbs (1999); Observation of species change under trees
Position in landscape				
Tree presence				Correlated with percentage of site under tree canopy and structural formation
Distance to travelling stock route				Correlation with NSR (r = 0.274)
Landscape morphology variables				
Aspect				

Table 11. Prioritisation of sampling time variables. Numbers in prioritisation column refer to priority for inclusion in the relevant model. The first number refers to rank within the native species richness model, the second number refers to rank within the exotic species richness and the third number refers to rank within the evenness model. Abbreviations: NSR – native species richness; ESR – exotic species richness; Even – evenness of plant cover.

Variable	Prioritisation			Reasoning
	NSR	ESR	Even	
Julian time				Correlation with NSR (r = 0.033), ESR (r = 0.049)

APPENDIX 5.2 RESIDUAL DIAGNOSTIC PLOTS FOR NATIVE SPECIES RICHNESS EQUATION 5.2.

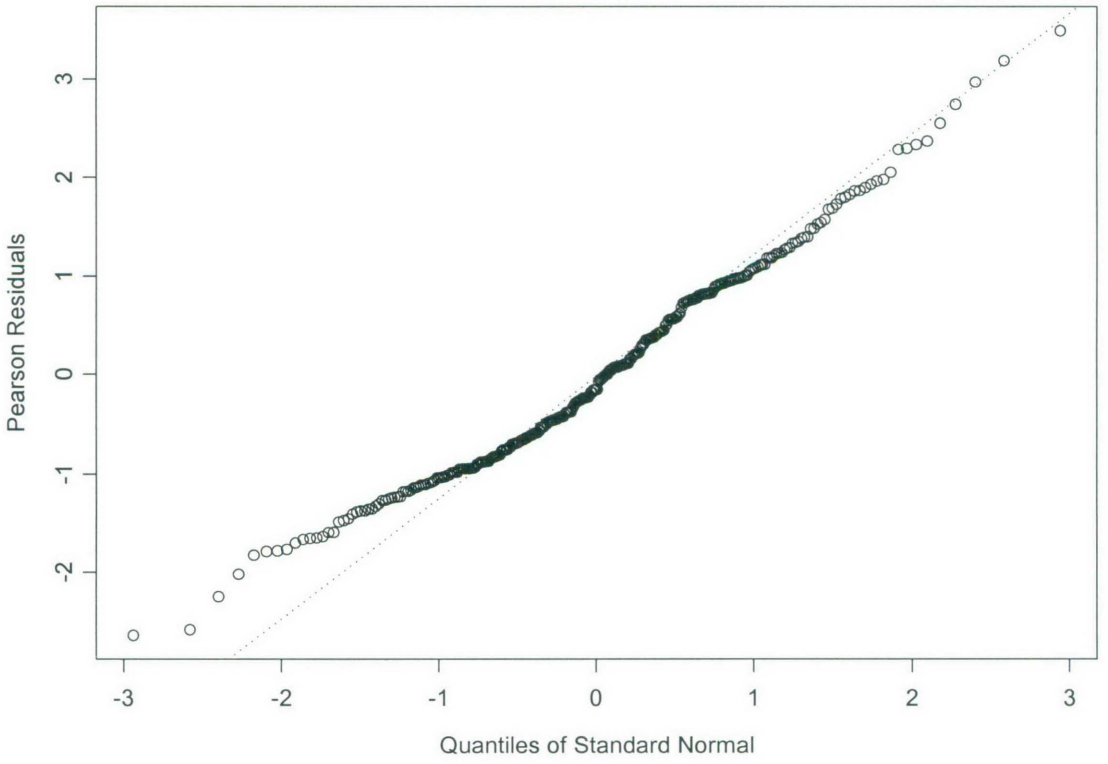

Figure 1. Plot of Pearson residuals around the quantiles of standard normal distribution for native species richness, Equation 5.2.

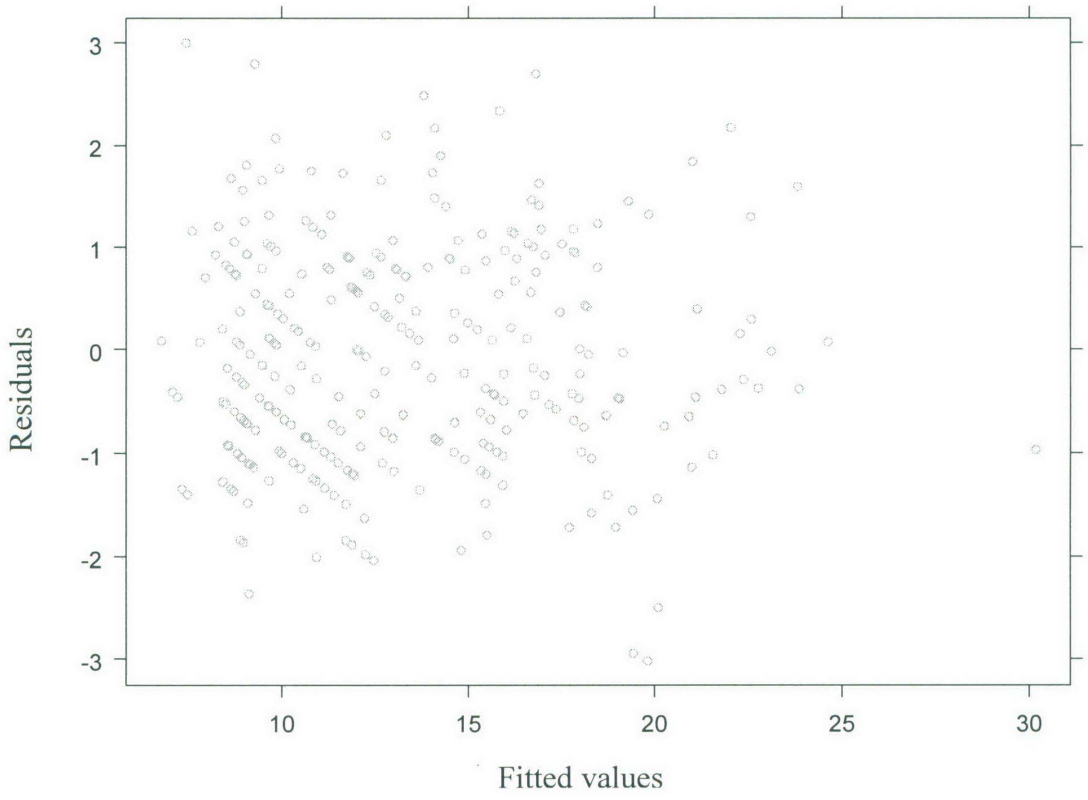

Figure 2. Plot of fitted values and residuals from native species richness Equation 5.2.

APPENDIX 5.3 RESIDUAL DIAGNOSTIC PLOTS FOR EXOTIC SPECIES RICHNESS EQUATION 5.3.

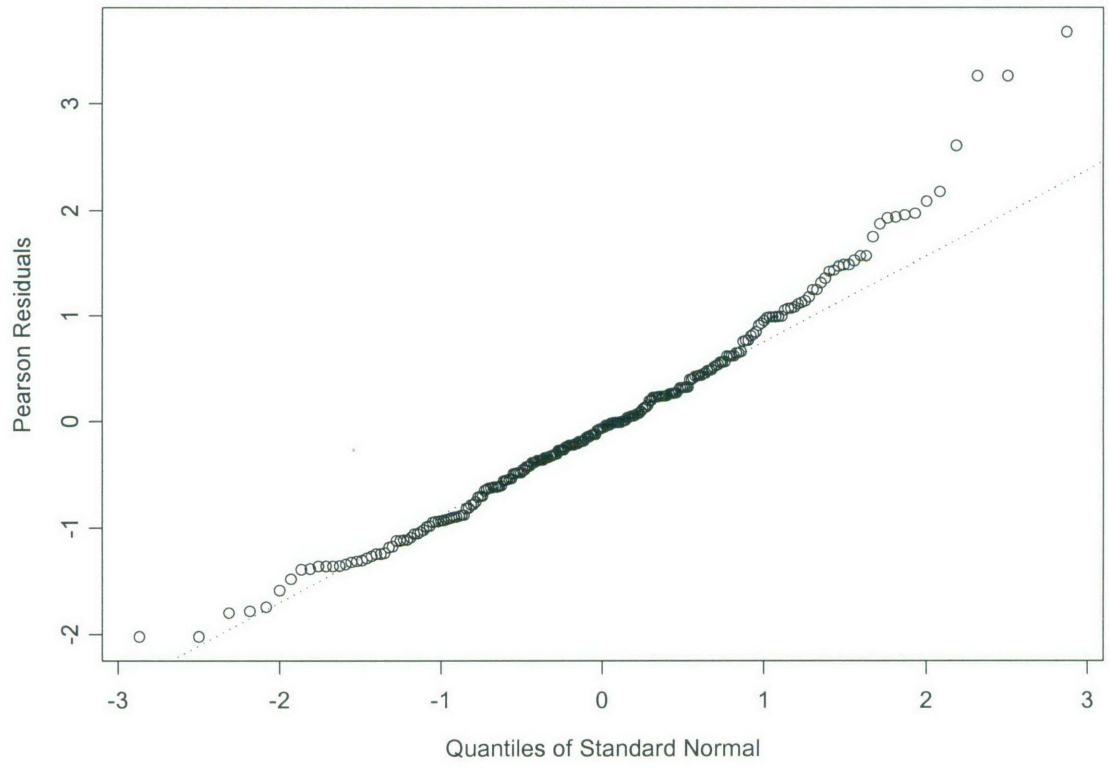

Figure 1. Plot of Pearson residuals around the quantiles of standard normal distribution for exotic species richness, Equation 5.3.

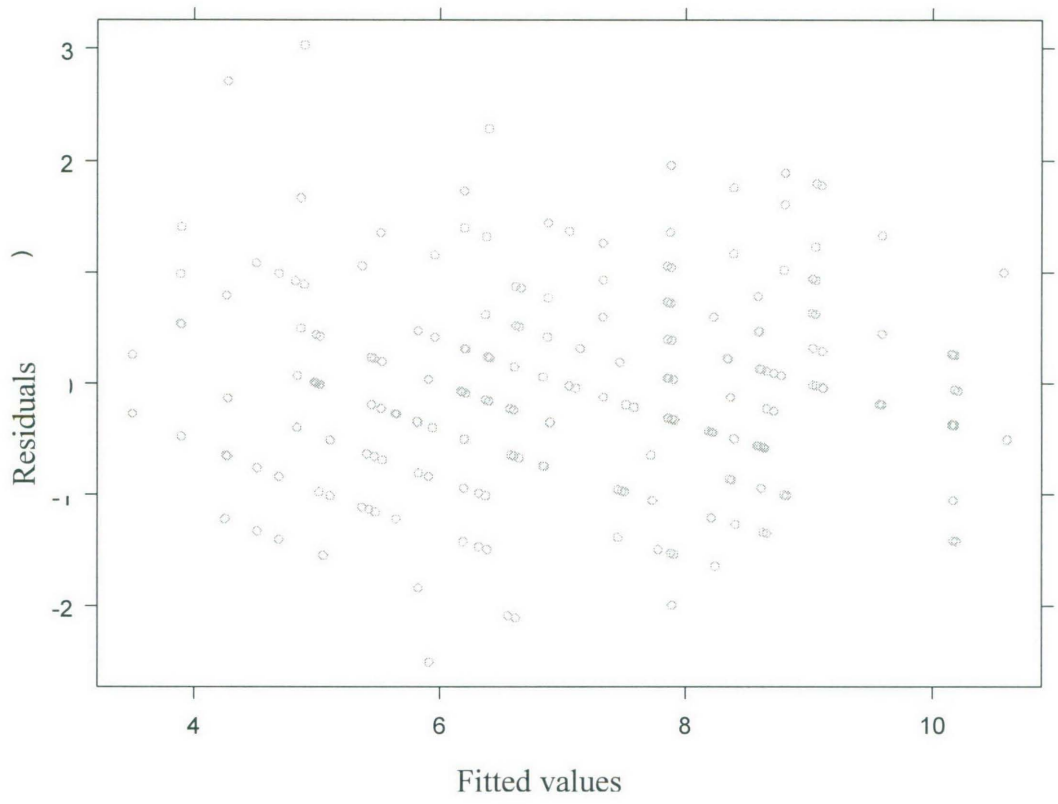

Figure 2. Plot of fitted values and residuals from exotic species richness, Equation 5.3.

APPENDIX 5.4 CORRELATION OF PRECIPITATION VARIABLES

Table 1. Correlation of precipitation variables with native and exotic species richness, Northern Tablelands, NSW.

	NSR	ESR	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Summer	Winter
NSR	1.000	-.232	-.066	-.149	-.024	-.113	-.285	-.193	-.251	-.224	-.153	-.138	-.068	-.058	-.222	-.087	-.238
ESR	-.232	1.000	.129	.181	.208	.298	.043	.384	.094	-.009	.019	.054	.242	.197	.267	.207	.117
Jan	-.066	.129	1.000	.933	.945	.821	.015	.127	-.476	-.698	-.694	-.312	.196	.899	.689	.965	-.418
Feb	-.149	.181	.933	1.000	.924	.894	.242	.330	-.267	-.485	-.468	-.089	.305	.857	.836	.966	-.165
Mar	-.024	.208	.945	.924	1.000	.870	.054	.276	-.432	-.673	-.618	-.227	.336	.905	.746	.974	-.334
Apr	-.113	.298	.821	.894	.870	1.000	.194	.527	-.183	-.432	-.381	-.116	.375	.815	.820	.906	-.092
May	-.285	.043	.015	.242	.054	.194	1.000	.454	.704	.614	.616	.734	.488	.183	.610	.161	.788
Jun	-.193	.384	.127	.330	.276	.527	.454	1.000	.596	.309	.435	.525	.656	.340	.700	.335	.653
Jul	-.251	.094	-.476	-.267	-.432	-.183	.704	.596	1.000	.907	.905	.778	.401	-.266	.240	-.327	.962
Aug	-.224	-.009	-.698	-.485	-.673	-.432	.614	.309	.907	1.000	.944	.684	.121	-.588	-.067	-.595	.877
Sep	-.153	.019	-.694	-.468	-.618	-.381	.616	.435	.905	.944	1.000	.825	.304	-.498	.012	-.545	.932
Oct	-.138	.054	-.312	-.089	-.227	-.116	.734	.525	.778	.684	.825	1.000	.652	-.058	.384	-.134	.890
Nov	-.068	.242	.196	.305	.336	.375	.488	.656	.401	.121	.304	.652	1.000	.475	.673	.393	.511
Dec	-.058	.197	.899	.857	.905	.815	.183	.340	-.266	-.588	-.498	-.058	.475	1.000	.801	.945	-.191
Mean	-.222	.267	.689	.836	.746	.820	.610	.700	.240	-.067	.012	.384	.673	.801	1.000	.828	.350
Summer	-.087	.207	.965	.966	.974	.906	.161	.335	-.327	-.595	-.545	-.134	.393	.945	.828	1.000	-.235
Winter	-.238	.117	-.418	-.165	-.334	-.092	.788	.653	.962	.877	.932	.890	.511	-.191	.350	-.235	1.000

APPENDIX 5.5 JULIAN TIME INFLUENCES ON NATIVE AND EXOTIC SPECIES RICHNESS.

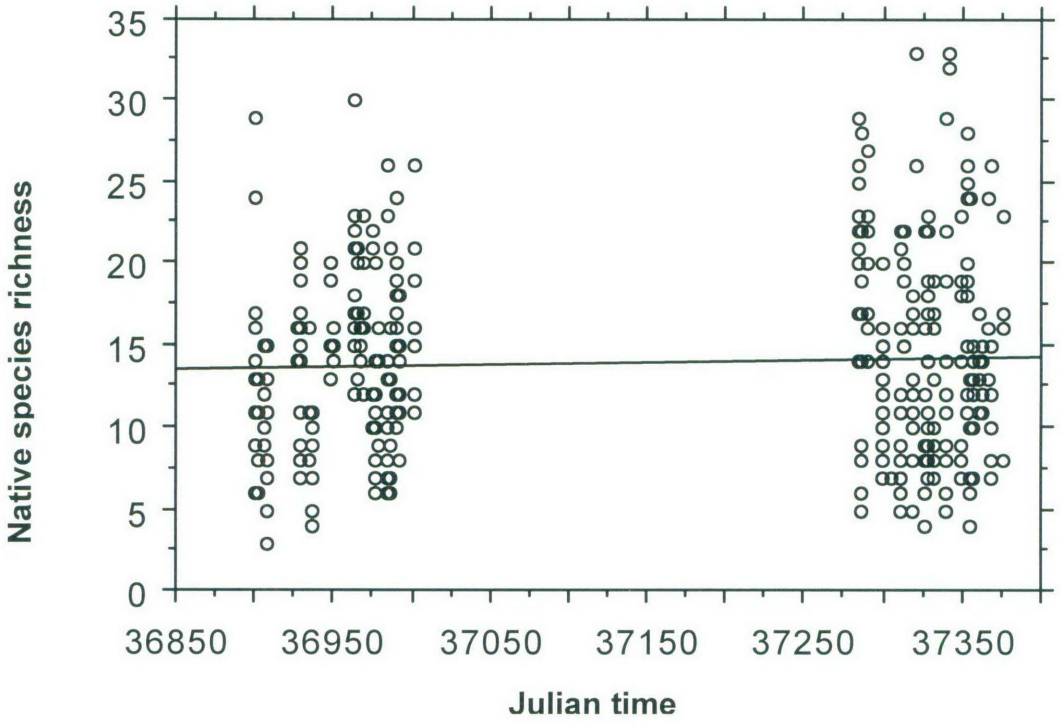

Figure 1 Observed native species richness by Julian time (F = 0.46; df = 1,372; p = 0.50).

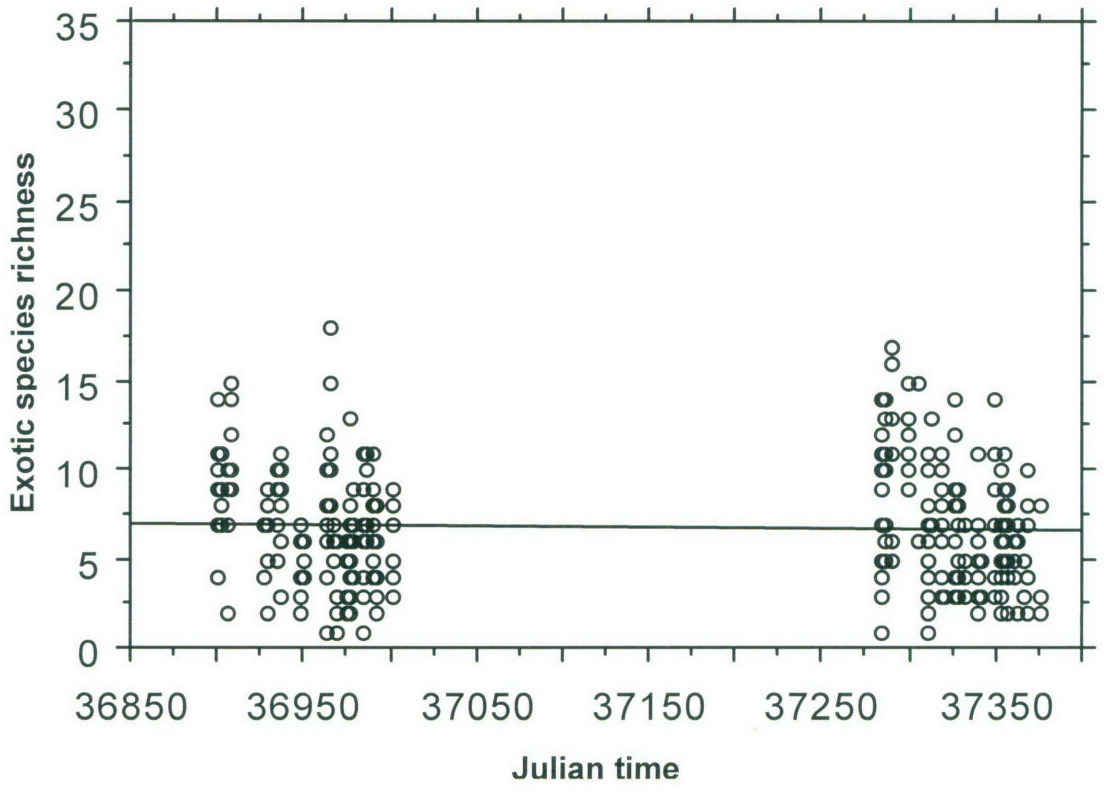

Figure 2 Observed exotic species richness by Julian time (F = 0.81; df =1, 372; p = 0.37)

APPENDIX 6.1 FULL MODEL FORWARD SELECTION FROM CCA ANALYSIS.

Table 1 All forward selection results for the CCA. Sorted by descending significance.

Environmental variable	F	p
Land tenure: production	5.06	0.002
Total nitrogen	4.85	0.002
Moisture index June	3.53	0.002
Structural formation: grassland	3.32	0.002
Precipitation December	3.12	0.002
Percentage of site under tree canopy	2.84	0.002
Structural formation: open woodland	2.73	0.002
Fertiliser stratification: high	2.41	0.002
Julian time	2.38	0.002
Lithology: metasediments	2.15	0.002
Mean annual precipitation	2.15	0.002
Precipitation April	2.12	0.002
Precipitation October	2.32	0.002
Lithology: Granite	2.04	0.002
Moisture index summer average	1.88	0.002
pH $_{(CaCl2)}$	1.86	0.002
Type of stock grazed: cattle	1.81	0.002
Grazing stratification: not grazed	1.78	0.002
Minimum temperature September	1.7	0.002
Precipitation February	1.79	0.002
Number of rests from grazing per year	1.75	0.002
Precipitation March	1.72	0.002
Moisture index October	1.97	0.002
Radiation November	1.72	0.002
Precipitation May	1.68	0.002
Moisture index February	1.69	0.002
Position in landscape: accumulating water	1.6	0.002
Tree presence	1.59	0.002
Minimum temperature January	1.5	0.002
Moisture index May	1.53	0.002
Organic carbon	1.49	0.002
Precipitation June	1.51	0.002
Grazing stratification: planned rest	1.5	0.002
Radiation July	1.48	0.002
Cultivation stratification: not cultivated	1.47	0.002
Landscape morphology: upper slope	1.45	0.002
Precipitation: summer average	1.45	0.002
Minimum temperature June	1.36	0.002
Radiation June	1.46	0.002
Maximum temperature August	1.39	0.002
Number of rest from grazing per year	1.42	0.002
Land tenure: public	1.69	0.004
Distance to travelling stock route	1.5	0.004
Minimum temperature July	1.44	0.004
Moisture index December	1.47	0.004
Radiation May	1.38	0.004

Environmental variable	F	p
Radiation: mean annual	1.39	0.004
Radiation December	1.48	0.004
Kangaroo grazing: moderate	2.32	0.006
Fertiliser application: various applications	1.5	0.006
Precipitation July	1.4	0.006
Seed added; rye grass	2.53	0.008
Phosphorous (Colwell)	1.54	0.008
Fertiliser stratification: not fertilised	1.3	0.008
Rabbit grazing: severe	2.5	0.01
Minimum temperature January	1.29	0.01
Kangaroo grazing: heavy	2.16	0.012
Slope	1.32	0.012
Maximum temperature June	1.27	0.012
Geographical position: northing	1.26	0.012
Type of stock grazed: sheep	1.3	0.012
Altitude	1.42	0.014
Maximum temperature January	1.24	0.014
Maximum temperature March	1.3	0.016
Time since fertiliser application	1.31	0.018
Type of stock grazed: both sheep and cattle	1.48	0.018
Maximum temperature January	1.24	0.018
Sulphur	1.48	0.022
Moisture index September	1.29	0.022
Species sown: barley	2.08	0.026
Type of fertiliser applied no type	1.45	0.026
Minimum temperature April	1.24	0.026
Paddock size	1.34	0.028
Moisture index August	1.25	0.028
Fertiliser application: every year	1.25	0.03
Geographical position: Easting	1.21	0.032
Time since cultivation	1.25	0.034
Minimum temperature 1	1.21	0.036
Species sown: Phalaris	1.23	0.036
Radiation October	1.21	0.042
Precipitation September	1.2	0.048
Aspect: cos	1.17	0.052
Minimum temperature May	1.19	0.054
Radiation March	1.19	0.058
Species sown: white clover	1.52	0.062
Dry sheep equivalents	1.26	0.068
Species sown: lucerne	1.39	0.072
Grazing stratification: episodic	1.42	0.082
$pH_{(H2O)}$	1.18	0.082
Minimum temperature August	1.16	0.088
Aspect: sin	1.14	0.088
Species sown: potatoes	1.58	0.09
Species sown: rye grass	1.21	0.092
Fertiliser application: every second year	1.15	0.098
Kangaroo grazing: nil	1.37	0.1
Species sown: vetch	1.61	0.11

Environmental variable	F	p
Fertiliser application: never applied	1.39	0.116
Radiation February	1.15	0.116
Species sown: pasture mix	1.13	0.126
Cultivation frequency: once	1.13	0.136
Maximum temperature May	1.12	0.138
Rabbit grazing: nil	1.44	0.14
Radiation September	1.1	0.164
Fertiliser application: once off	1.1	0.178
Minimum temperature January	1.1	0.18
Rabbit grazing: heavy	1.12	0.184
Radiation January	1.11	0.19
Cultivation frequency: various	1.14	0.192
Landscape morphology: flat	1.09	0.206
Radiation April	1.08	0.24
Bulk density	1.08	0.256
Cultivation frequency: twice	1.1	0.256
Species sown: fescue	1.09	0.256
Species sown: corn	1.1	0.282
Radiation August	1.07	0.288
Precipitation August	1.05	0.29
Moisture index: April	1.06	0.296
Type of fertiliser applied; single superphosphate	1.06	0.308
Minimum temperature March	1.06	0.31
Minimum temperature February	1.05	0.318
Absolute maximum temperature	1.06	0.322
Species sown: wheat	1.05	0.328
Length of time fertiliser applied	1.06	0.332
Maximum temperature January	1.06	0.338
Landscape morphology: ridge top	1.06	0.34
Moisture index: January	1.04	0.342
Maximum temperature July	1.03	0.398
Number of times cultivated	1.03	0.414
Precipitation November	0.98	0.528
Kangaroo grazing: severe	0.97	0.538
Cultivation frequency: every year	0.98	0.54
Landscape morphology: lower slope	0.99	0.55
Rabbit grazing: light or intermittent	0.89	0.638
Cultivation frequency: sporadic	0.93	0.71
Seed added to fertiliser	0.9	0.748
Maximum temperature September	0.9	0.752
Species sown: oats	0.9	0.782
Cultivation stratification cultivated >20 ya	0.89	0.782
Maximum temperature February	0.91	0.81
Cultivation stratification; 10-20 ya	0.86	0.834
Maximum temperature April	0.89	0.852
Moisture index November	0.87	0.862
Species sown: serradella	0.66	0.894
Species sown: cocksfoot	0.79	0.914
Landscape morphology: valley bottom	0.76	0.966
Fertiliser application: twice yearly	0.66	0.978

Environmental variable	F	p
Weight of fertiliser applied	0.62	1
Moisture index March	0.37	1

APPENDIX 6.2 INTRASET CORRELATIONS OF THE ENVIRONMENTAL VARIABLES FOR THE CORRESPONDENCE ANALYSIS AXES 1 AND 2.

Table 1 Intraset correlations of the environmental variables for the CCA axes 1 and 2.

Environmental variable	Axis1	Axis2
Position in landscape; accumulating water	-0.2229	0.1397
Altitude	0.0051	0.3708
Mean annual radiation	0.2904	-0.0861
Mean annual precipitation	-0.2396	0.0972
Lithology: basalt	-0.0239	0.5606
Type of stock: cattle	-0.0396	0.2984
Aspect: cos	0.0025	0.0282
Cultivation stratification: not cultivated	0.6286	0.0388
Cultivation stratification: cultivated > 20 ya	-0.3675	0.0138
Cultivation stratification: cultivated 10-20 ya	-0.4322	-0.0637
Dry sheep equivalents	-0.4211	-0.1038
Distance to travelling stock route	-0.3644	-0.0251
Geographical position: easting	-0.1033	0.2303
Seed added: white clover	-0.1153	-0.1309
Fertiliser stratification: not fertilised	0.6583	-0.1743
Fertiliser stratification: low	0.0193	0.1254
Fertiliser stratification: high	-0.6469	0.0641
Fertiliser frequency: every second year	-0.1725	-0.0911
Fertiliser frequency: every year	-0.4185	0.0727
Seed added: Hafia white clover	-0.0468	0.0184
Landscape morphology: flat	-0.1557	0.1099
Seed added: rye grass	-0.0816	0.2953
Fertiliser frequency: sporadic	-0.2203	-0.0406
Lithology: granite	-0.0368	-0.4766
Structural formation: grassland	-0.4397	-0.0329
Grazing stratification: not grazed	0.6284	0.03
Grazing stratification: episodic	0.2528	-0.0635
Grazing stratification: planned rest	0.109	-0.119
Grazing stratification: continuous	-0.2527	0.156
Number of months grazed per year	-0.3034	-0.1378
Julian time	0.0124	-0.1078
Kangaroo grazing: nil	0.0881	-0.0698
Kangaroo grazing: light	0.1625	-0.0326
Kangaroo grazing: heavy	0.1003	0.0257
Kangaroo grazing: severe	0.0841	0.0868
Landscape morphology: lower slopes	0.0462	-0.1073
Mean annual maximum temperature	0.075	-0.3613
Maximum temperature December	0.0307	-0.3741
Maximum temperature January	0.0295	-0.3626
Maximum temperature October	0.0478	-0.3778
Maximum temperature March	0.0475	-0.3764
Maximum temperature June	-0.0069	-0.3584
Maximum temperature August	0.0265	-0.3623
Winter average maximum temperature	0.0179	-0.3716

Mean annual minimum temperature	0.1258	-0.0637
Minimum temperature December	0.0385	-0.2964
Minimum temperature January	0.0477	-0.4082
Minimum temperature October	0.077	-0.3318
Minimum temperature April	0.0591	-0.2136
Minimum temperature May	0.1114	-0.1329
Minimum temperature June	0.0239	-0.1628
Minimum temperature July	0.1258	-0.0637
Minimum temperature August	0.0301	-0.0882
Minimum temperature September	0.1016	-0.2
Summer average minimum temperature	0.0473	-0.3609
Winter average minimum temperature	0.075	-0.1739
Summer average moisture index	-0.1143	0.1523
Winter average moisture index	-0.1025	0.1977
Landscape morphology: mid slope	-0.0215	-0.063
Total nitrogen	-0.1511	0.8138
Type of fertiliser applied: no type	0.6264	-0.1642
Geographical position: northing	0.0845	0.1349
Organic carbon	0.0249	0.7418
Structural formation: open woodland	0.3003	0.046
Type of fertiliser applied: other type of fertiliser	-0.098	0.0338
pH $_{(CaCl2)}$	0.2463	0.4802
Phosphorous (Colwell)	-0.1128	0.7482
pH $_{(H2O)}$	0.3202	0.3225
Land tenure: production	-0.7053*	0.0373
Land tenure: public	0.5639	-0.1181
Percentage of site under tree canopy	0.4228	0.315
Rabbit grazing: nil	0.0951	-0.0495
Rabbit grazing: light	-0.1391	0.0925
Rabbit: heavy3	0.0383	0.0581
Rabbit grazing: severe	0.2685	0.0794
Radiation October	0.0032	-0.007
Radiation November	0.1217	-0.1597
Radiation December	0.1677	-0.0773
Radiation March	0.1771	-0.1764
Radiation May	0.2021	0.2055
Radiation June	0.1369	0.0279
Radiation July	0.1345	0.2011
Precipitation January	-0.163	0.1018
Precipitation October	0.0259	-0.0049
Precipitation December	-0.156	0.0678
Precipitation February	-0.2099	0.1103
Precipitation March	-0.1546	0.1669
Precipitation April	-0.2186	0.1777
Precipitation May	-0.1649	-0.1914
Precipitation June	-0.2105	0.2265
Precipitation July	-0.1459	-0.0966
Precipitation September	-0.0078	-0.0374
Summer average precipitation	-0.1843	0.1259
Winter average precipitation	-0.1085	-0.0391
Moisture index October	-0.0047	0.1833

Moisture index December	-0.1291	0.1895
Moisture index February	-0.1809	0.1869
Moisture index May	-0.1766	0.0432
Moisture index June	-0.1664	0.3027
Moisture index July	-0.1258	0.0602
Moisture index August	-0.0738	0.0068
Moisture index September	-0.0171	0.0979
Land tenure: private remnant	0.3474	0.1007
Number of rests from grazing per year	-0.4184	-0.2738
Landscape morphology: ridge top	-0.0256	0.0762
Type of stock: both sheep and cattle	-0.3987	-0.1979
Position in landscape: shedding	0.2229	-0.1397
Type of stock: sheep	-0.2217	0.0448
Aspect: sin	-0.0729	-0.0542
Paddock size	-0.066	-0.1011
Slope	0.1426	0.0923
Species sown: Phalaris	-0.3452	0.0282
Species sown: barley	-0.0578	0.0355