



Collaboration for Environmental Evidence

Systematic Review No. *63*

*HOW DO GRAZING AND FERTILIZATION AFFECT COMPOSITION AND
CONSERVATION OF PLANT DIVERSITY IN AUSTRALIAN TEMPERATE
GRASSY EUCALYPT ECOSYSTEMS?*

Draft Review Report

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Cover Sheet

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Systematic Review Summary

Background

The understorey vegetation of Australia's temperate grassy ecosystems has been substantially modified by a long history of livestock grazing and associated management practices (e.g. fertilization, pasture sowing, cultivation). Although temperate grassy ecosystems occur across a range of climates, soils and landscapes throughout southern Australia, management activities such as livestock grazing and fertilization, are thought to have relatively consistent impacts on plant species composition. If consistent changes in the composition of understorey vegetation can be identified, it will be possible to predict how management modifies conservation values and functional attributes of understorey vegetation.

Objectives

To determine the effect of different levels of livestock grazing and fertilization on plant species composition in Australian temperate grassy ecosystems.

Methods

Search Strategy

Electronic data searching, using *a priori* search terms, of ISI Web of Knowledge, Directory of Open Access Journals, Scirus, ScienceDirect, Agricola, Australian Agriculture and Natural Resources Online (AANRO), Australian Natural Resources Index, Australian Natural Resources Index Archive, Agris, Cambridge Scientific Abstracts (CSA) – Natural Sciences, Australian Digital Theses Program and Google Scholar. We searched the full table of contents of all volumes of Australian Journal of Experimental Agriculture (and Animal Husbandry), Australian Journal of Agricultural Research, The Rangeland Journal, Pacific Conservation Biology and Cunninghamia. Specific author searches were also undertaken. Personal databases belonging to the authors were also examined. Bibliographies of accepted articles were searched.

Selection Criteria

Studies were included if they: i) contained data on the abundance of individual plant species or plant functional groups; ii) described livestock grazing management and soil enrichment history and iii) were conducted on temperate grassy eucalypt vegetation.

Data extraction and synthesis

For each study accepted for the analysis, the study characteristics (subject, intervention, and outcomes measured), study quality, sources of heterogeneity, and results were recorded in a relational database. All observations were categorized into one of six land-use states and or transitions between these states. The land-use states were defined as combinations of livestock grazing and fertilization management variables.

Two distinct types of observation were identified *a priori*. Firstly, summaries of vegetation composition and relative abundance, for a specific land-use state. In these cases the five most abundant species were ranked where sufficient data were available. Up to twenty additional species were recorded as not dominant. The

second type of study provided information regarding the response of individual species to transitions between land-use states. For these studies individual species responses were classified as either positive, neutral or negative.

Main results

Seventy eight studies were included in the review. These provided 227 observations of land-use states with a subset (51) describing transitions between some states. The most frequently recorded land-use states were (i) long ungrazed and never fertilized grassland (reference grassland), (ii) grazed and unfertilized pasture (native pasture), (iii) grazed and fertilized pastures (fertilized pasture) and (iv) currently ungrazed native pasture (exclosed native pasture). Previously fertilized pastures, but where nutrients had run-down (Past fertilized) and exclosed fertilized pastures (Enriched grassland) were rarely recorded in the studies, and few conclusions could be drawn about their likely species composition. The majority of transitions between land-use states (92%) were of reference grassland to native pasture, native pasture to fertilized pasture or native pasture to exclosed native pasture.

Studies varied widely in their objectives, design, methods and subjects. Many described only dominant species or life-history groups, while others provided full floristic lists. Study methodology (experimental manipulation or land tenure comparison) varied between observation type (vegetation composition within states or responses across transitions) and land-use state or transition. Observations relating to transitions were more likely to be experimental while floristic descriptions of land-use states were more commonly from land tenure comparisons.

The frequency of dominant plants varied between land-use states, although a small number of taxa, including the native perennial grass genera *Austrodanthonia* spp., the exotic perennial forb *Hypochaeris radicata*, and exotic annual grasses (*Vulpia* spp., *Bromus* spp.) and legumes (*Trifolium* spp.) were frequently recorded in most land-use states. The most apparent difference in species frequencies appeared to be between reference grassland and all other vegetation states. Reference grasslands were mostly dominated by the tall perennial grasses *Themeda triandra* and *Poa sieberiana*/ *P. labillardieri*. These two species were much less frequent in native pasture and rarely recorded from fertilized pasture. Of the native species, only *Austrodanthonia* spp. was relatively frequent in fertilized pasture. Exclosed native pastures supported a similar range of dominants to that of native pastures, although the annual exotic legumes (*Trifolium* spp.) and the exotic annual grass *Vulpia* spp. were less frequent.

Few species were recorded from more than 50% of observations of any one land-use state. It is therefore difficult to generalise about how vegetation composition varies among land-use states across the full extent of grassy eucalypt woodlands. Examination of covariates (sources of heterogeneity) may improve certainty, although inconsistent availability of key covariates would make such analysis problematic.

Individual species responses were collated across three of the transitions between land-use states. Most species were only recorded once for any one state.

Of the 16 species that were recorded from two or more observations for the reference grassland to native pasture transition, nine were found to respond negatively and three positively in all observations. The remaining four species were inconsistent in their

responses. Two of the species with positive responses were exotic annuals (a grass and a legume) and the other was a native perennial C4 grass. All but one of the species with negative responses were native perennials and included sedges, tall tussock grasses and forbs.

Ten species with two or more observations consistently responded negatively and eleven positively across the fertilization transition between native pasture and fertilized pasture. Twenty nine species had inconsistent responses. Most positive responses were of exotic annual grasses, forbs and legumes. Key exceptions were the perennial grasses *Microlaena stipoides*, *Sporolobus creber*, *Holcus lanatus* and *Cynodon dactylon*.

Thirty one species were recorded from two or more exclosed native pasture transitions. Most species responded inconsistently and only seven consistently responded negatively and three positively. Native species responded both negatively and positively. The exotic annuals *Trifolium* spp. and *Vulpia* spp. always responded negatively.

Native species on average responded negatively to grazing and fertilization while exotics responded positively. Native plant responses to exclosure were however only weakly positive and did not differ from 0. Exotic species on average had a weak negative response to grazing exclosure.

Conclusions

There is good evidence that vegetation composition is modified by differing combinations of livestock grazing and fertilization and that certain combinations are more likely to contribute to the conservation of plant diversity in grassy woodlands. Few studies refuted the general conclusion that the transitions from reference grassland to native pasture and native pasture to fertilized pasture resulted in loss of native plant diversity. The data obtained suggests that grazed, but not fertilized, pastures frequently support native perennial species and so play an important role in the conservation of native plant diversity in grassy woodlands. The dominant native species of native pastures do however differ from reference grasslands and many native plant species decline in abundance as a result of livestock grazing. Exclosure of native pasture does not consistently result in increased abundance or frequency of native plant species. Although exclosure of native pastures is often undertaken for the purposes of plant conservation, the conservation benefits appear variable and further investigation to examine those circumstances where benefits arise is required.

Almost all studies found fertilization to convert native pasture groundlayer vegetation to one dominated by exotic grasses and legumes with at most one or two frequent native grasses. The dominant native grasses within fertilized pastures are also frequent in native pasture. Some of the early studies on changes in botanical composition following fertilization suggest an initial increase in annual legumes followed shortly after by a decline in *Austroanthonia* spp. and an increase in the abundance of exotic annual grasses. Fertilized pastures appear to contribute little to the conservation of native plant diversity in grassy woodland landscapes.

The current understanding of how livestock grazing and fertilization affects groundlayer plant composition is primarily derived from studies that rely on contrasts

among sites with differing land use history. Most of our current knowledge therefore reflects the long-term, historical effects of these management practices. In this context the vegetation changes owing to livestock grazing of reference grassland or fertilization of native pasture are relatively well described.

There were very few studies that explicitly examined exclosure of enriched grasslands or the run-down of available nutrients in previously fertilised pastures. Information about the vegetation of these land-use states and respective transitions is required to assist managers in allocating limited conservation resources. A greater emphasis on experimental studies, supported by appropriately designed natural experiments, is needed to address our understanding of these land use states and respective land-use transitions.

Some previous syntheses of livestock grazing impacts on native vegetation have not separated the disturbance and restoration transitions between land-use states but rather treated them as both representing the effects of grazing. The available evidence suggests that studies examining the imposition of grazing, and possibly fertilizer, would generate different estimates of the effects of grazing (or fertilizer) than studies based on relief from these practices. Distinguishing between them in future studies is important in improving both our scientific knowledge of these ecosystems but also in informing management.

We did not examine covariates relating to grazing pressure, level of enrichment or primary productivity, but in compiling data for this review we did record or estimate these data where available. We note that few studies provided consistent measures of these covariates. For example only 33% of fertilized pasture observations provide data on the quantity of fertilizer applied and only 17% of observations included results of soil nutrient analyses (eg. available phosphorus, available nitrogen or total nitrogen). Development of consistent methodologies and presentation of such data is required in future research.

Many studies, particularly of grazed pastures and exclosed pastures were not included in this review owing to inadequate information on land-use history. Publication of data *must* include site history in relation to grazing and fertilization. Design of research projects should base site selection on the availability of such information.

Main Text

1. Background

The understorey vegetation of Australia's temperate grassy ecosystems has been substantially modified by a long history of livestock grazing and associated management practices (e.g. fertilization, pasture sowing, cultivation) (eg. Yates & Hobbs 1997; Dorrough *et al.* 2004; Kirkpatrick *et al.* 2005; McIntyre & Lavorel 2007). Temperate grassy ecosystems occur across a range of climates, soils and landscapes throughout south-eastern Australia and with some isolated occurrences in south-western Australia (Yates & Hobbs, 1997). Despite the broad distribution of these ecosystems, management activities such as livestock grazing and fertilization, appear to have relatively consistent impacts on plant species composition (Moore 1970; McIntyre & Lavorel 2007). Links between the composition of understorey vegetation, traits of the vegetation and subsequent ecosystem functions have also been identified (McIntyre & Lavorel 2007; McIntyre 2008). These links suggest that there are clear trade-offs between the agricultural production values of the understorey vegetation and environmental attributes such as soil protection and biodiversity preservation. If consistent changes in the composition of understorey vegetation can be identified then predictions can be made for how management will modify conservation values and functional attributes of understorey vegetation.

Most of the remaining temperate grassy vegetation occurs on private lands where livestock production is a major objective for managers. In these areas there is an interest in developing management strategies for meeting both conservation and production objectives (Crosthwaite *et al.* 2008). In some cases government financial incentives and stewardship payments are available to managers to help meet these objectives. On public lands, where conservation outcomes are preeminent, livestock grazing can be a cost-effective management tool in some cases (Lunt *et al.* 2007). On both public and private lands, empirical evidence is required to help guide management regimes for maintaining current plant diversity, and to restore plant diversity. Relief from grazing is often thought to be an important management intervention, but the effects of destocking on vegetation will vary owing to numerous factors including primary productivity, historical grazing impacts and current vegetation composition (Lunt *et al.* 2007). Varying the intensity, frequency and season of livestock grazing and the levels of fertilization are the primary strategies available to private land managers (Dorrough *et al.* 2008). Reducing available nutrients can also be essential for restoring plant diversity (Prober *et al.* 2005), particularly in areas subject to previous fertilization..

There has been a quantitative review of plant responses to livestock grazing within Australia (Vesk & Westoby 2001) and data from Australia's temperate grassy ecosystems was included in a recent meta-analysis of global effects of grazing on vegetation (Diaz *et al.* 2007). A review of the potential effects of grazing exclusion on plant diversity has also recently been published (Lunt *et al.* 2007). Vesk & Westoby (2001) identified inconsistencies in plant responses to grazing but did not examine interactions with soil enrichment. Díaz *et al.* (2007) also excluded potential interactions with soil enrichment through fertilization. Lunt *et al.* (2007) did consider how the effects of grazing exclusion on vegetation may vary according to soil nutrient enrichment but did not undertake a quantitative assessment of available literature.

A systematic review methodology (Pullin & Stewart 2006) will be used to examine the effects of livestock grazing and fertilization on plant composition in Australian temperate grassy ecosystems. Discussion with government investors and land management agencies also indicates a strong desire for quantitative evidence about the effects of various interventions on the direction and rate of restoration in grassy ecosystems. There is considerable interest in how ground layer plant diversity responds to relief from grazing and/or fertilization.

Variation in land-use practices and management histories is expected to impose considerable complexity on the assessment of evidence. For this reason we used the land-use categories described by McIntyre and Lavorel (2007) as an organising framework for the review (Figure 1) but exclude sown pastures (State 4). We also include two additional land-use states to enable us to differentiate states that were the result of reverse transitions, that is to differentiate (a) exclosed native pastures from reference grasslands (transition 2-1) and (b) past fertilized pastures from native pastures (transition 3-2). Using this framework we treated the two key interventions of livestock grazing and fertilization, in their binomial form. Due to resource constraints we were unable to examine evidence surrounding the effects of varying the frequency, intensity or timing of these interventions.

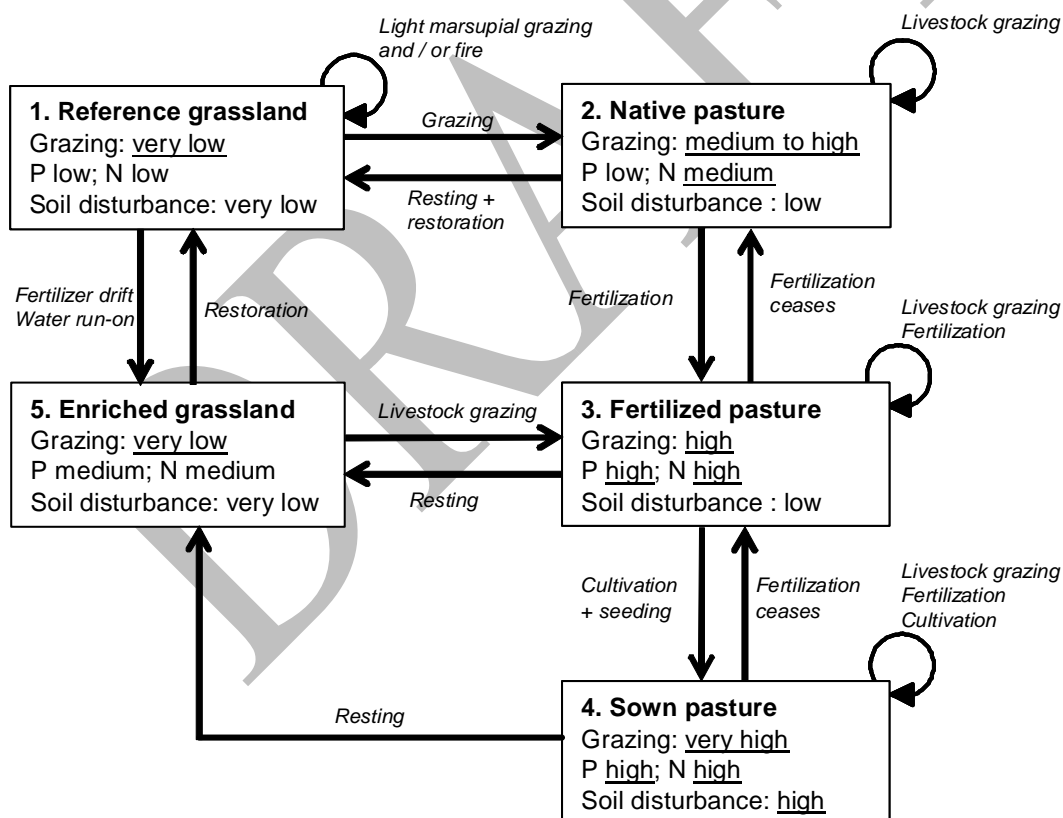


Fig. 1. State and transition model for understorey vegetation in temperate grassy ecosystem showing key management interventions (from McIntyre and Lavorel, 2007).

2. Objectives

2.1 Primary objective

The objective of the review is to determine the effect of grazing and fertilization on plant species composition in Australian temperate grassy ecosystems (Table 1 summarizes key elements). Studies will be placed within the organising framework of a modified form of the state and transition model of McIntyre and Lavorel (2007). To fully capture the effects of management history on vegetation an additional two states will be included. These are (a) *Exclosed Native Pasture*, an alternative state to *Reference Grassland* but one with a prior history of livestock grazing, and (b) *Past Fertilised Pasture*, an alternative state to *Native pasture*.

The primary question asked by this review is “what components of ground layer plant diversity occur in the temperate grassy woodland biome under different levels of grazing and fertilization?”

2.2 Secondary objective

How does ground layer plant diversity respond to relief from grazing and/or fertilization?

Table 1 Question elements and their description

Question Element	Description
Subject	Individual plant species (or groups of species / taxa) and their classifications into plant functional groups in temperate grassy ecosystems of Australia
Intervention	Livestock grazing, nutrient enrichment/fertilization separately and in combination (see Fig 1).
Outcome	Change in, or measure of, the frequency, biomass or cover of individual species
Comparator	No (limited) grazing, no fertilizer (Reference Grassland in Fig. 1)

3. Methods

3.1 Question formulation

The broad topic was formulated by Land & Water Australia (LWA) as one of two trial systematic reviews (see also Review No. 44). The topic, scope and questions were refined and developed through discussions between the authors and LWA prior to development of the review protocol. Feedback on the primary and secondary questions was sought through peer review of the review protocol. Reviewers included leading researchers, catchment managers and federal and state policy officers involved in grassy woodland conservation.

3.2 Search strategy

a. Electronic databases

The following electronic databases were searched:

1. ISI Web of Knowledge
2. Directory of Open Access Journals
3. Scirus
4. ScienceDirect
5. Agricola
6. Australian Agriculture and Natural Resources Online (AANRO)
7. Australian Natural Resources Index

8. Australian Natural Resources Index Archive
9. Agris
10. Cambridge Scientific Abstracts (CSA) – Natural Sciences
11. Australian Digital Theses Program

Searches were also undertaken using the internet-based search engine Google Scholar and the first 100 word document or PDF hits were examined for appropriate data.

General search terms were developed (see below). Preliminary searches indicated that several of these were likely to yield large result sets. In these cases study exclusion terms were used with “NOT” statements (e.g. NOT tropical, NOT arid), where the database allowed for this.

Subject only

1. Grass* & Woodland* & Australia
2. Temperate & Grass* & Australia
4. Botanical composition & Woodland & Australia
5. Temperate & Pasture* & Australia OR NSW, Victoria, Tasmania, South Australia

Intervention and subject

1. Plant* & Graz* & Australia
2. Vegetation & Graz* & Australia
3. Pasture & Graz* & Australia
3. Plant* & Nutrient* & Australia
4. Vegetation & Nutrient* & Australia
5. Plant* & Fertil* & Australia
6. Vegetation & Fertil* & Australia
7. Pasture & Fertil* & Australia
8. botanical composition & Fertil* & Australia
9. botanical composition & Graz* & Australia

b. Specific Authors

Our previous collective examinations of the literature identified a number of potential key authors (listed below). We searched Web of Science for each of these authors using the author field tag (i.e. to exclude multiple citations).

Allcock, K.G
 Badgery, W. B.
 Benson, J. S.
 Biddiscombe, E.F.
 Boulton, A.
 Bridle, K. L.
 Bruce, S.
 Chalmers, A. C.
 Chapman, D. F.
 Chilcott, C.
 Clarke, P. J.
 Cole, B. I.

Davison, E. A.
Doing, H.
Dowling, P. M.
Eldridge, D. J.
Facelli, J. M.
Fensham, R. J.
Foreman, P. W.
Fox, M.
Frood, D.
Garden, D. L.
Gibson, N.
Gilfedder, L.
Groves, R. H.
Hamilton, S.
Hyde, M. K.
Kemp, D. R.
King, W. M.
Kirkpatrick, J. B.
Lange, R. T.
Langford, C. M.
Leigh, J. H.
Li, J.
Lodge, G. M.
Lunt, I. D.
Magcale-Macandog, D. B.
Michalk, D. L.
Moore, R. M.
Morgan, J. W.
Munnich, D. J.
Nott, R.
Odgers, B. M.
Parsons, R. F.
Petit, N.
Prober, S. M.
Rehwinkel, R.
Reid, N.
Reseigh, J.
Robinson, B. B.
Rodgers, R. W.
Roe, R.
Scarlett, N. H.
Semple, W. J.
Simpson, P. C.
Stuwe, J.
Trémont, R. M.
Whalley, R. D. B.
Williams, O. B.

In addition, known active researchers were contacted with a request for refereed manuscripts in press and Masters or PhD theses relevant to the review topic.

c. Existing libraries

We also compiled extensive personal lists of research papers and theses from our own collections. These were scanned for additional references that met the study inclusion criteria.

d. Specific journals

The table of contents of all issues of the following journals were searched for possible relevant studies:

Australian Journal of Experimental Agriculture
Australian Journal of Agricultural Research
The Rangeland Journal
Pacific Conservation Biology
Cunninghamia

Bibliographies of all articles viewed at full text was also searched.

3.3 Study inclusion criteria

- **Relevant subject(s):**

Relevant subjects are any plant species or plant functional groups that occur in the understory / ground layer of temperate grassy ecosystems. We took a relatively broad interpretation to what comprised the geographic boundaries of the temperate woodlands, including studies from the E1 (Mediterranean), E2 (dry Mediterranean), E3 (mostly summer dominant growth), D5 (cool, dry) and F3 (warm, wet summer) agro-climates of Hutchinson *et al.* (2005). This excludes studies from the tropics, arid and alpine zones. We did however exclude all studies from southern Queensland and restricted our search to New South Wales, South Australia, Victoria, Western Australia, Tasmania and the Australian Capital Territory.

In many circumstances there were difficulties in determining whether a study specifically applied in terms of the vegetation envelope. Native and sown pastures can be derived from woodlands, grasslands or forest. Further, tree structural attributes (cover, density and height) are dynamic and spatial and temporal gradients between grassland, woodland and forest boundaries can increase difficulties regarding delineating the appropriate ecosystem. Additionally a number of studies collectively examine grassy ecosystems, and include cleared woodland, grassy woodland, grassland, and grassy forest. The search excluded studies of wet forests, wetlands (and associated vegetation types such as spagnum bogs, sedgeland), heathlands and dry sclerophyll forests with a shrub dominant understory. A further complication is the dynamic nature of shrub cover in many grassy ecosystems. Shrub invasion into temperate grasslands and woodlands is widely described in the literature, typically post relief from grazing and fire (eg. Costello, Lunt & Williams 2000). Studies that provided evidence of recent shrub invasion into grassy dominated temperate ecosystems were exceptions to the rule of current grassy dominance.

- **Types of intervention:**

Primary interventions were nutrient enrichment and commercial levels of livestock grazing. This includes sheep and cattle grazing but excludes goat, horse, native animal or feral animal grazing. Nutrient enrichment can be either through fertilizer

input (most frequently in the form of superphosphate with the introduction of exotic annual legumes for the fixation of nitrogen), enrichment through livestock camping or nutrient run-on. We excluded atmospheric soil nutrient enrichment. Where possible, levels of enrichment and grazing were assigned. Current knowledge of the literature suggests that categorical descriptions based on land-use are most prevalent and these tend to correspond to the land-use states in the model (Fig. 1). Often land-use descriptions include information about both fertilization and grazing (see Table 2)

To address the secondary question that relates to relief from grazing or fertilization, the previous land-use state provides the necessary context for analysis of the intervention (eg. Table 3). We also contrasted the vegetation responses across the restoration transitions with their reverse transitions (Table 3).

Table 2. Relationships between land-use descriptions and interventions

Land-use	Intervention
Native pasture	Grazed, never enriched
Fertilized pasture (incl. livestock camping)	Grazed, enriched
Exclosed native pasture	Past grazing, never enriched
Enriched grassland	Enriched, past grazing
Past fertilised/Degraded pasture	Grazed , past enriched

Table 3. Interventions, and current and prior land-use for analyses for state transitions owing to grazing and/or fertilization

	Prior Land-use	Intervention	Current Land-use
<i>Restoration Transitions</i>			
	Native pasture	Past grazing, never enriched	Exclosed native pasture
	Fertilized pasture	Past grazing, enriched	Enriched grassland
	Fertilized pasture	grazed, past enriched	Past fertilised
<i>Disturbance Transitions</i>			
	Reference Grassland	Grazed, never enriched	Native pasture
	Native Pasture	Grazed, enriched	Fertilised pasture
	Reference Grassland	never grazed, enriched	Enriched grassland

- **Types of comparator:**

Long-term relief from commercial levels of livestock grazing and absence of fertilization. However, studies providing information on the subject for any combination of the interventions were also included even if they did not contain a comparator.

- **Types of outcome:**

Studies included measures of, or changes in, individual species or plant functional group cover, biomass or frequency. Studies that only reported indices of diversity or richness were excluded. The exception was in cases where the raw data used to develop the indices was obtained from the author/s.

Two distinct types of study outcome were identified *a priori*. Firstly, summaries of vegetation composition and relative abundance, for a specific land-use state. In these cases the five most abundant species were ranked where sufficient data were available. Up to twenty additional species were recorded as not dominant. The second type of study provided information regarding the response of individual

species to transitions between land-use states. For these studies species responses were classified as either positive, neutral or negative. Assignment to the positive or negative classes was based on either (a) the study reporting a statistically significant effect, (b) if standard errors and mean abundance available a minimum change in abundance of +/- 20% and non overlapping 2xse or confidence intervals or (c) if no estimate of error available then a minimum change in abundance of +/- 20%.

- **Types of study:**

Studies included raw data or summaries of raw data - qualitative assessments based on supposition or personal/collective experience were excluded.

Our search strategy was limited to peer-reviewed data for quality control purposes and due to time constraints. Thus we included refereed journal articles and externally examined theses (Masters and PhD) and in only a few circumstances honours theses. Unpublished reports and conference proceedings were typically excluded unless already held by the authors and with a study quality of II-2 (see 3.4 below). Raw data sets were accepted only if they formed the basis for peer-reviewed manuscripts.

- **Potential reasons for heterogeneity:**

There are numerous possible reasons for heterogeneity. These include variation in:

1. Type of grazing animal and variation over time.
2. Grazing intensity
3. Grazing season and frequency
4. Spatial variability of nutrient enrichment
5. Type of fertilizer (e.g. single super phosphate, rock phosphate, urea) or dominant nutrient (e.g. nitrogen, phosphorus, potassium)
6. Method of enrichment (e.g. run-on, fertilizer, livestock accumulation)
7. Landscape position
8. Tree cover
9. Pasture sowing history
10. Spatial scale of the study
11. Recent rainfall, soil moisture, drought
12. Time since fertilization
13. Soil disturbance
14. Soil/substrate

These potential reasons for heterogeneity were considered when developing the data extraction forms (see 3.5 below). However, owing to time and resource constraints the sources of heterogeneity were used to provide additional assessment of study validity but were not considered further in analyses presented in this review. They could be used to form the subject of more intensive analyses at a later date. As a result our data presentation will only focus on the specific interventions described by our appended form of the McIntyre and Lavorel (2007) state and transition model framework.

3.4 Study quality assessment

Articles that meet study inclusion criteria were assessed at full text stage according to a hierarchy of evidence developed by Pullin & Knight (2003) (see Table 3). Only studies assessed as having a quality of **I - II-3** were retained in the review.

Table 3. Hierarchy of evidence based on the experimental design of research undertaken. From Pullin and Knight (2003).

Quality of evidence – Conservation	
I	Strong evidence obtained from at least one properly designed; randomised controlled trial of appropriate size.
II-1	Evidence from well designed controlled trials without randomisation.
II-2	Evidence from a comparison of differences between sites with and without (controls) a desired species or community.
II-3	Evidence obtained from multiple time series or from dramatic results in uncontrolled experiments.
III	Opinions of respected authorities based on qualitative field evidence, descriptive studies or reports of expert committees.
IV	Evidence inadequate owing to problems of methodology e.g. sample size, length or comprehensiveness of monitoring, or conflicts of evidence.

A large proportion of studies obtained through this review provided adequate information on the subject and interventions but only for a single study location. Although these studies singly are inadequate as a description of the vegetation of a land-use state, as a whole they represent an important body of evidence. We retained such observations and scored them as II-3.

All studies were assessed by a single reviewer. Studies were examined by a second reviewer if there is ambiguity about the study quality.

3.5 Data extraction

A single reviewer (JD) assessed relevance by excluding articles with obviously irrelevant titles. Subsequently, the abstracts, where available, of the remaining studies were examined with regard to possible relevance. Where there was insufficient information to make a decision regarding study inclusion when viewing titles and abstracts, then relevance to the next stage of the review process was assumed. The second reviewer (SM) independently assessed a random subset of 121 articles at the abstract stage to estimate the repeatability of the inclusion methodology.

For each study accepted into the final review, the study characteristics (subject, intervention, and outcomes measured), study quality, sources of heterogeneity, and results were recorded in a relational database.

3.6 Data synthesis

Our synthesis of data was primarily restricted to vote counting. While there are statistical concerns about this approach to synthesising data from multiple studies (Gurevitch & Hedges 1999), the examination of species composition among land use states was suited to simple summary of frequencies, rather than meta-analysis of effects sizes.

Ten genera were often only identified to genus level (*Austrodanthonia* spp., *Austrostipa* spp, *Trifolium* spp., *Vulpia* spp. *Bromus* spp., *Lolium* spp., *Hypochaeris* spp, *Briza* spp., *Carex* spp., *Glycine* spp.) and two species of the grass genus *Poa* were often not distinguished (*Poa labillardierii*, *Poa sieberiana*). For these groups of taxa we summarised their occurrences as individual species, where these data were available, but also collectively compiled all records of the genus/broader taxonomic group.

3.6.1 Species composition and land-use states

All quantitative data were compiled for each species or plant functional group. Two separate compilations were undertaken. Firstly we estimated the frequency of each species across all studies within each of the six land-use states (interventions). Different lists were compiled based on studies with a quality assessment of II-2 or greater and all included studies. A separate list was also compiled for species ranked dominant (five most abundant species) across the land-use states.

3.6.2 Species responses across land-use transitions

For each species the frequency of positive, negative and neutral responses were tabulated for each transition. Only three transitions were represented by more than two study observations. In addition we undertook a preliminary mixed effects model of species responses specifying each observation as a random effect and estimating individual residual terms for each. Species were also included as a random effect. Species occurring fewer than three times were excluded from models and analyses were restricted to only three transitions (see results for further details). Two separate fixed effects models were examined, firstly the interaction between land use transition and species and secondly the interaction between land-use transition and the origin of the plant species (either native or exotic).

4. Results

4.1 Review statistics

The electronic database search extracted a large number of studies (>25,000) indicating the poor specificity of the search terms, even with the extensive use of “NOT” terms (Table 4). Approximately 1% of these were judged as relevant based on title and abstract assessment. Both reviewers independently examined 121 randomly selected references at the abstract stage and the agreement was substantial (K=0.72). The selection or exclusion of references at this stage of the review process was fairly conservative to ensure relevant references were not excluded. Only 38 references, obtained through electronic sources, remained after full text viewing (Table 4). Of these only eight were not already in the private databases held by the authors. An additional 40 references were obtained from other sources, primarily from databases held by SM & JD and searching the table of contents of specific journals. The majority of studies included multiple observations. That is they included multiple land-use states and/or land-use transitions. From the 78 studies 227 observations were obtained (Appendix 2). A list of all included references is provided in Appendix 1.

Table 4 Search statistics

Electronic Searches	Number of Studies
References identified through electronic searches after removal of duplicates	>25,000
References remaining after relevance assessment at title and abstract stage	329
References remaining after full text viewing	38
Unique references (not already held within authors private databases)	8
Other sources (excluding duplicates)	
Bibliographies, specific journals, authors databases	40
Total references assessed as meeting criteria	78
Total observations meeting criteria	227

4.2 Description of studies

4.2.1 Geographic location and land-use states

The majority of studies were conducted within grassy woodlands of eastern Australia and primarily from the slopes and northern tablelands of NSW (see Figure 2, Table 5). Of these, most observations were recorded in grazed but unfertilized native pastures. Although there are similar landscapes within the slopes and uplands of Victoria relatively few native pasture observations have been made in that state. In contrast, over one third of all observations of enclosed native pasture were from Victoria, significantly more than expected. The majority of pasture studies in Victoria have been undertaken in sown pastures (irrigated and dryland) but these were not included in the current review. Few observations are from the Mediterranean woodlands of Western Australia and grasslands and woodlands of Mediterranean South Australia. South Australian research conducted through the Waite Institute in Adelaide provided the only two studies prior to 1945. These described the transformation of grasslands and grassy woodlands in South Australia owing to grazing and fertilization (Trumble

& Fraser 1932; Davies, Scott & Eraser 1934). These studies laid the key foundations for the “sub and super” (subterranean clover and superphosphate fertilizer) revolution that led to the rapid modification of temperate grassy woodlands of eastern Australia between 1950 and the 1970’s. Given this historical context it is not surprising that observations from South Australia described fertilized pastures more often than would be predicted from the observed total frequencies (Table 5).

There were a number of studies and observations that provided vegetation composition data for grazed pastures and exclosed pastures but did not control for fertilizer history (eg. Lunt & Morgan 1999; Spooner & Briggs 2008) or covered a range of fertilizer treatments but did not separate them within analyses (eg. Williams 1979; Munnich, Simpson & Nicol 1991; Garden *et al.* 2001). In some cases personal knowledge of the study sites or studies enabled SM or JD to classify the enrichment state for a observation (eg. Benson 1994). In a few studies soil fertility (available nitrogen or available phosphorus) was recorded as a surrogate for uncertain enrichment history but the absence of clear land-use history information did not permit their use in the data extraction for this review (eg. Dorrough & Scroggie 2008).

Enriched grasslands and past fertilised pastures are rarely described in the literature. We acknowledge that these vegetation states are often difficult to identify owing to a frequent lack of available information on the use of fertilizer prior to a study. However, it may also be that researchers have not attempted to obtain this information or not recognised the need to restrict their studies to sites where such data are available. As a result some observations may have been miss-classified as exclosed native pasture or fertilized pasture. There was only one study that was specifically designed to examine changes in species composition owing to a decline in soil fertility (Prober *et al.* 2005). Classification of an observation as “Past Fertilised” required the paper to either (i) explicitly describe a history of historical fertilization and the number of years since last fertilization (minimum 10 years) or (iii) use a management intervention to lower soil fertility. Of the eight observations of past fertilization six were single paddock descriptions (see 4.3).

Table 5. Observed frequency of observations for each land-use state grouped according to distribution within the southern and eastern states of Australia. Expected frequencies are given in parentheses. Chi-square = 61.2, $df=25$, $p<0.001$

Land-use State	ACT	NSW	SA	TAS	VIC	WA
Reference Grassland	1 (1.6)	19 (25.0)	1 (3.0)	11 (3.7)	6 (5.5)	2 (1.2)
Native Pasture	4 (3.5)	62 (55.7)	5 (6.7)	5 (8.2)	9 (12.2)	4 (2.7)
Fertilized Pasture	1 (2.0)	34 (31.9)	11 (3.8)	2 (4.7)	3 (7.0)	0 (1.6)
Enriched Grassland	1 (0.2)	1 (2.5)	0 (0.3)	1 (0.4)	1 (0.5)	0 (0.1)
Exclosed native pasture	1 (0.3)	19 (5.0)	0 (0.6)	2 (3.2)	12 (4.8)	1 (1.1)
Past fertilised	1 (0.3)	7 (5.0)	0 (0.6)	0 (0.7)	0 (1.1)	0 (0.2)
Total	9	142	17	21	31	7



Figure 2. Distribution of study observations in Australia.

4.2.2 Transitions among vegetation states

Fifty one of all observations reported data for the response of one or more plant species or species functional groups to a transition between land-use states. All possible transitions were represented in this dataset although only two reported a transition to an enriched and ungrazed grassland either as a result of grazing exclusion within a fertilized pasture or direct enrichment of reference grassland. Exclusion of native pastures and fertilization of native pastures were the most commonly reported transitions, 35% and 37% respectively. Grazing of reference grasslands were also frequently reported (20% of observations). Only two observations, from a single paper, described the vegetation responses to nutrient run-down (Prober *et al.* 2005). There were several recent papers that reported effects of livestock exclusion on vegetation but for many there was insufficient information to determine whether or not the woodland or pasture had previously been enriched (also see 4.2.1).

4.2.3 Study methodology

The majority of studies (76%) used comparisons among areas of differing land management history (land tenure comparisons) to obtain information about vegetation composition or plant responses owing to land-use interventions. Only 55 of all observations were obtained through experimental manipulation of livestock management or fertility and of these 27 described plant responses across a land-use state transition. Only excluded native pastures were more frequently represented in experimental studies (63% of native pasture observations, observed frequency = 22, expected = 8.5). Only 5% of Reference grasslands observations (observed frequency

= 2, expected frequency = 9.7) and 11% of native pasture observations (observed frequency = 10, expected frequency = 21.6) were from experimental studies.

4.3 Study quality assessment

The dominant study quality ranking for evidence was II-2 (60%), reflecting the prior observation in 4.2.3 that most studies were conducted using contrasts among pre-existing land-uses. A large proportion were also classified as II-3 (30%) and of these, most were descriptions of the vegetation composition for a single intervention with no comparator and often only for a single locality.

Few observations were from fully replicated experimental trials with randomisation. Typically experimental studies are small in scale i.e. small plots (<0.1ha) and/or few sites (eg. Williams 1969; Chalmers 1996; Allcock 2002; Prober *et al.* 2005). Few paddock scale experiments replicated across or among landscapes were found in the search process and only one fit the study criteria (Garden *et al.* 2003). In contrast, many of the cross site comparisons were undertaken over a large number sites and covered large geographic areas (Prober & Thiele 2004; Reseigh 2004).

The frequency of Native pasture, Reference grassland and Fertilized pastures within evidence quality rankings I and II-1 was significantly less than expected (Table 5). Most of the studies ranked I or II-1 that included native or fertilized pasture observations were primarily focused on changes in botanical composition within the context of agronomic and animal production research. Many of these studies therefore did not include data for all observed plant species and often concentrated on dominant grasses and legumes. In contrast ecological studies, that more typically included detailed floristics, were primarily based on comparing sites with known histories of management (II-2).

Table 6. Frequency of observations for each land-use state and grouped according to the hierarchy of evidence (see Table 3 and section 3.4). Expected frequencies are given in parentheses (chi-square=64.2, *df*=15, *p*<0.001).

Vegetation State	I	II-1	II-2	II-3	Total
Reference Grassland	0(3.5)	2(3.9)	33(22.2)	5(10.4)	40
Native Pasture	4(7.8)	4(8.6)	58(49.4)	23(23.1)	89
Fertilized Pasture	7(4.5)	4(4.9)	23(28.3)	17(13.3)	51
Enriched Grassland	0(0.4)	1(0.4)	2(2.2)	1(1.0)	4
Exclosed native pasture	9(3.1)	9(3.4)	10(19.4)	7(9.1)	35
Past fertilised	0(0.7)	2(0.8)	0(4.4)	6(2.1)	8
Total	20	22	126	59	227

4.4 Data synthesis

4.4.1 Vegetation composition within land-use states

While some studies provided detailed lists of all species along with measures of abundance many studies only recorded the dominant grasses or major functional groups. The median number of species reported across all observations was 15 but as few as one species was noted. The scale of observation also varied substantially among observations, with quadrat sizes varying more than ten-fold. There was no

consistent measure of species abundance. Owing to these variations among studies we opted to focus our synthesis of vegetation composition on simple tabulation of the most frequent species rather than attempting multivariate meta-analyses of species composition data.

We present three separate approaches to tabulating abundance. Firstly we treat all observations and studies equally and ignore measures of relative abundance or study quality. Secondly we discard studies with an evidence rating of II-3 as these include a large number of studies with data drawn from a single site or single observation. Finally we tabulate the frequencies of just those species that were ranked as dominant (ranked 1-5) in one or more studies.

The frequency of plant species was calculated for each vegetation state based initially on all observations (Table 7). Species occurring in 10% or more observations within a land-use state are listed except in cases where there are 10 or fewer observations for that land-use state. In those later circumstances, species with a frequency of two or more are listed.

The most frequently recorded species varied among land-use states, although the native perennial grass genus *Austrodanthonia* and a small group of exotic grasses and forbs were often amongst the most frequent. Native perennial tussock grasses, *Themeda triandra* and *Poa* spp. (*P. labillardierii* or *P. sieberiana*), were most frequently recorded in reference grasslands, along with the small native sedge, *Schoenus apogon*. *Themeda triandra* and *Poa sieberiana* were also frequent in native pastures, as was *Austrodanthonia* spp. and the exotics *Hypochaeris* spp, *Vulpia* spp and *Trifolium* spp.. While these later four species were also frequent in fertilized pastures, both *T. triandra* and *Poa* spp. were recorded in fewer than 10% of observations for this land-use state. *Austrodanthonia* spp. were one of the few native plant taxa frequently encountered in fertilized pastures. *Austrodanthonia* spp. *Vulpia* spp. and *Trifolium* spp. were also the most frequently encountered species in past fertilized pastures, ie. those in which the fertilization has ceased and nutrient levels have run-down. There were only two observations for enriched pastures (previously fertilized and now ungrazed), and the only similar species between those two observations were the exotic perennial grasses *Dactylis glomeratum* and *Phalaris aquatica* and the exotic annual grasses *Bromus* spp. Exclosed native pastures supported a similar range of dominants to that of native pastures, although the annual exotic legume *Trifolium* spp. and the exotic annual grass *Vulpia* spp. were less frequent.

Interstitial native forbs were are most prevalent in Reference grassland, Native grasslands (eg. *Leptorhynchus squamatus*, *Plantago varia*, *Geranium solanderi*, *Asperula conferta*) and exclosed native grasslands (eg. *Tricoryne elatior* , *Drosera peltata*)

Table 7. Relative frequency of species across land-use states. All species observed in 10% or more observations for at least one land-use state are listed. Frequencies are expressed as proportions of total observations for each land-use state except for enriched grassland and past fertilised. In these later cases observed frequency is presented. The five most frequent species within each state are in bold. Numbers in parentheses are the rank order (up to 10) when observations rated as evidence quality II-3 are excluded.

Species	Enriched Grassland (n=2)	Exclosed Native (n=22)	Fertilized Pasture (n=34)	Native Pasture (n=83)	Past Fertilised (n=8)	Reference Grassland (n=41)
<i>Acaena</i> spp.*	0	0.09	0.00	0.17	0	0.20
<i>Acetosella vulgaris</i> *	1	0.14 (10)	0.15	0.05	3	0.02
<i>Aira</i> spp.*	0	0.32 (5)	0.03	0.23	0	0.22
<i>Anthoxanthum odoratum</i> *	0	0.14	0.00	0.01	0	0.00
<i>Arctotheca calendula</i> *	0	0.14	0.12 (10)	0.11	1	0.02
<i>Aristida ramosa</i>	0	0.05	0.26	0.23	1	0.05
<i>Asperula conferta</i>	0	0.18	0.03	0.17	0	0.22 (10)
<i>Astroloma humifusum</i>	0	0.00	0.00	0.00	0	0.12
<i>Atriplex semibaccata</i>	0	0.14	0.00	0.00	0	0.00
<i>Austrodanthonia bipartita</i>	0	0.00	0.09	0.01	3 (1)	0.00
<i>Austrodanthonia caespitosa</i>	0	0.27	0.09	0.10	0	0.22
<i>Austrodanthonia pilosa</i>	0	0.00	0.00	0.08	2	0.12
<i>Austrodanthonia spp.</i>	0	0.59 (1)	0.50 (2)	0.51 (1)	7 (1)	0.32 (5)
<i>Austrostipa scabra</i>	0	0.18	0.21	0.20	0	0.10
<i>Austrostipa</i> spp.	0	0.45 (4)	0.26	0.42 (3)	0	0.34 (6)
<i>Austrostipa stuposa</i>	0	0.00	0.00	0.00	0	0.12
<i>Avena</i> spp.*	1	0.09	0.09	0.04	0	0.12
<i>Bothriochloa macra</i>	0	0.00	0.29 (9)	0.22	2	0.00
<i>Briza maxima</i> *	0	0.18	0.00	0.04	0	0.12
<i>Briza minor</i> *	0	0.18	0.09	0.17	1	0.17
<i>Briza</i> spp.*	1	0.23	0.09	0.19	1	0.20
<i>Bromus</i> spp.*	2 (1)	0.23	0.38 (4)	0.18 (10)	3	0.15
<i>Bulbine bulbosa</i>	0	0.14	0.00	0.08	0	0.20
<i>Carex breviculmis</i>	0	0.05	0.03	0.07	0	0.15
<i>Carex inversa</i>	0	0.18	0.09	0.11	0	0.00
<i>Carex</i> spp.	1	0.23	0.12	0.18	1	0.17
<i>Carthamus lanatus</i> *	0	0.00	0.12	0.07	0	0.00
<i>Cheilanthes sieberi</i>	0	0.05	0.06	0.07	0	0.12
<i>Chloris truncata</i>	0	0.23	0.15	0.24	1	0.00
<i>Chrysocephalum apiculatum</i>	0	0.18	0.00	0.18	0	0.17
<i>Cirsium vulgare</i> *	0	0.09	0.15	0.04	1	0.00
<i>Convolvulus erubescens</i>	0	0.05	0.00	0.08	0	0.15
<i>Cyperus tenellus</i>	0	0.18	0.03	0.02	0	0.05
<i>Dactylis glomerata</i> *	2 (1)	0.00	0.03	0.00	0	0.05
<i>Desmodium varians</i>	0	0.05	0.00	0.12	0	0.02

Species	Enriched Grassland (n=2)	Exclosed Native (n=22)	Fertilized Pasture (n=34)	Native Pasture (n=83)	Past Fertilised (n=8)	Reference Grassland (n=41)
<i>Dianella revoluta</i>	0	0.05	0.00	0.01	0	0.15
<i>Dichanthium sericeum</i>	0	0.00	0.12	0.06	0	0.00
<i>Dichelachne micrantha</i>	0	0.00	0.03	0.10	0	0.12
<i>Dichondra repens</i>	0	0.00	0.03	0.06	0	0.12
<i>Dichondra spp.</i>	0	0.00	0.03	0.11	0	0.17
<i>Drosera peltata</i>	0	0.14	0.00	0.04	0	0.10
<i>Elymus scaber</i>	0	0.00	0.09	0.19	2	0.27 (7)
<i>Enteropogon acicularis</i>	0	0.14	0.00	0.04	0	0.00
<i>Eragrostis brownii</i>	0	0.00	0.03	0.04	3 (1)	0.00
<i>Eragrostis leptostachya</i>	0	0.00	0.18	0.05	0	0.02
<i>Geranium solanderi</i>	1	0.00	0.03	0.13	0	0.24 (8)
<i>Glycine spp.</i>	0	0.00	0.06	0.18	0	0.12
<i>Gonocarpus tetragynus</i>	0	0.05	0.00	0.02	0	0.17
<i>Holcus lanatus*</i>	1	0.18 (6)	0.06	0.00	2	0.07
<i>Hordeum leporinum*</i>	0	0.05	0.15	0.13	1	0.00
<i>Hordeum marinum*</i>	0	0.00	0.12	0.02	0	0.00
<i>Hydrocotyle laxiflora</i>	0	0.09	0.00	0.13	0	0.22
<i>Hypericum gramineum</i>	0	0.00	0.03	0.18	0	0.15
<i>Hypochaeris glabra*</i>	0	0.09	0.06	0.11	0	0.02
<i>Hypochaeris radicata*</i>	0	0.41 (3)	0.24 (8)	0.29 (8)	3	0.17
<i>Hypochaeris spp.*</i>	0	0.55 (3)	0.32 (8)	0.47 (7)	3	0.37 (4)
<i>Leontodon taraxacoides*</i>	0	0.05	0.15	0.11	0	0.02
<i>Leptorhynchos squamatus</i>	0	0.14	0.03	0.13	0	0.20
<i>Lolium rigidum*</i>	0	0.05	0.15	0.05	1	0.00
<i>Lolium spp.*</i>	1	0.09	0.24	0.12	2	0.10
<i>Lomandra filiformis</i>	0	0.14	0.00	0.06	0	0.10
<i>Maireana excavata</i>	0	0.14	0.00	0.05	0	0.00
<i>Medicago spp.*</i>	0	0.00	0.03	0.11	1	0.00
<i>Microlaena stipoides</i>	1	0.14	0.21	0.22 (10)	4	0.37 (4)
<i>Oxalis corniculata*</i>	0	0.09	0.06	0.10	2	0.22
<i>Panicum effusum</i>	0	0.00	0.09	0.13	4 (1)	0.00
<i>Panicum spp.</i>	0	0.00	0.18	0.13	4	0.02
<i>Pentapogon quadrifidus</i>	0	0.05	0.00	0.01	0	0.15
<i>Phalaris aquatica*</i>	2 (1)	0.00	0.03	0.00	0	0.05
<i>Plantago gaudichaudii</i>	0	0.05	0.00	0.04	0	0.12
<i>Plantago lanceolata*</i>	0	0.09	0.06	0.13	0	0.17
<i>Plantago varia</i>	0	0.05	0.00	0.11	0	0.17
<i>Poa rodwayi</i>	0	0.05	0.00	0.02	0	0.20

Species	Enriched Grassland (n=2)	Exclosed Native (n=22)	Fertilized Pasture (n=34)	Native Pasture (n=83)	Past Fertilised (n=8)	Reference Grassland (n=41)
<i>Poa sieberiana/</i>						
<i>labillardierii</i>	1	0.14	0.09	0.34 (6)	1	0.59 (2)
<i>Poranthera</i>						
<i>microphylla</i>	0	0.05	0.00	0.04	0	0.15
<i>Romulea</i>						
<i>minutiflora*</i>	0	0.14	0.00	0.02	0	0.02
<i>Romulea rosea*</i>	1	0.14	0.09	0.11	1	0.10
<i>Rumex brownii</i>	1	0.05	0.12	0.08	0	0.02
<i>Schoenus apogon</i>	0	0.23 (7)	0.06	0.12	0	0.41 (3)
<i>Sclerolaena</i>						
<i>muricata</i>	0	0.14	0.00	0.00	0	0.00
<i>Sida spp.</i>	0	0.18	0.06	0.10	0	0.02
<i>Sporobolus creber</i>	0	0.00	0.15	0.04	0	0.00
<i>Sporobolus</i>						
<i>elongatus</i>	0	0.00	0.15	0.06	3 (1)	0.00
<i>Themeda triandra</i>	1	0.45 (2)	0.03	0.43 (5)	3	0.71 (1)
<i>Tricoryne elatior</i>	0	0.27 (8)	0.03	0.08	0	0.05
<i>Trifolium arvense*</i>	0	0.05	0.12	0.13	1	0.12
<i>Trifolium</i>						
<i>campestre*</i>	0	0.00	0.09	0.13	1	0.12
<i>Trifolium dubium*</i>	0	0.09	0.18	0.08	0	0.02
<i>Trifolium</i>						
<i>glomeratum*</i>	0	0.00	0.12	0.13	1	0.02
<i>Trifolium repens*</i>	0	0.05	0.26 (5)	0.06	1	0.00
<i>Trifolium spp.*</i>	1	0.27	0.79 (1)	0.43 (4)	5	0.20
<i>Trifolium</i>						
<i>subterraneum*</i>	0	0.14	0.26 (7)	0.16	4	0.05
<i>Triptilodiscus</i>						
<i>pygmaeus</i>	0	0.05	0.00	0.14	0	0.02
<i>Vulpia bromoides*</i>	0	0.09	0.03	0.22 (9)	1	0.12
<i>Vulpia myuros*</i>	0	0.09	0.18 (6)	0.07	0	0.02
<i>Vulpia spp.*</i>	0	0.27	0.41 (3)	0.48 (2)	4	0.24 (9)

Similar species predominated within each of the land-use states after exclusion of observations ranked II-3 (Table 7) and when only species ranked as a dominant (ranks 1-5) within an observation were included (Appendix 3.). Not surprisingly, interstitial native forb species were less apparent in the later dataset.

4.4.1 Plant responses across land-use transitions

The frequency of positive, negative and neutral responses to three land-use transitions were tallied for individual plant species and for broad functional groups where these were available. We excluded observations relating to transitions between reference grassland and enriched grassland, fertilized pasture and enriched grassland and fertilized pasture and past fertilized pasture owing to extremely low numbers of observations.

There were quite a number of studies that examined plant responses to grazing and or fertilization *within* one of the land-use states. For example studies that examined variation in grazing intensity or frequency within native pastures. Studies that did not examine responses across a transition between vegetation states were not included in this review.

We tabulate the results from this review along with data from two other datasets, that provide responses of understorey plants to fertilization and or grazing (Clarke 2003; Dorrough & Scroggie 2008). These later two datasets were not included in the review. The responses derived from Clarke (2003) were to “pastoralism” a term that collectively described the independent and/or combined effects of livestock grazing, fertilization and sowing of legumes.

Mixed effects models were also constructed to examine how species responses varied owing to land use transitions. The first model fitted species as both a fixed and random effect. In the second model species were included as a random effect and the origin of each species (either native or exotic) as a fixed effect. The interaction of species origin and transition on species responses was explored. In all cases study observation was treated as the experimental unit and individual residual terms estimated for each during model fitting.

Grazing: Reference grassland to Native pasture transition

We extracted the responses of 106 plant species across the transition between reference grassland and native pasture. Ninety of these plant species were recorded only once. Of the 16 species that were recorded from two or more observations, nine were found to respond negatively and three positively in all observations (Table 8). The remaining four species were inconsistent in their responses. These responses are largely consistent with the modelled responses of Dorrough & Scroggie (2008) ($F_{2,12}=8.3$, $p<0.001$; Negative = $-0.62\pm 0.14se$, Uncertain = 0.55 ± 0.23 , Positive = 0.67 ± 0.29) but less so with that of Clarke (2003) (Table 8). Two of the species with positive responses were exotic annuals (a grass and a legume) and the other was a native perennial C4 grass. All but one of the species with negative responses were native perennials and included sedges, tall tussock grasses and forbs.

Fertilization: Native pasture to Fertilized pasture transition

One hundred and thirty two species were recorded in observations of fertilization of native pastures, of which 79 occurred only once. Ten species with two or more observations consistently responded negatively and eleven positively across the fertilization transition (Table 9). Twenty nine species had inconsistent responses. These responses were correlated with the phosphorus responses of Dorrough and Scroggie (2008) ($F_{2,35}=7.6$; $p<0.01$; Negative = $-1.32\pm 0.18se$, Uncertain = -0.89 ± 0.11 , Positive = -0.38 ± 0.17). Exotic annual grasses, forbs and legumes predominated among those with positive responses. Key exceptions were the native perennial grasses *Microlaena stipoides* and *Sporolobus creber* and exotic perennial grasses *Holcus lanatus*, *Lolium* spp. (although this group includes both annual and perennial species) and *Cynodon dactylon* (this later species does include some native forms).

Table 8. Frequency of negative, neutral and positive responses to grazing across the reference grassland to native pasture transition and mean response predicted from a mixed effects model. Species with a majority of negative or positive responses and no conflicting response are shaded. Responses to pastoralism (Clarke 2003) and responses to grazing from the models of Dorrough and Scroggie (2008) are also presented. Only species with two or more observations are shown. T= tolerant of pastoralism; N=intolerant of intense pastoralism; P=tolerant of intense pastoralism.

Species	Negative	Neutral	Positive	Mean (se)	Clarke	Dorrough & Scroggie
<i>Acaena ovina</i>	2	0	0	-1.0 (0.002)	P	-0.63
<i>Asperula conferta</i>	4	0	0	-1.0 (0.001)	T	-0.80
<i>Austrostipa aristiglumis</i>	2	0	0	-		-0.33
<i>Bothriochloa macra</i>	0	0	3	1.0 (0.001)	P	
<i>Bromus hordeaceus</i>	0	0	2	1.0 (0.002)		0.78
<i>Carex breviculmis</i>	2	0	0	-1.0 (0.71)		-0.62
<i>Dianella longifolia</i>	2	0	0	-		-0.64
<i>Gonocarpus tetragynus</i>	1	0	1	-1.0 (0.002)	N	-0.87
<i>Hypochaeris radicata</i>	2	0	0	-1.0 (0.002)	T	-0.17
<i>Poa sieb/lab</i>	3	0	0	-1.0 (0.002)	T	-1.10
<i>Sporobolus creber</i>	0	1	2	1.0 (0.001)	P	
<i>Themeda triandra</i>	6	0	0	-1.0 (0.001)	T	-0.72
<i>Trifolium striatum</i>	0	0	2	1.0 (0.002)		0.56
<i>Veronica calycina</i>	1	0	1	-	N	-1.06
<i>Vittadinia muelleri</i>	2	0	0	-		
<i>Vulpia spp.</i>	1	0	2	1.0 (0.002)	T	0.29
TOTAL*	59	4	69	0.08 (0.10)		

*Total frequencies are based on all species observations, not just those in the table.

Table 9. Frequency of responses to fertilization across the native pasture to fertilized pasture transition and mean response predicted from a mixed effects model. Species with a majority of negative or positive responses and no conflicting response are shaded. Responses to pastoralism (Clarke 2003) and responses to phosphorus from the models of Dorrough and Scroggie (2008) are also presented. Only species with two or more observations are shown. T= tolerant of pastoralism; N=intolerant of intense pastoralism; P=tolerant of intense pastoralism.

Species	Negative	Neutral	Positive	Mean (se)	Clarke	Dorrough & Scroggie
<i>Aira cupaniana</i>	1	0	1	-0.90 (0.37)	T	-1.40
<i>Aristida ramosa</i>	3	2	0	-0.75 (0.25)	T	
<i>Austrodanthonia bipartita</i>	0	2	1	0.24 (0.38)	P	
<i>Austrodanthonia spp.</i>	5	0	0	-1.0 (0.001)	P,T,N	-0.95
<i>Austrostipa scabra</i>	0	1	1	0.31 (0.44)	P	-0.68
<i>Austrostipa spp.</i>	2	0	0	-1.0 (0.001)		-1.20
<i>Bothriochloa macra</i>	1	3	1	0.04 (0.25)	P	
<i>Briza minor</i>	3	1	1	-1.0 (0.001)		-1.58
<i>Bromus racemosus</i>	0	0	3	1.0 (0.33)		
<i>Bromus spp.</i>	0	0	4	1.0 (0.001)	P	-0.16
<i>Carthamus lanatus</i>	0	0	2	1.0 (0.4)		-0.52
<i>Cheilanthes sieberi</i>	2	0	0	-		-1.94
<i>Chloris truncata</i>	1	3	0	-0.11 (0.27)	P	-1.44
<i>Cirsium vulgare</i>	0	0	3	1.0 (0.002)	P	-0.55

Species	Negative	Neutral	Positive	Mean (se)	Clarke	Dorrrough & Scroggie
<i>Convolvulus erubescens</i>	2	0	0	-1.0 (0.001)		-1.31
<i>Cymbopogon refractus</i>	2	0	0	-	T	
<i>Cynodon dactylon</i>	0	0	2	-	P	-0.04
<i>Dichanthium sericeum</i>	1	1	0	-	P	
<i>Dichelachne micrantha</i>	3	0	0	-1.0 (0.29)		-1.21
<i>Dichondra repens</i>	2	1	0	-1.0 (0.001)	T	-1.50
<i>Echium plantagineum</i>	0	1	1	-		0.24
<i>Elymus scaber</i>	1	1	1	0.05 (0.31)	P	-1.36
<i>Eragrostis brownii</i>	0	2	1	0.08 (0.27)		-1.81
<i>Eragrostis leptostachya</i>	0	2	2	0.42 (0.27)	P	
<i>Eragrostis trachycarpa</i>	0	2	0	-		
<i>Erodium botrys</i>	1	0	1	-		-0.45
<i>Eulalia aurea</i>	1	0	1	-		
<i>Geranium spp.</i>	2	0	0	-1.0 (0.001)	T	-1.00
<i>Glycine tabacina</i>	1	1	0	-0.30 (0.42)		-0.81
<i>Holcus lanatus</i>	0	0	2	-	T	-0.54
<i>Hypochaeris radicata</i>	1	0	1	0.81 (0.47)	T	-0.97
<i>Leptorhynchus squamatus</i>	2	0	0	-1.0 (0.001)		-1.26
<i>Lolium spp.</i>	0	0	2	1.0 (0.001)		0.04
<i>Microlaena stipoides</i>	0	0	3	1.0 (0.27)	T	-1.13
<i>Panicum effusum</i>	3	3	0	-0.59 (0.22)	P	
<i>Plantago lanceolata</i>	1	0	2	0.69 (0.38)	T	-0.68
<i>Poa sieberiana</i>	1	1	0	0.0 (0.002)	T	-1.17
<i>Romulea rosea</i>	1	1	0	0.0 (0.002)		-0.72
<i>Rumex brownii</i>	0	1	1	-	P	0.02
<i>Sarga leiocladum</i>	2	0	0	-1.0 (0.34)	T	
<i>Setaria gracilis</i>	1	1	0	-0.68 (0.44)		
<i>Solenogyne dominii</i>	2	0	0	-1.0 (0.002)	N	-1.72
<i>Sporobolus creber</i>	0	0	2	1.0 (0.47)	P	
<i>Sporobolus elongatus</i>	1	2	0	-0.56 (0.29)		
<i>Themeda triandra</i>	2	1	0	-1.0 (0.002)	T	-1.61
<i>Trifolium repens</i>	0	2	2	0.69 (0.31)	P	-0.02
<i>Trifolium spp.</i>	0	1	4	1.0 (0.001)	P, N	-0.28
<i>Trifolium subterraneum</i>	0	0	4	1.0 (0.35)		-0.24
<i>Vulpia myuros</i>	0	1	1	0.20 (0.34)	T	-0.56
<i>Vulpia spp.</i>	0	2	2	1.0 (0.002)	T	-0.56
TOTAL*	84	36	82	0.09 (0.1)		

*Total frequencies are based on all species observations, not just those in the table.

Table 10. Frequency of negative, neutral and positive responses to grazing enclosure across the native pasture to enclosed native pasture transition and mean response predicted from a mixed effects model. Species with a majority of negative or positive responses and no conflicting response are shaded. Only species with two or more observations are shown.

Species	Negative	Neutral	Positive	Mean (se)
<i>Anagallis arvensis</i>	0	1	1	1.0 (0.003)
<i>Asperula conferta</i>	1	1	1	-1.0 (0.003)
<i>Austrodanthonia caespitosa</i>	1	2	0	0.0 (0.001)
<i>Calocephalus citreus</i>	0	0	2	-
<i>Chloris truncata</i>	2	0	0	-1.0 (0.98)
<i>Chrysocephalum apiculatum</i>	1	0	1	-1.0 (0.68)
<i>Convolvulus erubescens</i>	0	1	1	0.43 (0.98)
<i>Daucus glochidiatus</i>	2	0	0	-1.0 (1.09)
<i>Elymus scaber</i>	2	0	1	-1.0 (0.002)
<i>Enteropogon acicularis</i>	0	0	2	-
<i>Eryngium rostratum</i>	0	2	1	0.0 (0.002)
<i>Geranium spp.</i>	1	0	2	-1.0 (0.003)
<i>Hypochaeris glabra</i>	0	1	1	-
<i>Hypochaeris radicata</i>	2	1	1	-1.0 (0.002)
<i>Leontodon taraxacoides</i>	1	0	1	-
<i>Leptorhynchus squamatus</i>	2	0	0	-1.0 (0.002)
<i>Lolium rigidum</i>	1	0	1	-0.13 (0.98)
<i>Oxalis perennans</i>	1	1	0	-
<i>Plantago lanceolata</i>	1	0	2	-1.0 (0.003)
<i>Plantago varia</i>	1	0	1	0.59 (0.68)
<i>Rumex dumosus</i>	0	0	3	1.0 (0.002)
<i>Sida corrugata</i>	2	0	0	-
<i>Solenogyne dominii</i>	1	1	0	0.0 (0.002)
<i>Sonchus oleraceus</i>	0	0	2	-
<i>Spergularia rubra</i>	1	0	1	-
<i>Themeda triandra</i>	0	2	2	1.0 (0.001)
<i>Trifolium dubium</i>	1	1	0	-
<i>Trifolium spp.</i>	2	0	0	-1.0 (0.003)
<i>Trifolium subterraneum</i>	2	1	1	-0.28 (0.52)
<i>Vulpia bromoides</i>	2	0	0	-1.0 (0.002)
<i>Vulpia spp.</i>	2	0	0	-1.0 (0.8)
TOTAL*	109	53	107	-0.16 (0.1)

*Total frequencies are based on all species observations, not just those in the table.

Grazing: Native pasture to enclosed pasture transition

Two hundred species were recorded for the grazing enclosure transition of which 169 were only recorded once. Most species responded inconsistently and of those species with two or more responses, seven consistently responded negatively and three positively (Table 10). Native species responded both negatively and positively. The exotic annuals *Trifolium spp.* and *Vulpia spp.* always responded negatively.

A number of grazing enclosure studies only provided responses for broad life-history vegetation groups or provided these in addition to individual species responses. Overall, the exotic life-history groups tended to respond either positively or show no response (Table 11). The reverse pattern was true for native life-history groups (chi-square=10.8, $df=2$, $p<0.01$).

Table 11. Frequency of negative, neutral and positive responses to grazing enclosure by native and exotic life history groups.

Vegetation Group	Negative	Neutral	Positive
Exotic	2	1	0
Exotic annual	0	1	0
Exotic annual forb/herb	1	3	0
Exotic annual grass	2	2	0
Exotic perennial forb/herb	0	1	2
Native	0	0	1
Native annual forb/herb	0	1	0
Native perennial	0	0	1
Native perennial forb/herb	0	3	1
Native perennial geophyte	0	0	1
Native perennial grass	0	3	2
Native perennial shrub	0	0	2
All Native groups	0	7	8
All Exotic groups	5	8	2

Do the responses of native and exotic taxa differ?

The mixed model analyses suggest that native and exotic taxa on average differ in how they respond across land-use transitions (Table 12). Native taxa tend to respond negatively to both fertilization (of native pasture) and grazing (of reference grassland), while exotics show the opposite response. Interestingly native taxa have on average only weak, non-significant, positive responses to grazing enclosure, although exotics tend to respond negatively, but not strongly. There are a number of possible explanations for the weaker responses to enclosure. Enclosure studies are mostly experimental, of short duration and use small plots while in contrast studies examining grazing of reference grasslands used land tenure comparisons, had large plots sizes, were well replicated and the responses observed were averaged across long timescales. Enclosure studies are therefore more likely to only have the power to estimate effects for abundant species. Results from grazing transitions could be due to rare extreme historical events that may not be captured in the short timeframes of the experimental studies. In addition species susceptible to grazing impacts are likely to be rare or absent in native pastures prior to enclosure. Species tolerant of grazing or dependent on frequent, heavy livestock grazing dominate native pastures, and therefore strong responses to enclosure would not be expected.

Table 12. Predicted mean responses of native and exotic plant species to transitions between land-uses states.

Transition	Native	Exotic
Fertilization (native pasture to fertilized)	-0.50 (0.10)	0.67 (0.14)
Enclosure (native pasture to enclosed native)	0.12 (0.16)	-0.44 (0.20)
Grazing (reference to native pasture)	-0.50 (0.10)	0.67 (0.14)

4.5 Outcome of the review

The majority of empirical studies have focused on four of the six land-use states that we identified *a priori* as being of interest. These were: Reference grassland, native pasture, fertilised pasture and enclosed native pasture. Of the 78 studies used to compile data for this review most were undertaken using comparisons among sites

based on long-term land tenures and management regimes. To enable an examination of general patterns we jointly presented data from both experimental and cross site comparison studies. We did not examine variation owing to covariates. Studies varied considerably in the scale of observations and the methods of recording plant species abundance. Despite this, some general patterns emerged.

A small number of similar native and exotic plant species were frequently recorded in most land-use states, although their relative frequencies did vary. Although a quantitative analysis was not undertaken, reference grasslands and fertilized pastures appear to be most dissimilar with native pastures and exclosed native pastures sharing similar dominant species with both of these groups. The data obtained does suggest that grazed, but not fertilized pastures, frequently support native perennial species and so are likely to play an important role in the conservation of native plant diversity in grassy woodlands. The dominant native species do however differ from reference grasslands and many native plant species decline in abundance as a result of livestock grazing.

Following exclosure of native pasture some native species do increase in abundance, but responses are mostly uncertain and this land-use state does not appear to revert to a vegetation composition identical to that of reference grassland. Rather it seems to share more similarities with native pastures. Some native species decline in abundance following exclosure, while exotic plant abundance does not always decline. Although the responses to exclosure are variable, some conservation benefits are likely to occur, in particular a lower frequency of exotic annual grasses and legumes.

Fertilization appears to convert native pasture groundlayer vegetation to one dominated by exotic annual grasses and legumes with at most one or two frequent native grasses. The dominant native grasses of fertilized pastures are also frequent in native pastures. Some of the early studies on changes in botanical composition following fertilization suggest an initial increase in annual legumes followed shortly after by a decline in *Austrodanthonia* spp. and an increase in the abundance of exotic annual grasses (eg. Tiver & Crocker 1951). The data obtained through this review would therefore indicate that fertilized pastures contribute little to the conservation of native plant diversity in grassy woodland landscapes.

We compiled two different datasets while undertaking this review. The first provides an indication of vegetation composition in each of the land-use states, while the second is of individual plant species responses to transition between states. An important outcome of this review is that while both datasets generally provide a similar picture of vegetation change, presence in a particular vegetation state may not be indicative of the likely response of a species to that management regime. For example, although this review found that *Austrodanthonia* pp was the most frequently recorded native plant species in fertilized pastures, it consistently responded negatively to fertilization. An opposing pattern was observed for *Microlaena stipoides*, another native perennial grass. This species was most frequently observed in reference grasslands and equally frequent in both native and fertilized pastures. Despite this, it was found to consistently respond positively to fertilization.

When comparing studies across such a broad geographic area, changes in dominant species would be expected. An earlier synthesis of how grazing and fertilization modifies native groundlayer vegetation in grassy woodlands highlighted specific floristic differences but also noted strong similarities among regions (Moore & Biddiscombe 1964; Moore 1970). In this review, the floristic dominants, based on frequency of observations, rarely were observed in more than 50% of studies for a particular land-use state, suggesting considerable uncertainty in applying these results generally. Investigation of the data presented here to examine how species frequencies within land-use states varies across the range of grassy woodlands is an important next step and could provide more clarity relevant to regional conservation managers and researchers.

In terms of assessing the overall contribution of grazed lands to the conservation of grassy woodland vegetation, the data provided here only provides information on widespread and frequent species. Infrequent and locally abundant species are less well represented by this review. Often these may be species of greatest conservation concern. While individual studies provide specific information on may such species (eg. Gilfedder & Kirkpatrick 1994) broad conclusions cannot be drawn here.

5. Discussion

Livestock grazing and fertilization are two key management interventions that can be used to modify the composition of ground layer vegetation in grassy ecosystems. Different combinations of these management interventions and variation in their history and intensity are expected to greatly modify the vegetation composition and conservation value of grassy woodlands (Whalley, Robinson & Taylor 1978; McIntyre & Hobbs 1999; Lunt *et al.* 2007). The data compiled here does provide good evidence that vegetation composition is modified by differing combinations of these interventions and that certain combinations are more likely to contribute to the conservation of plant diversity in grassy woodlands.

Data for this review was compiled from a broad range of studies spanning almost eight decades of research. Across all these studies few provided evidence that refuted the general conclusion that the transitions from reference grassland to native pasture and native pasture to fertilized pasture resulted in declines in native plant diversity. The only contradictory study (McGufficke 2003), found no negative effects of fertilizer on the abundance and diversity of native plants. This study was undertaken using an unreplicated cross-fence comparison in a single paddock over a relatively short time-scale. The study was also marginal in terms of its geographic and climatic location, the most north-western study included in this data. Although it does suggest that the general conclusions may not apply in every circumstance, in terms of contradictory evidence it is extremely weak.

There are two distinct bodies of research that have examined how these management activities impact grassy vegetation – those that have had as their core focus the production values of the vegetation and those more focused on ecological or conservation issues. This review has drawn together data from both groups of studies in an attempt to determine the effect of different levels of grazing and fertilization on plant species composition in Australian temperate grassy ecosystems. These studies are likely to emphasise different aspects of the vegetation and changes in vegetation as a result of management interventions. For example ecological work can often be

concerned with identifying all native species present and focus specifically on infrequent species and those of conservation concern. In contrast, livestock production research has been most concerned with dominant perennial grasses, “weeds” and productive legumes. The absence of species in the vegetation lists for a particular study therefore in no way indicates actual absence.

Of the 78 studies and 227 observations obtained in this review, a large proportion of observations were from comparisons among sites with differing management history. Many of these studies were designed as a “natural experiments” (Diamond 1986) and were well replicated, often over fairly broad landscape scales. Despite this, these studies will always suffer from an inability to conclusively identify causal factors in determining the current vegetation patterns. The first approach we took to examining the contribution of grazing and fertilization to native plant diversity made no assumption about the causal processes and simply examined the frequency of species observations within and among each land-use state. The second approach, assessing plant responses across transitions between land-use states, did however assume causality. While the majority of transition studies were experimental we did not weight these in our analyses

This review has shown that land tenure comparisons, largely providing information on disturbance transitions do tend to predominate in Australian literature, a conclusion also made by Lunt *et al.* (2007). We explicitly differentiated between disturbance transitions and restoration transitions. The later tend to be experimental (eg. 83% of enclosure transitions were from experimental studies) and mostly provided evidence for the effects of current grazing (exclusion) on vegetation. In contrast, all reference grassland to native pasture transitions and 58% of fertilization observations were derived from land tenure comparisons. Land tenure comparisons represent the effects of a regime over the long term and so can capture rare combinations of events that influence species persistence. As Lunt *et al.* (2007) point out such historical drivers may not be relevant to estimating the current effects of management on the vegetation.

Most previous quantitative reviews do not separate the alternative transitions. Our results suggest that the grazing disturbance transition tends to have relatively consistent effects on frequent plant species. The majority of species either consistently respond negatively or positively. In contrast, plant responses to the opposing transition are more commonly uncertain – that is both negative and positive responses are observed across the studies. This later observation fits with the results of Vesk and Westoby 2001.

This unfortunately does raise an interesting dilemma – are the differing results observed across the opposing transitions owing to purely ecological processes eg. loss of grazing sensitive species from reference grasslands and the varying contribution of species composition, historical grazing pressure, site productivity and propagule availability? Alternatively are the differences also or solely the outcome of different methodologies? At present the consensus generally present in the literature, and existing models, suggest that the differing outcomes can be explained by ecological processes (Milchunas & Lauenroth 1993; Olff & Ritchie 1998) and are not an artefact of study methodology. Even so, this issue does require consideration and investigation.

6. Reviewers' Conclusions

6.1 Implications for management / policy / conservation

6.1.1 Exclusion of livestock from unfertilized pastures

While few individual plant species appear to have consistent responses to livestock exclusion in native pastures, there was a general trend to suggest that exclusion did not favour exotics (mostly annuals). In studies that provided data on broad life-history groups, none found native plant groups to respond negatively to livestock exclusion, although approximately 50% reported a neutral response. The reverse was the case for exotics. Thus, the current data suggests that while individual species responses are often uncertain, broad responses of native vegetation to exclusion are typically neutral or positive. From a conservation managers perspective complete enclosure of livestock in native pastures is risky in terms of increasing species diversity as many species responses are uncertain and some native species could be negatively impacted. However, at a broader scale, if plant diversity and individual species are not the focus of management, but rather soil protection and a general increase in the cover of native groundlayer vegetation are, then enclosure could be appropriate. Examination of co-variates, as suggested by Lunt *et al.* (2007) could help to refine these conclusions.

6.1.2 Restoration of fertilised pastures

There were very few studies that explicitly examined enclosure or the run-down of available nutrients in previously fertilised pastures. Information about the vegetation of these land-use states and respective transitions is required to assist managers in allocating limited conservation resources. Large proportions of the temperate grassy woodlands have been affected by soil nutrient enrichment either through fertilization, run-on or stock camping. There are indications that the removal of grazing from fertilized pastures results in low diversity and dominance by large perennial grasses (Wilkins, Keith & Adam 2003; McIntyre 2008), but there are few data from the review. It is not possible to make recommendations about the potential long-term effects of enclosure or nutrient run-down in such landscapes.

6.1.3 Grazing grassy woodlands

Most reference grassland sites are rarely, if ever, grazed by livestock. The effects of grazing in reference grassland are almost certain to have negative consequences for native plant diversity. However, grazed native pastures are also important in the conservation of plant diversity in grassy woodland landscapes as they still retain many native plant species. In this review we did not examine how plant diversity varied among native pastures owing to differences in grazing intensity, season or frequency. Compiling existing data on these interventions is clearly important for guiding conservation management in native pastures. Further data extraction and analyses are required to examine this.

6.2 Implications for research

Further exploration of covariates, particularly in relation to variation in the composition of vegetation in the most frequently reported land-use states (exclosed, fertilised and native pastures) is required. There were insufficient resources available for such analyses as part of this review, but much of the relevant data has been collected through the data extraction phase. However, in highlighting this we do note

that consistent measures of key covariates relating to livestock grazing pressure or the degree of soil nutrient enrichment were rarely available.

While dry sheep equivalents is a standard measure of livestock grazing in most agronomic studies it was infrequently available in ecological studies. Even so, it is not an exact measure of actual grazing pressure when comparing sites varying in primary productivity and vegetation composition. Measurements of sward height would provide a consistent indicator of stock pressure, albeit confounded with primary productivity, but less than 10% of studies provide such data. The ideal data to enable cross study comparisons would be off-take as a proportion of dry matter production.

The minority of studies reported actual fertilizer histories in terms of total superphosphate applications (35%) and surprisingly only 33% of fertilized pasture observations provide such data. Only 17% of observations include results of soil nutrient analyses (eg. available phosphorus, available nitrogen or total nitrogen) and methods of extraction vary. In unfertilized reference grasslands and native pastures landscape position, lithology, mean annual temperature and precipitation can be used as surrogates for site productivity – this information is available for most observations.

The current understanding of how livestock grazing and fertilization affects groundlayer plant composition is primarily derived from studies that rely on contrasts among sites with differing land use history. Most of our current knowledge therefore reflects the long-term, historical effects of these management practices. In this context the vegetation changes owing to livestock grazing of reference grassland or fertilization of native pasture are relatively well described. A greater emphasis on experimental studies, particularly of reverse (restoration) transitions that are relevant to conservation managers, is needed. These should be supported by appropriately designed natural experiments that enable the examination of longer-term patterns.

There is very little documentation of the vegetation of enriched grasslands. Most data relating to exclosed pastures, that documented fertility, was apparently from native pastures with no recent history of soil enrichment. Many such studies however do not provide the prior enrichment context and so were excluded from this review. Future research on de-stocking should prioritize the collection of good historical data on enrichment history and/or clearly document soil fertility (available P, N and total N), rainfall or an estimate of pasture growth/primary production. Few studies currently provide this context.

The role of enrichment, via direct fertilization of grassland or through the transportation and re-cycling of nutrients by livestock, is increasingly recognised as a major factor determining vegetation composition in grasslands (Prober, Thiele & Lunt 2002; Dorrough *et al.* 2006; McIntyre & Lavorel 2007). The results of this review do support this conclusion. However, there is very little data examining how vegetation responds to declines in soil fertility. Most of the data relating to past fertilized pastures was from pasture research where the context was degraded pastures with a history of prior fertilizer. In these cases the observations were typically descriptions of the vegetation prior to conducting an experiment to examine grazing and fertilizer practices to improve the productivity of the run-down pastures. Only one study

directly examined the effects of nutrient decline on vegetation composition (Prober *et al.* 2005). There is continuing international interest in the role of soil fertility in the restoration success of temperate and Mediterranean ecosystems (eg. Blumenthal, Jordan & Ruselle 2003; Pywell *et al.* 2007; Gilbert, Gowing & Wallace 2009) and such research could have global implications.

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8. Potential Conflicts of Interest and Sources of Support

None to report.

9. References

- Allcock, K.G. (2002) *Effects of grazing on vegetation dynamics in Australian white box woodland*, PhD Thesis, University of Alberta, Edmonton, Alberta.
- Benson, J.S. (1994) The native grasslands of the Monaro region: Southern Tablelands of NSW. *Cunninghamiana*, 3, 609-650.
- Blumenthal, D.M., Jordan, N.R. & Ruselle, M.P. (2003) Soil carbon addition controls weeds and facilitates prairie restoration. *Ecological Applications*, 13, 605-615.
- Chalmers, A.C. (1996) *Plant strategies in herbaceous vegetation in relation to soil disturbance, fertilisation and sowing on the northern tablelands of NSW*. PhD Thesis, University of New England, Armidale.
- Clarke, P.J. (2003) Composition of grazed and cleared temperate grassy woodlands in eastern Australia: patterns in space and inferences in time. *Journal of Vegetation Science*, 14, 5-14.
- Costello, D.A., Lunt, I.D. & Williams, J.E. (2000) Effects of invasion by the indigenous shrub *Acacia sophorae* on plant composition of coastal grasslands in south-eastern Australia. *Biological Conservation*, 96, 113-121.
- Crosthwaite, J., Malcolm, B., Moll, J. & Dorrough, J. (2008) Future investment in landscape change in southern Australia. *Landscape Research*, 33, 225-239.
- Davies, J.G., Scott, A.E. & Eraser, K.M. (1934) Natural pastures: their response to superphosphate. *Commonwealth of Australia Council for Scientific and Industrial Research Bulletin*, 83, 1-76.
- Diamond, J.M. (1986). Overview: Laboratory experiments, field experiments, and natural experiments. *Community Ecology* (eds J. Diamond & T.J. Case), pp. 3-22. Harper & Row, New York.
- Diaz, S., Lavorel, S., McIntyre, S., Falczuk, V., Casanoves, F., Milchunas, D.G., Skarpe, C., Rusch, G., Sternberg, M., Noy-Meir, I., Landsberg, J., Zhang, W., Clark, H. & Campbell, B.D. (2007) Plant trait responses to grazing - a global synthesis. *Global Change Biology*, 13, 313-341.
- Dorrough, J., Yen, A.L., Turner, V., Clark, S., Crosthwaite, J. & Hirth, J.R. (2004) Livestock grazing management and biodiversity conservation in Australian temperate grassy landscapes. *Australian Journal of Agricultural Research*, 55, 279-295.

- Dorrrough, J., Moxham, C., Turner, V. & Sutter, G. (2006) Soil phosphorus and tree cover modify the effects of livestock grazing on plant species richness in Australian grassy woodland. *Biological Conservation*, 130, 394-405.
- Dorrrough, J., McIntyre, S., Stol, J., Brown, G.W. & Barrett, G. (2008) *Understanding the interactions between biodiversity and the management of native pastures in the Murray Darling Basin*. Meat & Livestock Australia.
- Dorrrough, J. & Scroggie, M.P. (2008) Plant responses to agricultural intensification. *Journal of Applied Ecology*, 45, 1274-1283.
- Garden, D.L., Dowling, P.M., Eddy, D.A. & Nicol, H.I. (2001) The influence of climate, soil, and management on the composition of native grass pastures on the Central, Southern, and Monaro Tablelands of New South Wales. *Australian Journal of Agricultural Research*, 52, 925-936.
- Garden, D.L., Ellis, N.J.S., Rab, M.A., Langford, C.M., Johnston, W.H., Shields, C., Murphy, T., Holmberg, M., Dassanayake, K.B. & Harden, S. (2003) Fertiliser and grazing effects on production and botanical composition of native grasslands in south-east Australia. *Australian Journal of Experimental Agriculture*, 43, 843-859.
- Gilbert, J., Gowing, D. & Wallace, H. (2009) Available phosphorus in semi-natural grasslands: Assessment methods and community tolerances. *Biological Conservation*, 142, 1074-1083.
- Gilfedder, L. & Kirkpatrick, J.B. (1994) Climate, grazing and disturbance, and the population dynamics of *Leucochrysum albicans* at Ross, Tasmania. *Australian Journal of Botany*, 42, 417-430.
- Gurevitch, J. & Hedges, L.V. (1999) Statistical issues in ecological meta-analyses. *Ecology*, 80, 1142-1149.
- Hutchinson, M.F., McIntyre, S., Hobbs, R.J., Stein, J.L., Garnett, S. & Kinloch, J. (2005) Integrating a global agro-climatic classification with bioregional boundaries in Australia. *Global Ecology and Biogeography*, 14, 197-212.
- Kirkpatrick, J.B., Gilfedder, L., Bridle, K. & Zacharek, A. (2005) The positive and negative conservation impacts of sheep grazing and other disturbances on the vascular plant species and vegetation of lowland subhumid Tasmania. *Ecological Management and Restoration*, 6, 51-60.
- Lunt, I.D. & Morgan, J.W. (1999) Effect of fire frequency on plant composition at the Laverton North Grassland Reserve, Victoria. *The Victorian Naturalist*, 116, 84-89.
- Lunt, I.D., Eldridge, D.J., Morgan, J.W. & Witt, G.B. (2007) TURNER REVIEW No. 13. A framework to predict the effects of livestock grazing and grazing exclusion on conservation values in natural ecosystems in Australia. *Australian Journal of Botany*, 55, 401-415.
- McGufficke, B.R. (2003) Native vegetation management: a botanical study of two native grassland management options on a commercial cattle property. *Rangeland Journal*, 25, 37-46.
- McIntyre, S. & Hobbs, R. (1999) A framework for conceptualizing human effects on landscapes and its relevance to management and research models. *Conservation Biology*, 13, 1282-1292.
- McIntyre, S. & Lavorel, S. (2007) A conceptual model of land use effects on the structure and function of herbaceous vegetation. *Agriculture, Ecosystems & Environment*, 119, 11-21.
- McIntyre, S. (2008) The role of plant leaf attributes in linking land use to ecosystem function in temperate grassy vegetation. *Agriculture Ecosystems & Environment*, 128, 251-258.

- Milchunas, D.G. & Lauenroth, W.K. (1993) Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological Monographs*, 63, 327-366.
- Moore, R.M. & Biddiscombe, E.F. (1964). The effects of grazing on grasslands. *Grasses and Grasslands* (ed C. Barnard), pp. 221-235. Macmillan and Company Ltd., London.
- Moore, R.M. (1970). South-eastern temperate woodlands and grasslands. *Australian Grasslands* (ed R.M. Moore), pp. 169-190. Halstead Press, Canberra.
- Munnich, D.J., Simpson, P.C. & Nicol, H.I. (1991) A survey of native grasses in the Goulburn district and factors influencing their abundance. *Rangeland Journal*, 13, 118-129.
- Olf, H. & Ritchie, M.E. (1998) Effects of herbivores on grassland plant diversity. *Trends in Ecology and Evolution*, 13, 261-265.
- Prober, S.M., Thiele, K.R. & Lunt, I. (2002) Identifying ecological barriers to restoration in temperate grassy woodlands: soil changes associated with different degradation states. *Australian Journal of Botany*, 50, 699-712.
- Prober, S.M. & Thiele, K.R. (2004) Floristic patterns along an east-west gradient in grassy box woodlands of Central New South Wales. *Cunninghamia*, 8, 307-325.
- Prober, S.M., Thiele, K.R., Lunt, I.D. & Koen, T.B. (2005) Restoring ecological function in temperate grassy woodlands: manipulating soil nutrients, exotic annuals and native perennial grasses through carbon supplements and spring burns. *Journal of Applied Ecology*, 42, 1073-1085.
- Pullin, A.S. & Knight, T.M. (2003) Support for decision making in conservation practice: an evidence-based approach. *Journal for Nature Conservation*, 11, 83 - 90.
- Pullin, A.S. & Stewart, G.H. (2006) Guidelines for systematic review in conservation and environmental management. *Conservation Biology*, 20, 1647-1656.
- Pywell, R.F., Bullock, J.M., Tallwin, J.R.B., Walker, K.J., Warman, E.A. & Masters, G. (2007) Enhancing diversity of species-poor grasslands: an experimental assessment of multiple constraints. *Journal of Applied Ecology*, 44, 81-94.
- Reseigh, J. (2004) *Grazing management and environmental determinants of the diversity and composition of ground-storey vegetation on the Northern Tablelands, NSW*. PhD Thesis, University of New England, Armidale, New South Wales.
- Spooner, P.G. & Briggs, S.V. (2008) Woodlands on farms in southern New South Wales: A longer-term assessment of vegetation changes after fencing. *Ecological Management & Restoration*, 9, 33-41.
- Tiver, N.S. & Crocker, R.L. (1951) The grasslands of south-east South Australia in relation to climate, soils and developmental history. *Journal of the British Grassland Society*, 6, 29-80.
- Trumble, H.C. & Fraser, K.M. (1932) The effect of top-dressing with artificial fertilisers on the annual yield, botanical composition, and carrying capacity of a natural pasture over a period of seven years. *The Journal of Agriculture South Australia*, 35, 1342-1353.
- Vesk, P.A. & Westoby, M. (2001) Predicting plant species' responses to grazing. *Journal of Applied Ecology*, 38, 897-909.
- Whalley, R.B.D., Robinson, G.G. & Taylor, J.A. (1978) General effects of management and grazing by domestic livestock in the rangelands of the northern tablelands of NSW. *Australian Rangeland Journal*, 1, 174-190.

- Wilkins, S., Keith, D.A. & Adam, P. (2003) Measuring success: Evaluating the restoration of a grassy eucalypt woodland on the Cumberland Plain, Sydney, Australia. *Restoration Ecology*, 11, 489-503.
- Williams, A.R. (1979) *A survey of natural pastures in the North-West slopes of New South Wales*. New South Wales Department of Agriculture, Sydney.
- Williams, O.B. (1969) Studies in the ecology of Riverine Plain .V. Plant density response of species in a *Danthonia caespitosa* grassland to 16 years of grazing by Merino sheep. *Australian Journal of Botany*, 17, 255-&.
- Yates, C.J. & Hobbs, R. (1997) Temperate eucalypt woodlands: A review of their status, processes threatening their persistence and techniques for restoration. *Australian Journal of Botany*, 45, 949-973.

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10. Appendices

Appendix 1. Studies accepted into the final review

1. Allcock, K.G. (2002) *Effects of grazing on vegetation dynamics in Australian white box woodland*, PhD Thesis, University of Alberta, Edmonton, Alberta.
2. Allcock, K.G. & Hik, D.S. (2004) Survival, growth, and escape from herbivory are determined by habitat and herbivore species for three Australian woodland plants. *Oecologia*, **138**, 231-241.
3. Austin, M.P., Williams, O.B. & Belbin, L. (1981) Grassland Dynamics under Sheep Grazing in an Australian Mediterranean Type Climate. *Vegetatio*, **46-7**, 201-211.
4. Bean, J.M. & Whalley, R.D.B. (2002) Native grasslands on non-arable slopes of the Garrawillie Creek sub-catchment, western Liverpool Plains, New South Wales. *Rangeland Journal*, **23**, 119-147.
5. Benson, J.S. (1994) The native grasslands of the Monaro region: Southern Tablelands of NSW. *Cunninghamiana*, **3**, 609-650.
6. Benson, J.S., Ashby, E.M. & Porteners, M.F. (1997) The native grasslands of the Riverine Plain, New South Wales. *Cunninghamiana*, **5**, 1-48.
7. Benson, D. & Howell, J. (2002) Cumberland Plain Woodland ecology then and now: interpretations and implications from the work of Robert Brown and others. *Cunninghamiana*, **7**, 631-650.
8. Biddiscombe, E.F. (1953) A Survey of the Natural Pastures of the Trangie District, New-South-Wales, with Particular Reference to the Grazing Factor. *Australian Journal of Agricultural Research*, **4**, 1-&.
9. Bruce, S. (1998) *The role of resources and grazing in determining pasture community structure on the Monaro*. Honours Thesis, Australian National University, Canberra.
10. Burrows, G.E. (1999) A survey of 25 remnant vegetation sites in the South Western Slopes, New South Wales. *Cunninghamiana*, **6**, 283-314.
11. Chalmers, A.C. (1996) *Plant strategies in herbaceous vegetation in relation to soil disturbance, fertilisation and sowing on the northern tablelands of NSW*. PhD Thesis, University of New England, Armidale.
12. Chilcott, C., Reid, N.C.H. & King, K. (1997). Impact of trees on the diversity of pasture species and soil biota in grazed landscapes on the northern tablelands, NSW. *Conservation outside nature reserves* (eds P. Hale & D. Lamb), pp. 378-386. Centre for Conservation Biology, University of Queensland, Brisbane.
13. Conway, M.G. (2000) *The effects of grazing exclusion on a long-grazed species-rich Riverina grassland*. Honours Thesis, Charles Sturt University, Albury.
14. Davies, J.G., Scott, A.E. & Eraser, K.M. (1934) Natural pastures: their response to superphosphate. *Commonwealth of Australia Council for Scientific and Industrial Research Bulletin*, **83**, 1-76.
15. Doing, H. (1972) *Botanical composition of pasture and weed communities in the Southern Tablelands region, south-eastern Australia*. CSIRO, Canberra.
16. Donald, C.M. & Williams, C.H. (1954) Fertility and productivity of a podzolic soil as influenced by subterranean clover (*Trifolium subterranean* L.) and superphosphate. *Australian Journal of Agricultural Research*, **5**, 664-687.
17. Dorough, J. (2001) *The impact of grazing and exotic invasion on the persistence of native grassland*. PhD Thesis, Australian National University, Canberra.

18. Dorrough, J., Ash, J. & McIntyre, S. (2004) Plant responses to livestock grazing frequency in an Australian temperate grassland. *Ecography*, **27**, 798-810.
19. Dorrough, J. & Ash, J.E. (2004) The impact of livestock grazing on the persistence of a perennial forb in a temperate Australian grassland. *Pacific Conservation Biology*, **9**, 302-307.
20. Dowling, P.M., Robinson, G.G. & Murison, R.D. (1987). Sheep production from improved and native grasses in the presence of white clover. *Temperate pastures: their production, use and management* (eds J.L. Wheeler, C.J. Pearson & G.E. Robards), pp. 551-553. CSIRO & Australian Wool Corporation, Australia.
21. Dowling, P.M., Kemp, D.R., Ball, P.D., Langford, C.M., Michalk, D.L., Millar, G.D., Simpson, P.C. & Thompson, R.P. (2005) Effect of continuous and time-control grazing on grassland components in south-eastern Australia. *Australian Journal of Experimental Agriculture*, **45**, 369-382.
22. Dowling, P.M., Michalk, D.L., Kemp, D.R., Millar, G.D., Priest, S.M., King, W.M., Packer, I.J., Holst, P.J. & Tarleton, J.A. (2006) Sustainable grazing systems for the Central Tablelands of New South Wales. 2. Effect of pasture type and grazing management on pasture productivity and composition. *Australian Journal of Experimental Agriculture*, **46**, 457-469.
23. Earl, J.M. (1998) *The role of grazing management in the functioning of pasture ecosystems*.
24. Fensham, R.J. (1989) The pre-European vegetation of the Midlands, Tasmania: A floristic and historical analysis of vegetation patterns. *Journal of Biogeography*, **16**, 29-45.
25. Fensham, R.J. & Kirkpatrick, J.B. (1989) The conservation of original vegetation remnants in the Midlands, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania*, **123**, 229-246.
26. Foreman, P.W. (1997) *Ecology of native grasslands on Victoria's Northern Riverine Plain*. Masters Thesis, La Trobe University, Melbourne.
27. Frood, D. (1992) *Vegetation of the native grasslands in the Merri Creek Valley, Outer Melbourne Area*. Department of Conservation and Environment, Melbourne.
28. Garden, D.L., Lodge, G.M., Friend, D.A., Dowling, P.M. & Orchard, B.A. (2000) Effects of grazing management on botanical composition of native grass-based pastures in temperate south-east Australia. *Australian Journal of Experimental Agriculture*, **40**, 225-245.
29. Garden, D.L., Ellis, N.J.S., Rab, M.A., Langford, C.M., Johnston, W.H., Shields, C., Murphy, T., Holmberg, M., Dassanayake, K.B. & Harden, S. (2003) Fertiliser and grazing effects on production and botanical composition of native grasslands in south-east Australia. *Australian Journal of Experimental Agriculture*, **43**, 843-859.
30. Gilfedder, L. & Kirkpatrick, J.B. (1994) Climate, Grazing and Disturbance, and the Population-Dynamics of *Leucochrysum albicans* at Ross, Tasmania. *Australian Journal of Botany*, **42**, 417-430.
31. Grant, C. & Macgregor, C. (2001) Topsoil seed banks in grazed and ungrazed eucalypt woodlands at Newholme, Armidale, New South Wales, Australia. *New Zealand Journal of Botany*, **39**, 471-481.
32. Hamilton, S.D., O'Dwyer, C., Dettmann, P.D. & Curtis, A.L. (2004) The habitat quality of private land Box-Ironbark remnant vegetation in southern Australia. *Journal of Sustainable Agriculture*, **25**, 19-42.

33. Hill, J.O., Simpson, R.J., Moore, A.D., Graham, P. & Chapman, D.F. (2004) Impact of phosphorus application and sheep grazing on the botanical composition of sown pasture and naturalised, native grass pasture. *Australian Journal of Agricultural Research*, **55**, 1213-1225.
34. Hill, S.J. & French, K. (2004) Potential impacts of fire and grazing in an endangered ecological community: plant composition and shrub and eucalypt regeneration in Cumberland Plain Woodland. *Australian Journal of Botany*, **52**, 23-29.
35. Hill, S.J., Tung, P.J. & Leishman, M.R. (2005) Relationships between anthropogenic disturbance, soil properties and plant invasion in endangered Cumberland Plain Woodland, Australia. *Austral Ecology*, **30**, 775-788.
36. Hyde, M.K. (1994) *A Vegetation Survey of Disused Railway Corridors in the Mid-north Region of South Australia*. Nature Conservation Society of South Australia, Adelaide.
37. King, W.M., Dowling, P.M., Michalk, D.L., Kemp, D.R., Millar, G.D., Packer, I.J., Priest, S.M. & Tarleton, J.A. (2006) Sustainable grazing systems for the Central Tablelands of New South Wales. 1. Agronomic implications of vegetation-environment associations within a naturalised temperate perennial grassland. *Australian Journal of Experimental Agriculture*, **46**, 439-456.
38. Kirkpatrick, J.B., Gilfedder, L., Bridle, K. & Zacharek, A. (2005) The positive and negative conservation impacts of sheep grazing and other disturbances on the vascular plant species and vegetation of lowland subhumid Tasmania. *Ecological Management & Restoration*, **6**, 51-60.
39. Leonard, S.W.J. & Kirkpatrick, J.B. (2004) Effects of grazing management and environmental factors on native grassland and grassy woodland, Northern Midlands, Tasmania. *Australian Journal of Botany*, **52**, 529-542.
40. Lodge, G.M. & Roberts, E.A. (1979) The effects of phosphorus sulphur and stocking rate on the yield, chemical and botanical composition of natural pastures, North-West Slopes, New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandary*, **19**, 698-705.
41. Lodge, G.M. (1981) The role of plant mass, basal area and density in assessing the herbage mass response to fertility of some native perennial grasses. *Australian Rangeland Journal*, **3**, 92-98.
42. Lodge, G.M. & Gleeson, A.C. (1982) The importance of plant density, plant basal area and plant mass per unit basal area as factors influencing the herbage mass of some native perennial grasses. *Australian Rangeland Journal*, **4**, 61-66.
43. Lodge, G.M. & Whalley, R.D.B. (1985) The manipulation of species composition of natural pastures by grazing management on the Northern Slopes of NSW. *Australian Rangeland Journal*, **7**, 6-16.
44. Lunt, I.D. (1997) Effects of long-term vegetation management on remnant grassy forests and anthropogenic native grasslands in south-eastern Australia. *Biological Conservation*, **81**, 287-297.
45. Lunt, I.D. & Morgan, J.W. (1999) Vegetation changes after 10 years of grazing exclusion and intermittent burning in a *Themeda triandra* (Poaceae) grassland reserve in south-eastern Australia. *Australian Journal of Botany*, **47**, 537-552.
46. Lunt, I.D., Jansen, A., Binns, D.L. & Kenny, S.A. (2007) Long-term effects of exclusion of grazing stock on degraded herbaceous plant communities in a riparian *Eucalyptus camaldulensis* forest in south-eastern Australia. *Austral Ecology*, **32**, 937-949.

47. Magcale-Macandog, D.B. & Whalley, R.D.B. (1991) Distribution of *Microlaena stipoides* and its association with introduced perennial grasses in a permanent pasture on the northern tablelands of New South Wales. *Australian Journal of Botany*, **39**, 295-303.
48. Maron, M. & Lill, A. (2005) The influence of livestock grazing and weed invasion on habitat use by birds in grassy woodland remnants. *Biological Conservation*, **124**, 439-450.
49. McGufficke, B.R. (2003) Native vegetation management: a botanical study of two native grassland management options on a commercial cattle property. *Rangeland Journal*, **25**, 37-46.
50. McIntyre, S. & Lavorel, S. (1994) Predicting richness of native, rare, and exotic plants in response to habitat and disturbance variables across a variegated landscape. *Conservation Biology*, **8**, 521-531.
51. McIntyre, S. (2008) The role of plant leaf attributes in linking land use to ecosystem function in temperate grassy vegetation. *Agriculture Ecosystems & Environment*, **128**, 251-258.
52. Meers, T.L., Bell, T.L., Enright, N.J. & Kasel, S. (2008) Role of plant functional traits in determining vegetation composition of abandoned grazing land in north-eastern Victoria, Australia. *Journal of Vegetation Science*, **19**, 515-524.
53. Moore, C.W.E. (1953) The Vegetation of the South-Eastern Riverina, New South Wales. II. The disclimax communities. *Australian Journal of Botany*, **1**, 548-567.
54. Morgan, J.W. & Rollason, T.S. (1995) Base-line monitoring of a significant grassland remnant at Evans Street, Sunbury, Victoria. *The Victorian Naturalist*, **112**, 148-159.
55. Morgan, J.W. (1997) *Regeneration Processes in an Endangered Species-Rich Grassland Community on the Volcanic Plains of Western Victoria*, PhD Thesis, La Trobe University, Melbourne.
56. Pettit, N.E., Ladd, P.G. & Froend, R.H. (1998) Passive clearing of native vegetation: livestock damage to remnant jarrah (*Eucalyptus marginata*) woodlands in Western Australia. *Journal of the Royal Society of Western Australia*, **81**, 95-106.
57. Pettit, N.E. & Froend, R.H. (2001) Long-term changes in the vegetation after the cessation of livestock grazing in *Eucalyptus marginata* (jarrah) woodland remnants. *Austral Ecology*, **26**, 22-31.
58. Price, J.N. & Morgan, J.W. (2007) Vegetation dynamics following resource manipulations in herb-rich woodland. *Plant Ecology*, **188**, 29-37.
59. Prober, S.M. & Thiele, K.R. (1995) Conservation of the Grassy White Box Woodlands - Relative Contributions of Size and Disturbance to Floristic Composition and Diversity of Remnants. *Australian Journal of Botany*, **43**, 349-366.
60. Prober, S.M., Lunt, I.D. & Thiele, K.R. (2002) Determining reference conditions for management and restoration of temperate grassy woodlands: relationships among trees, topsoils and understorey flora in little-grazed remnants. *Australian Journal of Botany*, **50**, 687-697.
61. Prober, S.M. & Thiele, K.R. (2004) Floristic patterns along an east-west gradient in grassy box woodlands of Central New South Wales. *Cunninghamia*, **8**, 307-325.
62. Prober, S.M., Thiele, K.R., Lunt, I.D. & Koen, T.B. (2005) Restoring ecological function in temperate grassy woodlands: manipulating soil nutrients, exotic

- annuals and native perennial grasses through carbon supplements and spring burns. *Journal of Applied Ecology*, **42**, 1073-1085.
63. Reseigh, J. (2004) *Grazing management and environmental determinants of the diversity and composition of ground-storey vegetation on the Northern Tablelands, NSW*. PhD Thesis, University of New England, Armidale, New South Wales.
 64. Robertson, D. (1985) *Interrelationships between kangaroos, fire and vegetation dynamics at Gellibrand Hill Park, Victoria*. , University of Melbourne, Melbourne.
 65. Robinson, G.G. & Dowling, P.M. (1976) Management of natural pastures on the Northern Tablelands of New South Wales - a survey. *Australian Rangeland Journal*, **1**, 70-74.
 66. Robinson, G.G. & Lazenby, A. (1976) Effect of superphosphate, white clover and stocking rate on the productivity of natural pastures, Northern Tablelands, New South Wales. *Australian Journal of Experimental Agriculture and Animal Husbandary*, **16**, 209-217.
 67. Roe, R. (1947) *Preliminary survey of the natural pastures of the New England district of New South Wales and a general discussion of their problems*. Commonwealth of Australia.
 68. Rogers, R.W. & Whalley, R.D.B. (1989) The relationship between diaspore characteristics and the distribution of grasses around sheep camps on the Northern Tablelands of New South Wales. *Australian Journal of Botany*, **37**, 501-510.
 69. Stuwe, J. & Parsons, R.F. (1977) *Themeda australis* grasslands on the Basalt Plains Victoria: floristics and management effects. *Australian Journal of Ecology*, **2**, 467-476.
 70. Tiver, N.S. & Crocker, R.L. (1951) The grasslands of south-east South Australia in relation to climate, soils and developmental history. *Journal of the British Grassland Society*, **6**, 29-80.
 71. Tremont, R.M. (1994) Life-history attributes of plants in grazed and ungrazed grasslands on the northern tablelands of New South Wales. *Australian Journal of Botany*, **42**, 511-530.
 72. Trumble, H.C. & Fraser, K.M. (1932) The effect of top-dressing with artificial fertilisers on the annual yield, botanical composition, and carrying capacity of a natural pasture over a period of seven years. *The Journal of Agriculture South Australia*, **35**, 1342-1353.
 73. Verrier, F.J. & Kirkpatrick, J.B. (2005) Frequent mowing is better than grazing for the conservation value of lowland tussock grassland at Pontville, Tasmania. *Austral Ecology*, **30**, 74-78.
 74. Whalley, R.B.D., Robinson, G.G. & Taylor, J.A. (1978) General effects of management and grazing by domestic livestock in the rangelands of the northern tablelands of NSW. *Australian Rangeland Journal*, **1**, 174-190.
 75. Williams, O.B. (1955) Studies in the ecology of the Riverine Plain. I. the gilgai microrelief and associated flora. *Australian Journal of Agricultural Research*, **3**, 99-112.
 76. Williams, O.B. (1956) Studies in the ecology of the Riverine Plain. II. Plant soil relationships in three semi-arid grasslands. *Australian Journal of Agricultural Research*, **7**, 127/139.

77. Williams, O.B. (1969) Studies in ecology of Riverine Plain .V. Plant density response of species in a *Danthonia caespitosa* grassland to 16 years of grazing by Merino Sheep. *Australian Journal of Botany*, **17**, 255-&.
78. Zimmer, H.C., Turner, V.B., Mavromihalis, J., Dorrrough, J. & Moxham, C. (submitted) Forb responses to grazing-rest management in a critically endangered Australian native grassland ecosystem.

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Appendix 2 Study observations

Obs.	Author	Date	Grazing Intervention	Fertilizer Intervention	Land-use State	Study Method	Evidence Rank	Location
1	Allcock	2002	Grazed	not enriched	Native Pasture	Experimental manipulation	I	NSW
2	Allcock	2002	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	NSW
3	Allcock	2002	Grazed	not enriched	Native Pasture	Experimental manipulation	I	NSW
4	Allcock	2002	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	NSW
5	Allcock	2002	Grazed	not enriched	Native Pasture	Experimental manipulation	I	NSW
6	Allcock	2002	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	NSW
7	Allcock & Hik	2004	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	NSW
8	Austin, Williams and Belbin	1981	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	NSW
9	Bean and Whalley	2002	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
10	Bean and Whalley	2002	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
11	Bean and Whalley	2002	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
12	Bean and Whalley	2002	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
13	Bean and Whalley	2002	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
14	Benson	1994	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	ACT
15	Benson	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
16	Benson	1994	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
17	Benson and Howell	2002	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-3	NSW
18	Benson, Ashby, Porteners	1997	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
19	Benson, Ashby, Porteners	1997	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
20	Benson, Ashby, Porteners	1997	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	NSW
21	Benson, Ashby, Porteners	1997	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
22	Benson, Ashby, Porteners	1997	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
23	Biddiscombe	1953	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
24	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
25	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
26	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
27	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
28	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
29	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW

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30	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
31	Biddiscombe	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
32	Bruce	1998	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
33	Bruce	1998	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
34	Bruce	1998	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
35	Burrows	1999	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
36	Burrows	1999	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
37	Chalmers	1996	Grazed	not enriched	Native Pasture	Experimental manipulation	I	NSW
38	Chalmers	1996	Grazed	enriched	Fertilized Pasture	Experimental manipulation	I	NSW
39	Chalmers	1996	Grazed	enriched	Fertilized Pasture	Experimental manipulation	I	NSW
40	Chilcott et al.	1997	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
41	Chilcott et al.	1997	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
42	Conway	2000	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	VIC
43	Conway	2000	Grazed	not enriched	Native Pasture	Experimental manipulation	II-1	VIC
44	Davies, Scott, Fraser	1934	Grazed	not enriched	Native Pasture	Experimental manipulation	II-1	SA
45	Davies, Scott, Fraser	1934	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-1	SA
46	Davies, Scott, Fraser	1934	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-1	SA
47	Davies, Scott, Fraser	1934	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-3	SA
48	Doing	1972	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	ACT
49	Doing	1972	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	ACT
50	Doing	1972	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	ACT
51	Doing	1972	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	ACT
52	Doing	1972	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	ACT
53	Doing	1972	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	ACT
54	Doing	1972	Ungrazed	enriched	Enriched Grassland	Land tenure comparison	II-2	ACT
55	Donald and Williams	1954	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
56	Donald and Williams	1954	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
57	Dorrrough	2001	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
58	Dorrrough	2001	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
59	Dorrrough	2004	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	NSW
60	Dorrrough	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
61	Dorrrough	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
62	Dowling et al	2005	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW

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63	Dowling et al	2006	Grazed	enriched	Fertilized Pasture	Experimental manipulation	I	NSW
64	Dowling, Robinson, Murison	1987	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-3	NSW
65	Earl	1998	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
66	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
67	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
68	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
69	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
70	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
71	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
72	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
73	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
74	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
75	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
76	Fensham	1989	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	TAS
77	Fensham & Kirkpatrick	1989	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	TAS
78	Foreman	1996	Grazed	not enriched	Native Pasture	Experimental manipulation	II-1	VIC
79	Foreman	1996	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	VIC
80	Frood	1992	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	VIC
81	Frood	1992	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	VIC
82	Frood	1992	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	VIC
83	Frood	1992	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	VIC
84	Garden et al.	2000	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
85	Garden et al.	2000	Grazed	not enriched	Past fertilised	Land tenure comparison	II-3	NSW
86	Garden et al.	2000	Grazed	not enriched	Past fertilised	Land tenure comparison	II-3	ACT
87	Garden et al.	2000	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	TAS
88	Garden et al.	2003	Grazed	not enriched	Native Pasture	Experimental manipulation	II-3	VIC
89	Garden et al.	2003	Grazed	not enriched	Native Pasture	Experimental manipulation	II-3	NSW
90	Garden et al.	2003	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-3	SA
91	Garden et al.	2003	Grazed	enriched	Fertilized Pasture	Experimental manipulation	I	VIC
92	Garden et al.	2003	Grazed	enriched	Fertilized Pasture	Experimental manipulation	I	NSW
93	Garden et al.	2003	Grazed	enriched	Fertilized Pasture	Experimental manipulation	I	SA
94	Gilfedder & Kirkpatrick	1994	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-3	TAS
95	Grant & MacGregor	2001	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-3	NSW

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96	Hamilton	2001	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-3	VIC
97	Hamilton	2001	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	VIC
98	Hamilton	2001	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	VIC
99	Hamilton	2001	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	VIC
100	Hill & French	2004	Ungrazed	not enriched	Reference Grassland	Experimental manipulation	II-1	NSW
101	Hill & French	2004	Ungrazed	not enriched	Reference Grassland	Experimental manipulation	II-1	NSW
102	Hill et al	2004	Grazed	not enriched	Past fertilised	Experimental manipulation	II-3	NSW
103	Hill et al	2004	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-3	NSW
104	Hill et al	2004	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-3	NSW
105	Hill, Tung, Leishman	2005	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-3	NSW
106	Hill, Tung, Leishman	2005	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
107	Hyde	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	SA
108	King et al	2006	Grazed	not enriched	Past fertilised	Land tenure comparison	II-3	NSW
109	King et al	2006	Grazed	not enriched	Past fertilised	Land tenure comparison	II-3	NSW
110	Kirkpatrick et al	2005	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	TAS
111	Kirkpatrick et al	2005	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	TAS
112	Kirkpatrick et al	2005	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	TAS
113	Kirkpatrick et al	2005	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	TAS
114	Kirkpatrick et al	2005	Ungrazed	enriched	Enriched Grassland	Experimental manipulation	II-3	TAS
115	Leonard & Kirkpartrick	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	TAS
116	Lodge	1981	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
117	Lodge	1981	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
118	Lodge	1982	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
119	Lodge & Roberts	1979	Grazed	enriched	Fertilized Pasture	Land tenure comparison	I	NSW
120	Lunt	1997	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	VIC
121	Lunt	1997	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	VIC
122	Lunt & Morgan	1999	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	VIC
123	Lunt & Morgan	1999	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-3	VIC
124	Lunt et al.	2007	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	NSW
125	Macgale-Macandog	1991	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
126	Maron & Lill	2005	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	VIC
127	McGufficke	2003	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
128	McGufficke	2003	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW

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129	McIntyre	2008	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	NSW
130	McIntyre	2008	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
131	McIntyre	2008	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
132	McIntyre	2008	Ungrazed	enriched	Enriched Grassland	Land tenure comparison	II-2	NSW
133	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
134	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
135	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
136	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
137	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
138	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
139	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
140	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
141	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
142	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
143	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
144	McIntyre & Lavorel	1994	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
145	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
146	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
147	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
148	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
149	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
150	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
151	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
152	McIntyre & Lavorel	1994	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
153	Meers et al	2008	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	VIC
154	Meers et al	2008	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	VIC
155	Moore	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
156	Moore	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
157	Moore	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
158	Moore	1953	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
159	Morgan	1997	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	VIC
160	Morgan & Rollason	1995	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-3	VIC
161	Pettit & Friend	2001	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	WA

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162	Pettit, Ladd & Froend	1998	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	WA
163	Pettit, Ladd & Froend	1998	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-3	WA
164	Pettit, Ladd & Froend	1998	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	WA
165	Pettit, Ladd & Froend	1998	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	WA
166	Pettit, Ladd & Froend	1998	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-3	WA
167	Pettit, Ladd & Froend	1998	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	WA
168	Price and Morgan	2007	Ungrazed	enriched	Enriched Grassland	Experimental manipulation	II-1	VIC
169	Prober & Theile	1995	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
170	Prober & Theile	1995	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
171	Prober & Thiele	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
172	Prober & Thiele	2004	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
173	Prober & Thiele	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
174	Prober & Thiele	2004	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
175	Prober et al.	2002	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
176	Prober et al.	2002	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
177	Prober et al.	2002	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	NSW
178	Prober et al.	2005	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	NSW
179	Prober et al.	2005	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	NSW
180	Reseigh	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
181	Reseigh	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
182	Reseigh	2004	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	NSW
183	Reseigh	2004	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
184	Reseigh	2004	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
185	Reseigh	2004	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
186	Reseigh	2004	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
187	Robertson	1985	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-3	VIC
188	Robertson	1985	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-3	VIC
189	Robinson & Dowling	1976	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
190	Robinson & Dowling	1976	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
191	Robinson & Dowling	1976	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	NSW
192	Robinson & Dowling	1976	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
193	Robinson & Lazenby	1976	Grazed	not enriched	Past fertilised	Experimental manipulation	II-1	NSW
194	Robinson & Lazenby	1976	Grazed	not enriched	Past fertilised	Experimental manipulation	II-1	NSW

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195	Robinson & Lazenby	1976	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-1	NSW
196	Robinson & Lazenby	1976	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-1	NSW
197	Robinson & Lazenby	1976	Grazed	not enriched	Past fertilised	Land tenure comparison	II-3	NSW
198	Roe	1947	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
199	Roe	1947	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
200	Roe	1947	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
201	Rogers and Whalley	1989	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
202	Stuwe & Parsons	1977	Ungrazed	not enriched	Reference Grassland	Land tenure comparison	II-2	VIC
203	Stuwe & Parsons	1977	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	VIC
204	Tiver	1947	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	SA
205	Tiver	1947	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	SA
206	Tiver	1947	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	SA
207	Tiver	1947	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	SA
208	Tiver	1947	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	SA
209	Tiver	1947	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	SA
210	Tiver	1947	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	SA
211	Tiver	1947	Grazed	not enriched	Native Pasture	Land tenure comparison	II-2	SA
212	Tiver	1947	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-2	SA
213	Tremont	1994	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	NSW
214	Tremont	1994	Grazed	not enriched	Native Pasture	Experimental manipulation	II-1	NSW
215	Trumble and Fraser	1932	Grazed	enriched	Fertilized Pasture	Experimental manipulation	II-3	SA
216	Verrier & Kirkpatrick	2005	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	TAS
217	Whalley et al.	1978	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
218	Whalley et al.	1978	Grazed	enriched	Fertilized Pasture	Land tenure comparison	II-3	NSW
219	Whalley et al.	1978	Grazed	not enriched	Native Pasture	Land tenure comparison	II-3	NSW
220	Williams	1955	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-3	NSW
221	Williams	1956	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	NSW
222	Williams	1956	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	NSW
223	Williams	1956	Ungrazed	not enriched	Exclosed native pasture	Land tenure comparison	II-2	NSW
224	Williams	1969	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	II-1	NSW
225	Zimmer et al	2009	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	VIC
226	Zimmer et al	2009	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	VIC
227	Zimmer et al	2009	Ungrazed	not enriched	Exclosed native pasture	Experimental manipulation	I	VIC

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Appendix 3 Frequency of species in each land-use state based only on those ranked 1-5 within an observation. Total number of observations provided for enriched grassland and past fertilized pasture.

Species	Enriched Grassland (n=2)	Exclosed Native (n=20)	Fertilized Pasture (n=32)	Native Pasture (n=78)	Past Fertilized (n=8)	Reference Grassland (n=39)
<i>Acetosella vulgaris</i> *	1	0.00	0.00	0.00	2	0.00
<i>Anthoxanthum odoratum</i> *	0	0.10	0.00	0.00	0	0.00
<i>Aristida ramose</i>	0	0.05	0.09	0.14	0	0.00
<i>Arthropodium minus</i>	0	0.10	0.00	0.00	0	0.00
<i>Austrodanthonia bipartita</i>	0	0.00	0.00	0.00	3	0.00
<i>Austrodanthonia caespitosa</i>	0	0.20	0.06	0.04	0	0.10
<i>Austrodanthonia spp.</i>	0	0.35	0.31	0.28	7	0.13
<i>Austrostipa scabra</i>	0	0.15	0.09	0.12	0	0.05
<i>Austrostipa spp.</i>	0	0.15	0.09	0.24	0	0.18
<i>Austrostipa stiposa</i>	0	0.00	0.00	0.00	0	0.13
<i>Bothriochloa macra</i>	0	0.00	0.19	0.13	1	0.00
<i>Briza spp.*</i>	1	0.15	0.03	0.01	1	0.05
<i>Bromus spp.*</i>	2	0.00	0.25	0.08	1	0.03
<i>Chloris truncata</i>	0	0.05	0.03	0.13	1	0.00
<i>Echium plantagineum</i> *	0	0.00	0.00	0.03	2	0.00
<i>Epilobium billardieranum</i>	0	0.05	0.00	0.00	2	0.00
<i>Eragrostis brownie</i>	0	0.00	0.03	0.00	3	0.00
<i>Holcus lanatus</i> *	1	0.10	0.06	0.00	2	0.05
<i>Hordeum leporinum</i> *	0	0.00	0.13	0.05	1	0.00
<i>Hypochaeris radicata</i> *	0	0.15	0.09	0.09	2	0.03
<i>Hypochaeris spp.*</i>	0	0.20	0.16	0.19	2	0.05
<i>Juncus bufonius</i>	0	0.00	0.00	0.00	2	0.00
<i>Leontodon taraxacoides</i> *	0	0.00	0.13	0.05	0	0.00
<i>Leptorhynchus squamatus</i>	0	0.10	0.00	0.03	0	0.03
<i>Lolium rigidum</i> *	0	0.00	0.13	0.04	1	0.00
<i>Lolium spp.*</i>	1	0.00	0.16	0.08	2	0.05
<i>Maireana ciliata</i>	0	0.10	0.00	0.00	0	0.00
<i>Microlaena stipoides</i>	1	0.05	0.13	0.14	4	0.23
<i>Oxalis corniculata</i> *	0	0.00	0.00	0.00	2	0.00
<i>Panicum effusum</i>	0	0.00	0.09	0.04	4	0.00
<i>Phalaris aquatica</i> *	2	0.00	0.03	0.00	0	0.05
<i>Poa costiniana</i>	0	0.10	0.00	0.00	0	0.00
<i>Poa rodwayi</i>	0	0.00	0.00	0.01	0	0.21
<i>Poa sieb/lab</i>	2	0.10	0.06	0.23	0	0.59
<i>Polygonum aviculare</i> *	0	0.00	0.00	0.00	2	0.00
<i>Romulea minutiflora</i> *	0	0.10	0.00	0.03	0	0.00
<i>Romulea rosea</i> *	1	0.10	0.00	0.03	1	0.03
<i>Sida spp.</i>	0	0.10	0.00	0.04	0	0.00
<i>Sporobolus elongatus</i>	0	0.00	0.09	0.03	3	0.00
<i>Themeda triandra</i>	1	0.45	0.03	0.31	1	0.59
<i>Trifolium dubium</i> *	0	0.05	0.13	0.01	0	0.00
<i>Trifolium repens</i> *	0	0.00	0.25	0.01	0	0.00
<i>Trifolium spp.*</i>	0	0.05	0.66	0.18	3	0.03
<i>Trifolium subterraneum</i> *	0	0.05	0.16	0.06	3	0.00
<i>Vulpia spp.*</i>	0	0.05	0.25	0.22	3	0.13