Chapter 2

COMPOSITION, STRUCTURE AND DISTRIBUTION OF NATIVE GRASSLAND AND GRASSY WOODLAND REMNANTS ON VICTORIA'S NORTHERN RIVERINE PLAIN

Abstract

Community data derived from existing databases and sampled from least disturbed grasslands and grassy woodland remnants throughout the Northern Plain were analysed using TWINSPAN to describe the nature and extent of community variation in relation to the environment and land management. Grassy vegetation of this region has been decimated over the past 160 years of agricultural land use. Today, native vegetation is represented by small, often isolated and threatened refugia scattered across all tenures including freehold land, and is of high conservation significance. Initial classification identified 196 samples as the grassy vegetation of interest and further analysis divided this subset into 14 discrete floristic groups. The grassy vegetation of the region has many floristic links with similar vegetation elsewhere in south-eastern Australia, but is characterised by the presence of chenopods and native therophytes. The groups were structurally either grassland (primarily western) with little representation from woody species, or woodland often with a well developed shrub layer, and were broadly floristically distinct. Community variation was linked to both environmental (i.e. geology, soils and precipitation) and anthropogenic factors (i.e. post-settlement land management linked to tenure). In grasslands much of the floristic patterning can be understood as shifts in the richness of structural/functional components in the vegetation in response to particular disturbance regimes - a framework that can be used to predict the impact of an applied disturbance. This framework will assist in the development of more appropriate and effective conservation management strategies for the region and lay the foundation for establishing experimentation designed to maintain and manipulate vegetation for conservation purposes.

Introduction

Consistent with patterns of land use and exploitation throughout temperate Australia, the vast majority of the Victorian landscape that lends itself to modern agricultural practices is privately owned, intensively managed and highly modified. The remaining non-arable regions, largely due to soil fertility and inaccessible terrain, are in contrast under public ownership and often managed as parks because of their 'natural' condition and scenic beauty (Gibbons and Rowan 1993). This polarity in land capability reflects a great variation in the structure and composition of natural vegetation and the wildlife it supports; each region contains a unique and often endemic assemblage of flora and fauna (Conn 1993). Consequently the characteristic grassy vegetation of the lowland fertile plains of Victoria such as the Northern Plain, Wimmera, Volcanic Plains and Gippsland Plains (Fig. 2.1*a*) has been decimated and replaced by exotic pastures and crops over the last 160 years of intensive agricultural land use (Stuwe 1986; Woodgate and Black 1988; Lunt 1991; McDougall and Kirkpatrick 1994). Furthermore, little area remains on public land or adequately protected in conservation reserves and there is a poor understanding of conservation management requirements (Frankenberg 1971; LCC 1983; Frood and Calder 1987; Department of Conservation and Environment 1992). Grassy refugia have great conservation value, often supporting many rare or threatened flora and fauna, because they are the best remaining examples of the former landscape that is now virtually extinct (Stuwe 1986; Foreman 1995*b*; Kirkpatrick *et. al.* 1995).

In the Northern Plain and Wimmera, remnant vegetation is typically present as small and often discrete refugia along roadsides, railway lines, miscellaneous parcels of public reserves (i.e. cemeteries, gravel/sand reserves and water reserves) and private property (Foreman and Westaway 1994). Whilst the cover of remnant woody vegetation can be as high as 8% (Robinson and Traill 1996), the area of least disturbed remnants ranges from 4% (across the former Shire of Gordon in Foreman and Westaway 1994) down to 1% with an average area of 28 hectares, 90% of which occur on roadsides and on private property (across the former Shires of Birchip and Wycheproof in Foreman and Bailey 1996). Although under some circumstances very significant refugia occur on public land, the vast majority of the remaining area of quality grassland vegetation is privately owned (Baker-Gabb 1993; Maher and Baker-Gabb 1993; Foreman and Westaway 1994).

The history of botanical exploration and survey in Victoria is predominantly a history of the public estate, in particular parks (Willis and Cohn 1993). Consequently, current knowledge is disproportionately biased towards the non-arable natural regions such as East Gippsland, the Snowfields and the Grampians (Costermans 1983; Conn 1993). Whilst there is a general understanding of broad vegetation patterns in the lowland regions, considerable detail is lacking - as this extract for Northern Plain grasslands from the recently published "Flora of Victoria" demonstrates:

> "Prior to European settlement, large areas of this region supported indigenous grasslands.... Only scattered remnants remain, and these have been greatly modified. It is assumed that these grasslands were dominated by species of *Danthonia* and *Stipa*." (Conn 1993)

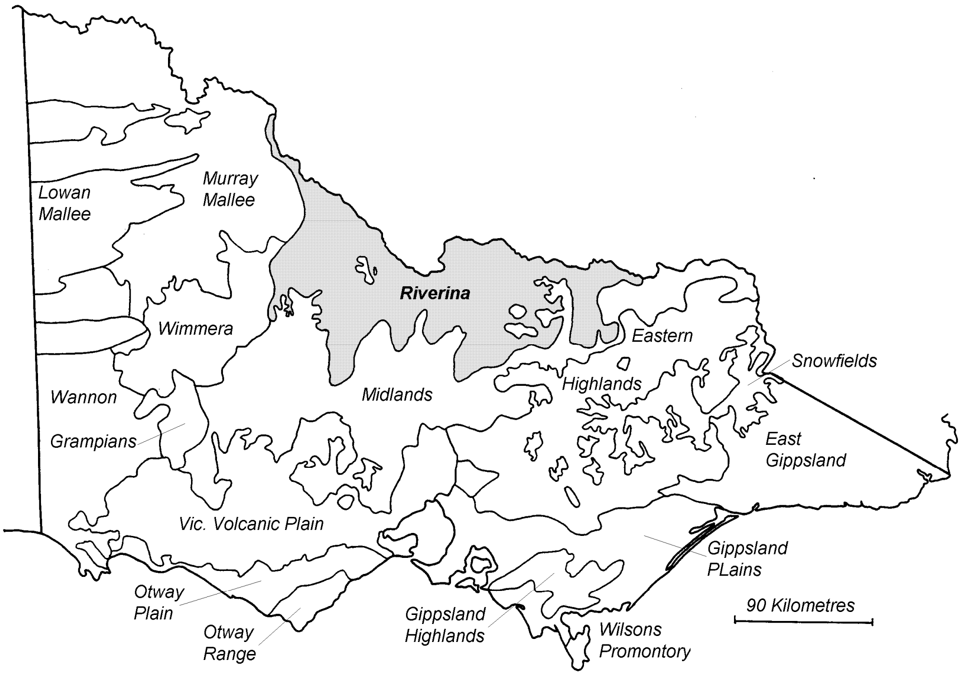
Results of the first botanical exploration in the Northern Plain were presented in Floras (Bentham 1863-78) and vascular plant censuses (Mueller 1886-88). This information was the result of numerous collections undertaken principably by T. L. Mitchell and Ferdinard J. H. Mueller (in his capacity as Government Botanist between 1853 and 1896). Others who contributed included: John Dallachy, J.G. Luehmann, Dr. Harmanns Beckler and William Lockhart Morton (Willis and Cohn 1993). Revised Floras (Ewart 1931; Willis 1970, 1972) and various additional censuses (Churchill and deCorona 1972; Beauglehole 1979, 1980, 1982, 1986, 1987, 1988) incorporating the work of the Victorian Field Naturalists Club, represented the culmination of over a century of botanical exploration in Victoria and the Northern Plain, although relatively little information on community composition and ecological relations has been documented (Willis 1935; Willis 1962).

Only in relatively recent times have efforts been made to describe and understand the vegetation of the lowland plains of Victoria (Stuwe and Parsons 1977; Stuwe 1986; McDougall and Kirkpatrick 1994) by sampling least modified refugia; a technique which has been rarely used in Australia despite the enormous potential (Fensham 1989).

The first significant attempt to systematically describe the vegetation of the Northern Plain was undertaken by Frood (1983) for the Land Conservation Council's report on the Murray Valley Area (LCC 1983). This study was restricted to the largest blocks of public land and vegetation classification was based on the structural dominants (Specht 1972) rather than community composition (LCC 1983). Since that time a number of relevant studies have been undertaken on crown land (Chesterfield *et. al.* 1984; Margules *et. al.* 1990; Horrocks *et. al.* 1989; Morcom 1990*a*), rail reserves (Frood 1985*a*; Ingeme 1994), for specific rare taxa and communities (Scarlett no date; Scarlett and Parsons 1982, 1993; McDougall *et. al.* 1991*a*, 1991*b*; Maher and Baker-Gabb 1993; McDougall and Kirkpatrick 1994; Foreman 1995*a*) and in specific regions (Foreman and Westaway 1994; Foreman and Bailey 1996; Foreman and Garner 1996) which have all contributed community information. However, these often narrowly focused projects have failed to provide a comprehensive overview of the complexity of the grassy vegetation in the Northern Plain. Most previous survey and knowledge are based on the larger remnants of public land in the region (collectively representing 8% of the region) such as Gunbower Island State Forest and Barmah Forest on the Murray River (Fig. 2.1*b*) and to a lesser extent areas such as Terrick Terrick State Park (Morcom 1990*a*). These areas typically represent the non-arable portions of the region (due to flooding) or in the case of Terrick Terrick are associated with unique geological features which are atypical of the region (Frankenberg 1971).

This chapter aims to address the deficiencies in knowledge of the vegetation of the Northern Plain by: (a) undertaking a floristic classification of remnant grassy vegetation for the entire Northern Plain and adjacent areas; (b) describing the nature and extent of community variation in relation to the environment; and (c) discussing the implications for conservation management.

(a)



(b)

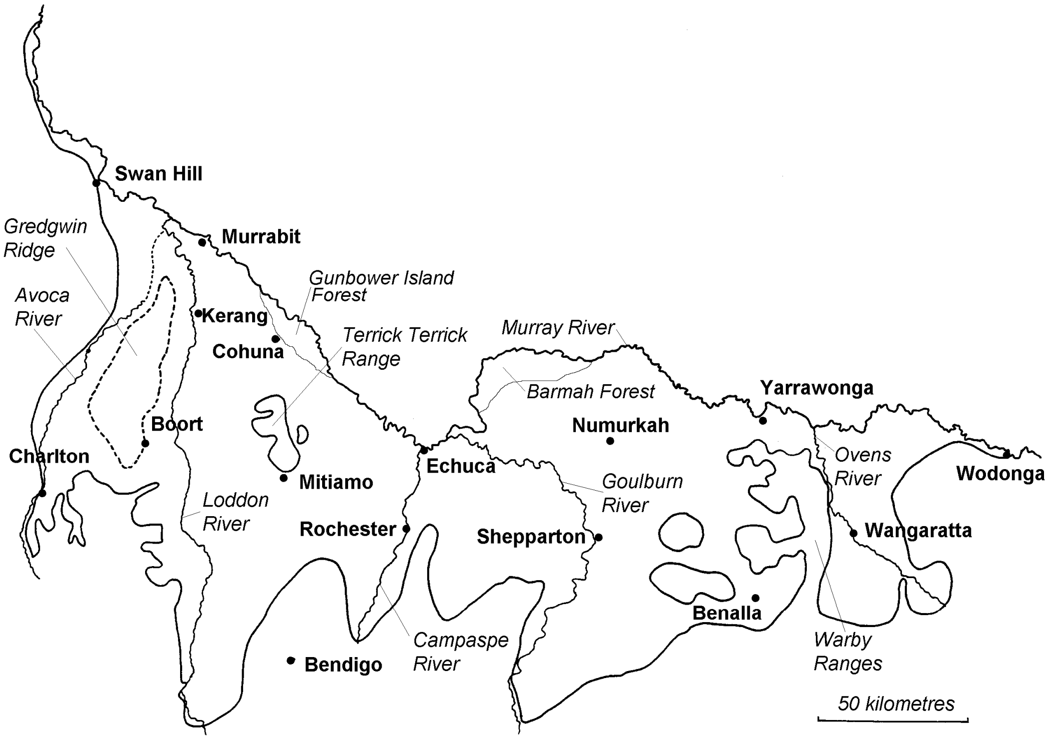


Fig. 2.1. (a) Map of Victoria depicting the extent of the Northern Plain (Riverina) and immediately adjacent biogeographic regions, and (b) Map of the Northern Plain highlighting key towns, rivers and other relevant features. Source: Conn (1993) and National Herbarium of Victoria (1992).

Materials and Methods

Study Area Location

The Riverine Plain of south-eastern Australia is the eastern portion of the Cainozoic sedimentary Murray River basin dominated by Quaternary alluvial sediments, and occupies a large portion of both Victoria and NSW (Butler *et al.* 1973). The Victorian portion is typically referred to as the Northern Plain (or Victorian Riverina in Conn 1993). The Northern Plain occupies approximately 25,000 km^2 and extends from Wangaratta and Wodonga in the east to Charlton in the west (National Herbarium of Victoria 1992) (Fig. 2.1*b*). It is bordered to the south by the uplifted Palaeozoic sedimentary, igneous and metamorphic ranges of central and eastern Victoria. This boundary meanders in a roughly east-west direction at an elevation of about 150 metres (Muir *et. al.* 1995). There are several prominent inliers including Palaeozoic granites and sediments such as the Terrick Terrick Range, and Tertiary marine sands such as the Gredgwin Ridge (Fig. 2.1*b*) (Macumber 1991). To the north, the study area is bounded by the Murray River, although the Riverine Plain extends into NSW to a latitude of about 33^{o}S (Butler *et. al.* 1973; Conn 1993). The north western boundary is an abrupt transition to the undulating aeolian landforms of the Murray Mallee (National Herbarium of Victoria 1992). The extreme western margin of the region where the Wimmera Plains adjoin is more difficult to define, although this edge is usually depicted as coinciding with the Avoca River (Butler *et al.* 1973; Cochrane *et. al.* 1991; Conn 1993). The Avoca River marks the transition between predominantly alluvial plains and those with closer affiliation with the aeolian landforms of the Victorian Mallee (Butler *et. al.* 1973; Macumber 1991).

In places across the Northern Plain, siliceous deposits associated with either palaeo-channels or dunes of an aeolian origin (including source bordering dunes and lake-side lunettes) are frequently found (Macumber 1978). These areas consist of relatively lighter textured soils than the surrounding plains and consequently support different vegetation (LCC 1983; Conn 1993).

This study focuses on grassy vegetation on the higher level Riverine Plain which is not generally subject to inundation, a region geologically referred to as the Shepparton Formation (Macumber 1991).

Study Area Climate and Land Use

The Northern Plain contains two broad climatic zones, each broadly to the east and west of the Campaspe River. The eastern region receives an annual rainfall of greater than 400 mm per annum with a "temperate, hot summer" climate, whilst the western portion receives less than 400 mm (LCC 1983). Because of the general lack of significant relief across the region, the climate changes gradually. Along a transect from south-east to north-west, summers become increasingly warmer and longer, and annual rainfall uniformly decreases, although the monthly rainfall distribution pattern is similar throughout (LCC 1983). Sixty percent of the annual precipitation falls in winter as low intensity, prolonged showers, whilst the remainder falls generally as brief, high intensity thunderstorms over summer (Bureau of Meteorology and Walsh 1993). Most precipitation is rainfall or occasionally hail and ranges from almost 700 mm per annum south of Benalla (Benalla 672 mm) and south-east of Wangaratta, to less than 350 mm north of Kerang at Murrabit (LCC 1983) (Fig. 2.1*b*). An average of 8 severe frosts and 21 mild frosts are experienced primarily between May and October. Droughts (defined as <200 mm between April and October) may occur every five years in the west and half as frequently in the east. The prevalent winds come from the north-west, west and south-west, with the summer characterised by hot and strong, north and westerly winds (LCC 1983).

Data Collection and Analysis

Field Survey

Remnant grasslands and grassy woodlands of the Northern Plain were sampled based on the following criteria: (a) districts not or poorly surveyed for remnant vegetation in the past, (b) districts not entirely modified by irrigation and other forms of agriculture, and (c) districts thought to have previously supported grassy vegetation (especially grasslands) based on historical records (see Chapter 3). Degree of modification was gauged by assessing the indigenous vascular flora richness and the cover-abundance of exotic vascular species (based on Fensham 1989).

Known and potential sites identified using this procedure were sampled by the author between 1992 and 1994 using 106, 25 m^2 quadrats (Gullan 1978; Gullan *et. al.* 1981; Fensham 1989). Quadrats were placed in the most diverse and/or least exotic dominated portions of the remnants in order to best reflect indigenous alliances of flora rather than those created by management or disturbance. Where more than one vegetation type (using structural and environmental indicators) was present, additional sampling was undertaken. All vascular plants growing in or with cover extending into each quadrat were recorded and assigned a visually assessed cover/abundance value based on a system modified from Braun-Blanquet (1965). Cover was defined as the percentage vertical projection of plant tissue: + = cover less than 5%, few individuals; 1 = cover less than 5%, many individuals; 2 = cover 5% to <25%, any number of individuals; 3 = cover 25% to <50%, any number of individuals; 4 = cover 50% to <75%, any number of individuals; and 5 = cover 75% to 100%, any number of individuals (Mueller-Dombois and Ellenberg 1974; Gullan 1978; Gullan *et. al.* 1981; Kent and Coker 1992).

The precise location of each site was recorded using geographical references along with a brief description and where appropriate, a small map of the remnant, specifying distances and directions from prominent fixed features such as fence lines. Notes were also made on features of ecological relevance such as vegetation structure (e.g. percent cover of grasses, herbs, litter, bare ground, shrubs, trees and other life-form groups where appropriate), surface soil features, geology and geomorphology, flooding regimes, management regimes (i.e. disturbances such as grazing or burning) and land tenure.

Species nomenclature follows Ross (1993), the systematics of Monocotyledons and Dicotyledons follows Cronquist (1981) and that of the remaining divisions follows Commonwealth of Australia (1981). Determinations made during survey work are based on Floras from South Australia (Jessop and Toelken 1986), NSW (Harden 1990-1993), Victoria (Willis 1970 and 1972) and subsequent advice from botanists at the Melbourne (MEL) and the Adelaide (AD) Herbaria. Specimens of some taxa collected are lodged at MEL and the reference collection was used to make determinations for difficult or critical groups. Specimens which could not be identified to species level usually because of infertile or immature material, were referred to by genus only. An asterisk preceding a plant name denotes that the taxon is naturalised.

Selection of Quadrat Data for TWINSPAN Analysis

All of the 106 newly sampled quadrats were stored on the Flora Information System (FIS) database maintained by the Department of Natural Resources and Environment (NRE) at the Arthur Rylah Institute (ARI) for Environmental Research in Heidelberg, Melbourne. Additional quadrats from the Northern Plain were extracted from the FIS in order to study broad vegetation patterning in the region and to select as broad a sample as possible of grassy vegetation quadrats for further investigation (356 quadrats in total collected by *McDougall et. al.* 1991*b* and NRE). This broad sample was classified using the polythetic divisive, two-way indicator species analysis, TWINSPAN (Hill 1979) and the program DECODA (Minchin 1991). Interpretation of this preliminary classification identified a further subset of grassy vegetation quadrats which became the focus of a second TWINSPAN classification (196 quadrats - the main subject of this study). Because this subset of grassy vegetation quadrats was split in half in the first classification (at a slightly lower level), the second classification was done in two sections (130 and 66 quadrats each). Investigation of the results emerging from these classifications formed the focus of the results and discussion.

Environmental, Climatic and Statistical Analyses

Each quadrat in the second TWINSPAN classification was assigned soil type derived from relevant soil survey publications (Butler *et. al.* 1942; Skene and Poutsma 1962; Skene 1963; Skene and Harford 1964; Skene 1971). These data were extracted from a Geographic Information System (GIS) database managed by the Institute for Sustainable Irrigated Agriculture (ISIA), Tatura. Mean annual precipitation was also predicted for each quadrat using BIOCLIM (Nix 1986).

In total 29 separate statistical analyses were performed; 7 floristic variables (total species richness, total exotic, total indigenous, woody, perennial indigenous herbs, annual indigenous, perennial graminoids, Victorian Rare or Threatened (VROT)) x 4 environmental variables (floristic group, grazing, geology and tenure), plus predicted mean annual rainfall (BIOCLIM) x floristic group. ANOVA provided the capacity to compare means of floristic variables through the calculation of Least Significant Difference (LSD) values.

Analysis of variance (ANOVA) was performed using GENSTAT 5.3 (Lawes Agricultural Trust, Rothamsted Experimental Station). In some cases data had to be log (natural) and inverse square-root transformed and/or treatments had to be removed in order to obtain homoskedasticity (homogeneity of variance).

Results

Preliminary Classification of Broad Vegetation Types on the Northern Plain

The preliminary TWINSPAN analysis separated the 462 sampled quadrats into 15 floristic groups at the fifth division in the classification (groups A to O in Fig. 2.2). Group J represents the key grassy vegetation of interest and consists of 196 quadrats comprising all 106 (54%) quadrats collected primarily from grasslands specifically for this study and an additional 90 quadrats from the FIS, which were collected for previous independent and unpublished surveys. These additional data were collected using identical techniques (see field sampling in methods) and dated from as far back as December 1986. All quadrats were distributed throughout the region, but were mainly concentrated in the area, west of the Campaspe River (Fig. 2.3, Fig. 2.1*b*).

Grp	Qd	Environment	Structure	Dominant plant groups/species
A	4	Saline depressions (not flooded)	SL	*Halosarcia* spp., **Juncus acutus* **Critesion* spp.
B	2	Dry (summer) freshwater lake beds	HL	**Heliotropium* spp., *Centipeda* spp. *Mimulus* spp.
C	5	Fast moving streams and channels (disturbed)	HL	*Vallisneria americana*
D	43	Stagnant billabongs and lagoons	F, WL	*Eucalyptus camaldulensis* and various aquatics
E	117	Riparian floodlands	WL, F, SL	*Eucalyptus camaldulensis* *Muehlenbeckia florulenta* and various semi-aquatics
F	1	Large freshwater permanent lake	HL	*Myriophyllum muelleri* *M. verrucosum*
G	3	Low clay plains (occasionally flooded)	WL	*Eucalyptus largiflorens* various Chenopodiaceae
H	8	Low clay plains (occasionally flooded)	WL, SL	*Eucalyptus largiflorens* *Halosarcia* spp. various annual exotics
I	53	Riparian plains (occasionally flooded)	WL	*Eucalyptus largiflorens* various perennial grasses, forbs and shrubs
J	**196**	**High level Riverine plain and surrounding slopes**	**WL, GL**	**Various trees, perennial grasses and herbs**
K	4	North east granite and associated slopes	WL, SL	*Eucalyptus blakelyi* and various shrubs, forbs and grasses
L	13	Upper slope Palaeozoic sediments - north east	F, WL	*Eucalyptus* spp., shrubs *Chionochloa pallida* and various herbs
M	9	Upper slope Palaeozoic sediments - north east (Chiltern)	F, WL	*Eucalyptus sideroxylon*, *E. microcarpa* and various shrubs
N	3	Lower slope Palaeozoic sediments - north east (Chiltern)	F, WL	*Eucalyptus microcarpa* various grasses and herbs
O	1	Permanent saline lake	Wet	*Ruppia megacarpa*
Tot	462			

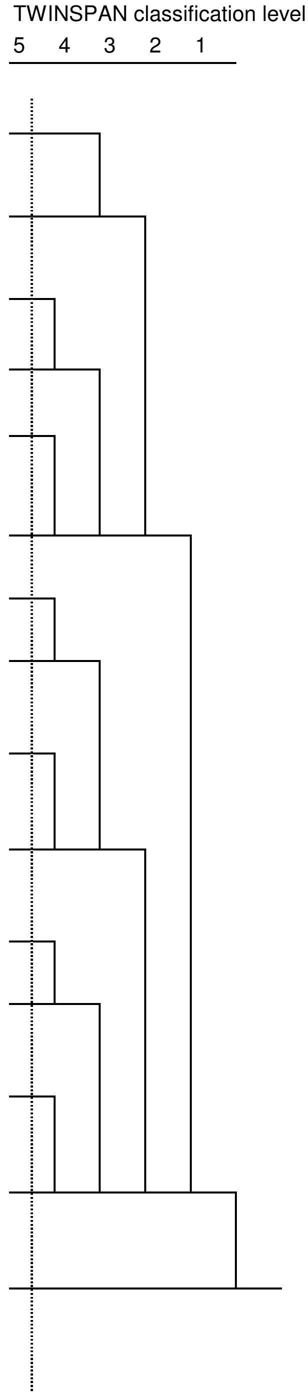


Fig. 2.2. Preliminary TWINSPAN classification of 462 quadrats from throughout the Northern Plain. Grassland and grassy woodland quadrats in group J were selected from this classification for further analysis. Grp = floristic group number (alpha). Qd = number of quadrats in each floristic group. Structure; HL = herbland, SL = shrubland, GL = grassland, WL = woodland, F = forest, Wet = wetland.

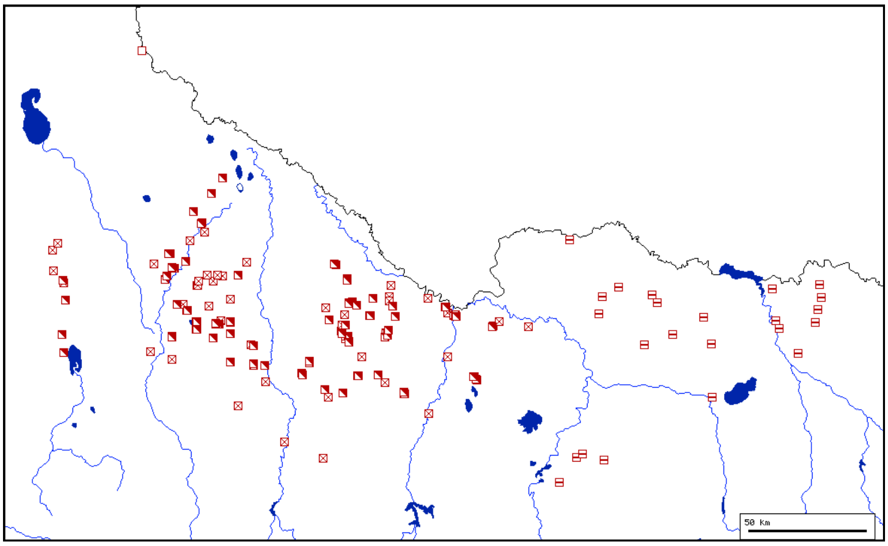


Fig. 2.3. Distribution of 196 grassland and grassy woodland quadrats in group J (Fig. 2.2). Source: the FIS. (Note: different symbols denote different database sources in the FIS)

The flora of group J consisted of 521 indigenous and exotic taxa. Of the 381 indigenous taxa (73% of all taxa), 39 are listed as rare or threatened in Victoria (Gullan *et. al.* 1990), five of which are also of national significance (Briggs and Leigh 1988) (Table 2.1). Twenty-seven percent of the flora consists of exotic taxa. The richest families contribute 53% of taxa to the total flora and are, in decreasing order: Poaceae, Asteraceae, Fabaceae (Mimosaceae has an additional seven taxa), Chenopodiaceae and Liliaceae (Table 2.1). One hundred and eighty-five taxa (65 exotic and 120 indigenous) occurred in over 50% of quadrats in group J (Appendix 2.1).

Table 2.1. Summary of the vascular flora of grassland and grassy woodland vegetation of the Northern Plain based on group J (Fig. 2.2). Victorian Rare or Threatened (VROT) source: Gullan *et. al.* (1990).

Division	Indigenous Taxa	VROT	Exotic Taxa	Total Taxa
Gymnosperms		1	-	1
Pteridophytes (Ferns and Fern Allies)	6	-	-	6
Monocotyedons	99	11	54	164
Dicotyledons	237	27	86	350
(Poaceae)	*54*	*8*	*47*	*109*
(Asteraceae)	*67*	*5*	*17*	*89*
(Fabaceae)	*6*	*6*	*20*	*32*
(Chenopodiaceae)	*22*	*5*	*-*	*27*
(Liliaceae)	*20*	*-*	*-*	*20*
Key Families Total	*169*	*24*	*84*	*277*
Total Taxa	342	39	140	521

Groups G, H, and I are closest to group J in the dendrogram (Fig. 2.2) and consist of *Eucalyptus largiflorens* dominated woodlands restricted to the periphery of riparian zones in the drier north-western portions of the study area generally west of the Campaspe River (Fig. 2.1*b*). The understorey is graminoid and herb-rich on Gunbower Island State Forest and dominated by various taxa of Chenopodiaceae near Kerang (frequently degraded by groundwater salinity). Vegetation of these groups is well represented on public land and is described in more detail in Chesterfield *et. al.* (1986), Horrocks *et. al.* (1989) and Margules *et. al.* (1990).

Groups K, L, M and N are next closest in the dendrogram to group J and represent various forms of Box Ironbark and related vegetation dominant on the Palaeozoic sedimentary and Devonian granite hills and ranges of the Midlands or Goldfields (Fig. 2.1*a*). Typically this forest or woodland vegetation is dominated by a variety of *Eucalyptus* species with a well developed shrubby understorey and is described in more detail in Muir *et. al.* (1995).

Groups C, D and E are further removed from group J and represent a series of riparian *Eucalyptus camaldulensis* forest or woodland dominated floodlands or associated fast or slow moving lagoons and billabongs. This vegetation is very widespread along all major water courses in northern Victoria and is described in further detail in Chesterfield *et. al.* (1984), Horrocks *et. al.* (1989) and Margules *et. al.* (1990).

The remaining groups A, B, F and O represent a series of miscellaneous wetland communities including permanent freshwater and saline lakes dominated by obligate aquatic flora, and the dry lake beds of ephemeral wetlands dominated by summer active herbs. The flora of these wetland environments is described in Frood (1995*b*), Victorian Government (1989) and O'Donnell (1990).

Thus the main trend in the vegetation classification (Fig. 2.2) is (except for groups A, B), from relatively fertile and/or inundated wetland vegetation (groups C, D, F and O), through seasonally flooded wetlands (groups E, G, H and I), to non-flooded woodlands and grasslands (group J), and drier woodlands and forests on less fertile slopes and hills (groups K, L, M and

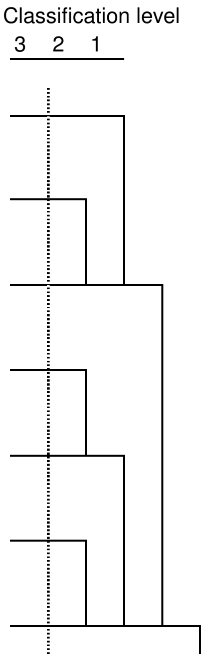
N). The higher level woodlands and grasslands which will be examined further (group J) are most closely related to irregularly flooded wetlands often dominated by *E. largiflorens*.

Detailed Classification of Grassy Vegetation Types on High Level Riverine Plain and Surrounding Slopes.

Further TWINSPAN classification of the quadrats selected from the preliminary classification (group J) separated the 196 quadrats into 14 groups at the third division in the classification (Fig. 2.3). Species occurring in 50% or more of quadrats in each group are listed in Appendix 2.1, and summaries of the general floristic and environmental characteristics of each group are shown in Appendix 2.2. The groups range in size from 1 to 34 quadrats. It is difficult to draw conclusions on those groups with low quadrat numbers (i.e. groups 1, 8, 10 and 14).

(a)

Grp	Qd	Label
1	2	Miscellaneous 1
2	34	Annual grassland and grassy woodland (south)
3	30	Annual grassland (north)
4	29	Perennial grassland (1)
5	21	Perennial grassland (2)
6	8	Western wet grassland
7	6	Northern grassland (species - poor)
Tot	130	



(b)

Grp	Qd	Label
8	1	Miscellaneous 2
9	9	Eastern wet grassland
10	2	Miscellaneous 3
11	28	Perennial grassy woodland (south)
12	12	Perennial grassy woodland (north west)
13	13	Marine plain (shrubby) woodland
14	2	Granite outcrop shrubland
Tot	66	

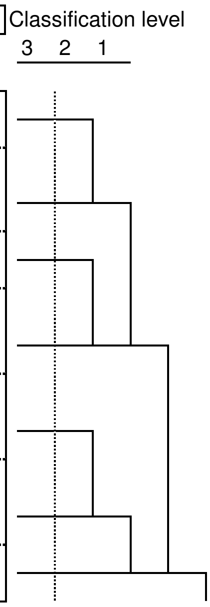
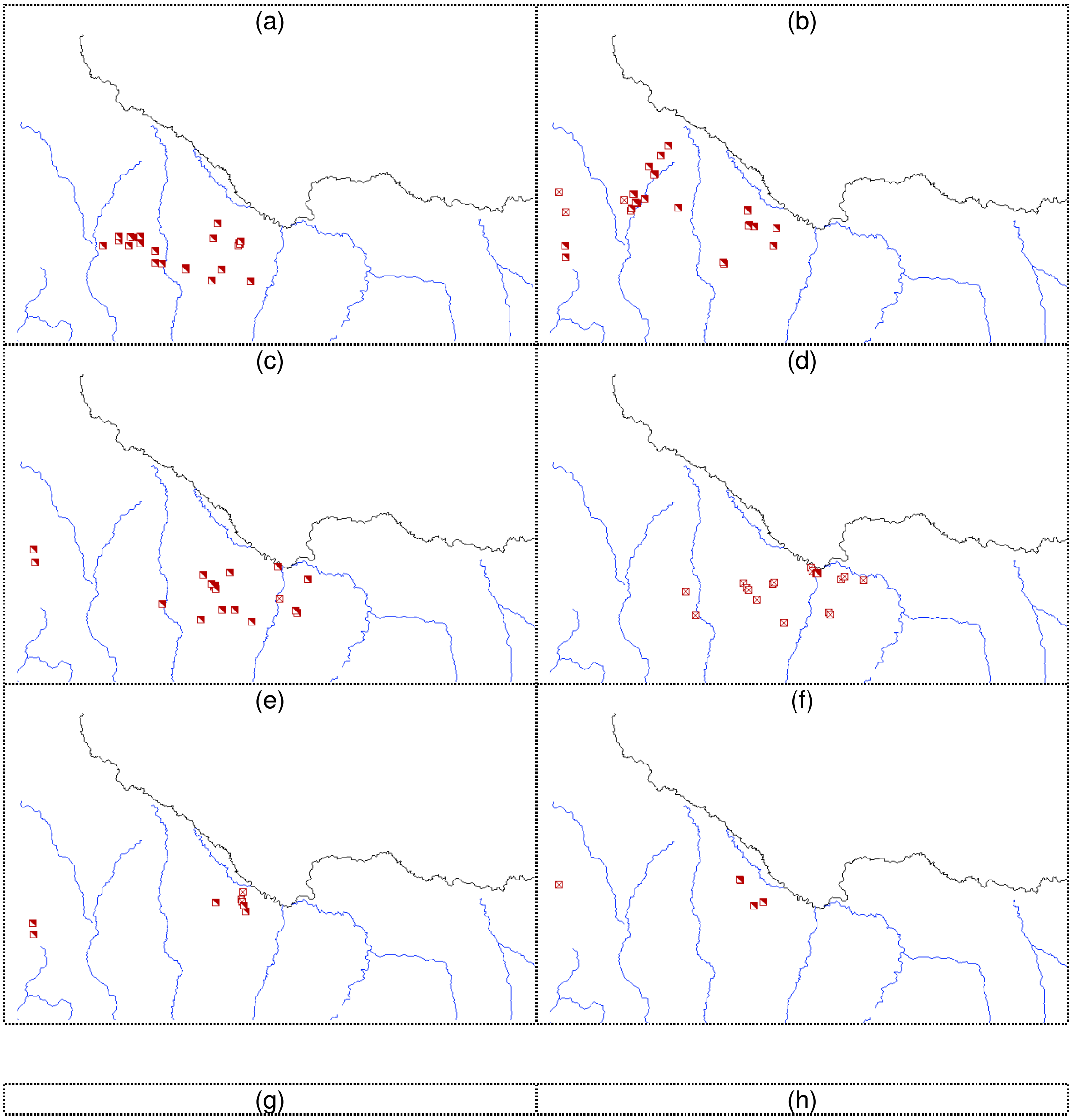


Fig. 2.4. TWINSPAN classification [in two parts, (a) and (b)] of grassland and grassy woodland quadrats in group J (Fig. 2.2) from throughout the Northern Plain. Grp = Group number. Qd = number of quadrats in each group.

Geographic Distribution of Grassland and Grassy Woodland Vegetation Groups

Many of the grassland and grassy woodland vegetation groups (Fig. 2.4) were of relatively restricted distribution, whereas others were widespread in the region. Groups 2, 3 and 13 are concerntrated in the western portions of the study area, whilst groups 4, 5, 6 and 7 are largely distributed in the central-west from around Echuca on the Campaspe River to Mitiamo (Fig. 2.5). Groups 3, 6 and 7 are generally more dominant at latitudes north of that at Echuca (approx 36°10’00”). Group 9 is restricted to the far eastern reaches of the Northern Plain around Wangaratta on the Ovens River. Groups 11 and 12 span the full width of the region from the Ovens River to the Avoca River (Fig. 2.5), with group 11 in particular having significant representation in the eastern parts of the area.



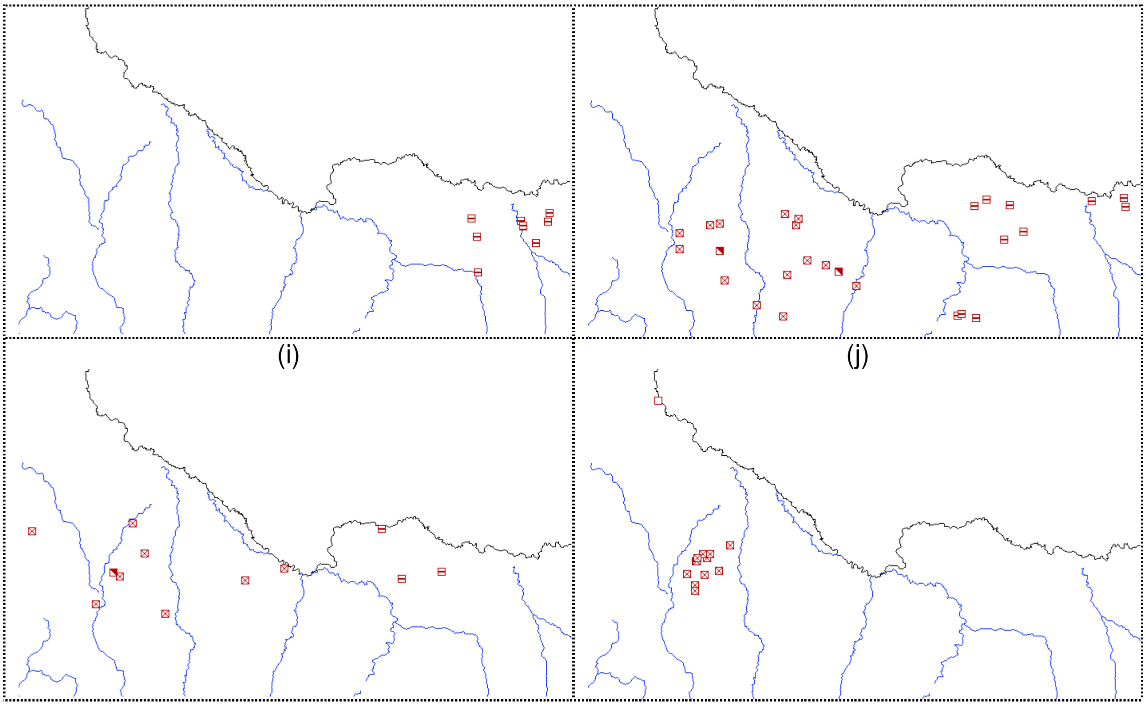


Fig. 2.5. Geographic distribution maps of quadrats in 10 of the 14 groups identified by the second TWINSPAN analysis. (a) group 2, (b) group 3, (c) group 4, (d) group 5, (e) group 6, (f) group 7, (g) group 9, (h) group 11, (i) group 12, (j) group 13. (Note: different symbols denote different database source in the FIS).

Structure and Dominant Species Composition

The grassy vegetation of the Northern Plains encompasses a great variety of structures and dominance, although the overwhelming majority of remnants are grassy woodlands (34%) and grasslands (57%) with various dominant species. The exceptions are shrublands (mallee) and low shrublands. In general, groups 1 to 9 are grasslands (73% of quadrats), whereas groups 10 to 14 are grassy woodlands (84% of quadrats) (Table 2.2).

Whilst groups 2 and 3 have a clear *Danthonia* spp. and *Stipa* spp. grassland component there is also a significant element *of Allocasuarina luehmannii*, *Callitris* spp. and *Eucalyptus* spp. grassy woodlands and shrublands. The closely associated groups 4 and 5 are primarily *Danthonia* spp. and *Stipa* spp. grasslands whilst group 9 is identical except for the addition of *Themeda triandra*. The characteristic feature of group 7 is the presence of *Nitraria billardierei* which creates a structure of a low-open shrubland. Group 6 consists of grasslands dominated by species such as *Homopholis proluta*, *Agrostis avenacea* and *Danthonia duttoniana* which prefer moist conditions (Table 2.2).

Groups 11, 12 and 13 are, in contrast to all other groups, primarily grassy woodlands. Group 11 encompasses the full range of grassy woodlands with a grassland structure dominating occasionally, whilst groups 12 and 13 are mainly dominated by *Eucalyptus* species and a combination of *Allocasuarina luehmannii* and *E. microcarpa* (box) respectively. Group 14 is a shrubland dominated by *Acacia deanei* subsp. *paucijuga* (Table 2.2).

Table 2.2. Relationship between the 14 grassland and grassy woodland groups and vegetation structure and dominant species composition. (see Fig. 2.2 for structure abbreviations)

Structure	Groups	1	2	3	4	5	6	7	8	9		10	11	12	13	14		Tot
WL	*Eucalyptus leucoxylon*	1	1	-	-	-	-	-	-	-	**2**	-	1	4	-	-	**5**	7
	Callitris spp.	-	2	-	-	-	-	-	-	-	**2**	-	1	-	-	-	**1**	3
	Allocasuarina luehmannii	-	5	3	-	-	-	-	-	-	**8**	-	1	-	4	-	**5**	13
	E. melliodora	-	1	-	-	-	-	-	-	-	**1**	-	-	-	-	-	**0**	1
	E. microcarpa	-	1	2	-	-	-	-	-	-	**3**	-	7	4	1	-	**12**	15
	E. largiflorens	-	-	1	2	1	-	-	-	-	**4**	-	-	1	-	-	**1**	5
	Combinations (various)	1	3	1	-	-	-	-	-	-	**5**	1	10	-	7	-	**18**	23
SL	*Eucalyptus* spp. (mallee)	-	2	-	-	-	-	-	-	-	**2**	-	-	1	1	-	**2**	4
	Acacia spp.	-	1	-	-	-	-	-	-	-	**1**	-	1	-	-	2	**3**	4
L/SL	*Nitraria billardierei*	-	-	5	1	-	-	4	-	-	**10**	-	-	-	-	-	**0**	10
WL/SL	**Totals**	**2**	**16**	**12**	**3**	**1**	**0**	**4**	**0**	**0**	**38**	**1**	**21**	**10**	**13**	**2**	**47**	**85**
GL	*Danthonia* spp. and *Stipa* spp.	-	18	18	26	19	-	2	1	6	**90**	-	7	2	-	-	**9**	99
	Themeda triandra	-	-	-	-	-	-	-	-	3	**3**	-	-	-	-	-	**0**	3
	Poaceae (hydrophilic spp.)	-	-	-	-	1	8	-	-	-	**9**	-	-	-	-	-	**0**	9
GL	**Totals**	**0**	**18**	**18**	**26**	**19**	**8**	**2**	**1**	**9**	**102**	**0**	**7**	**2**	**0**	**0**	**9**	**111**
	Total Quadrats	2	34	30	29	21	8	6	1	9	**140**	1	28	12	13	2	**56**	196

Quadrats from grassy woodlands contained significantly more total species and native species than grassland quadrats (***P<0.001) (Fig. 2.6). Quadrats of grassy woodland vegetation also had a significantly greater number of species of trees, tall shrubs, low shrubs, total woody component (***P<0.001), indigenous perennial forbs (*P=0.034) and grasses (***P<0.001). The richness of indigenous annual forbs, in contrast, is higher in grassland quadrats (***P<0.001). The presence of rare or threatened plants (Gullan *et. al.* 1990) is virtually identical between grasslands and grassy woodlands (mean richness = 1.8 and 1.5 species respectively) (Fig. 2.6).

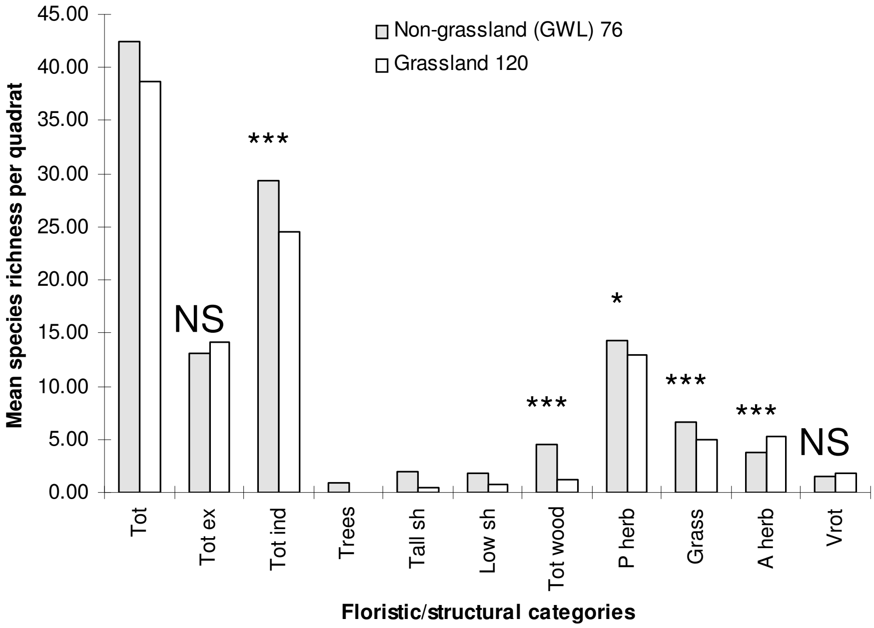


Fig. 2.6. Comparison of the floristic and structural features of grasslands with grassy woodlands throughout the Northern Plain. Non-grassland vegetation (primarily grassy woodlands, shaded columns, N = 76) and grassland vegetation (non-shaded columns, N = 120). See Table 2.3 for full names of floristic/structural categories. NS = not significantly different P=0.05, * = 0.01 < P < 0.05, ** 0.001 < P < 0.01, *** = P < 0.001. Tot woody, natural log transformed.

Floristics: Richness and Conservation Status

Total indigenous richness averaged 26 species per quadrat throughout the region, with the lowest and highest levels in groups 7 and 13 respectively (***P<0.001, Table 2.3). The species paucity in group seven is due to a combination of low indigenous perennial forbs (***P<0.001) and grasses. In contrast, the richness of group 13 is entirely because of the high number of shrubs. The exotic component is consistently rich in the vegetation (typically exceeding 11 species) with highest levels reached in groups 9 and 14 (>20 exotics per quadrat, ***P<0.001 for group 9) (Table 2.3).

Many of the 14 groups differed significantly in the number of total native species, woody species, perennial forbs, perennial grasses, annual forbs and VROT, per quadrat, as shown in Table 2.3.

Table 2.3. Summary of the vascular flora within each of the 14 groups by selected life-form groups (habit and life history). Indig = indigenous species (I). VROT = Victorian Rare Or Threatened species (Source: Gullan *et. al.* 1990). P = F probability, T(superscript) = natural log transformation required to stabilise variances. Not significantly different values within each floristic category have the same superscripts.

Group	P	1	2	3	4	5	6	7
All species	-	41.0	41.1	33.7	36.8	41.8	36.5	29.0
Exotic species	<0.001	11.0	13.4^{ac}	11.0^{a}	13.8^{ac}	15.0^{cb}	11.0^{a}	11.2^{a}
Indigenous species	<0.001	30.0	27.8^{bc}	22.7^{abc}	23.0^{ac}	26.8^{bc}	25.5^{bc}	17.8^{a}
Trees (I)	-	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Tall-med shrubs (I)	-	3.0	0.3	0.1	0.6	1.0	0.5	1.0
Low shrubs (I)	-	1.0	0.4	1.1	1.6	1.1	0.6	1.8
All woody species (I)	<0.001	4.0	0.8^{ab}	1.2^{abc}	2.1^{bc}	2.1^{bc}	1.1^{abc}	2.8^{c}
Perennial forbs (I)	<0.001	18.0	14.6^{c}	9.9^{b}	12.7^{bc}	16.0^{c}	14.0^{c}	5.2^{a}
Perennial grasses (I)	<0.001^{I}	5.5	5.1^{ab}	4.0^{ab}	5.0^{ab}	4.9^{ab}	4.1^{a}	3.3^{a}
Annual forbs (I)	<0.001	2.5	7.3^{b}	7.6^{b}	3.2^{a}	3.8^{a}	6.3^{b}	6.5^{b}
VROT	<0.001	2.0	2.2^{bcd}	1.7^{abc}	1.6^{ab}	2.7^{d}	1.6^{ab}	1.3^{a}
Number of Quadrats		2	34	30	29	21	8	6

Group	P	8	9	10	11	12	13	14	Grand Mean
All species	-	19.0	47.1	25.0	45.8	44.5	45.5	43.0	40.1
Exotic species	<0.001	9.0	20.7^{d}	14.0	16.5^{c}	13.3^{ac}	11.6^{ab}	21.5	13.8
Indig species	<0.001	10.0	26.4^{bc}	11.0	29.3^{cd}	31.3^{cd}	33.8^{e}	21.5	26.4
Trees (I)	-	0.0	0.1	2.0	0.7	0.8	2.2	0.0	0.3
Tall-med shrubs (I)	-	0.0	0.1	2.0	1.0	1.8	5.5	4.5	1.0
Low shrubs (I)	-	0.0	0.0	0.0	0.5	3.3	3.7	0.0	1.2
All woody species (I)	<0.001	0.0	0.2^{a}	4.0	2.2^{bc}	5.8^{d}	11.4^{e}	4.5	2.5
Perennial forbs (I)	<0.001	6.0	16.0^{c}	2.0	15.8^{c}	14.8^{c}	13.8^{c}	10.0	13.5
Perennial grasses (I)	<0.001^{T}	4.0	7.2^{ab}	3.0	8.4^{b}	7.3^{b}	6.8^{ab}	4.0	5.6
Annual forbs (I)	<0.001	0.0	3.0^{a}	2.0	2.9^{a}	3.3^{a}	1.8^{a}	3.0	4.7
VROT	<0.001	0.0	0.8^{a}	0.0	1.0^{a}	0.8^{a}	2.5^{bcd}	0.0	1.7
Quadrat Number		1	9	1	28	12	13	2	196

Relationship to Grazing

Total, exotic and indigenous richness of the grassland and grassy woodland vegetation is lower under grazing (indigenous richness *P=0.02, Fig. 2.7). Ungrazed vegetation has a greater richness in trees, tall shrubs, low shrubs, total woody component, indigenous perennial forbs and grasses (all ***P<0.001, Fig. 2.7). The richness of indigenous annual forbs, in contrast, is significantly higher in quadrats under grazing (***P<0.001, Fig. 2.7). The presence of rare or threatened plants (Gullan *et. al.* 1990) is virtually the same in quadrats with and without frequent grazing (mean richness = 1.9 and 1.6 species respectively, NS P=0.1, Fig 2.7).

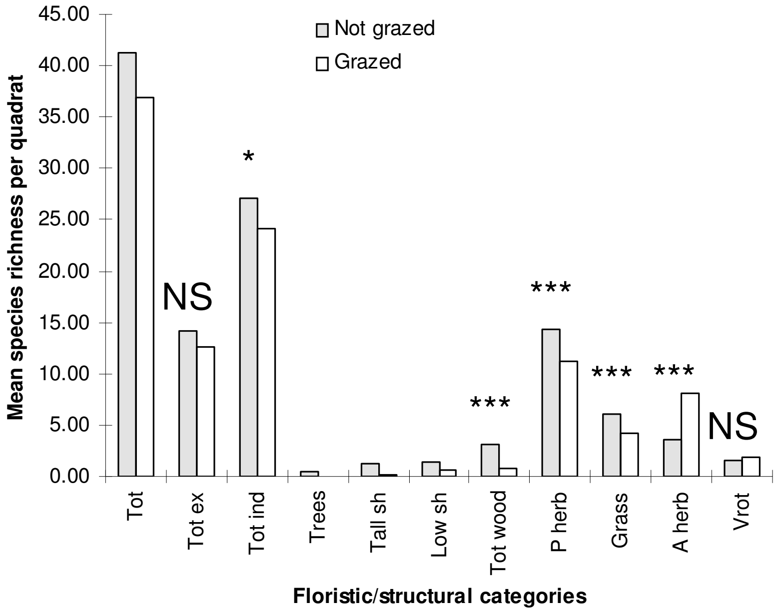


Fig. 2.7. Relationship between stock grazing and florsitics/structure of grassland and grassy woodland remnants throughout the Northern Plain (196 quadrats). All quadrats are (non-shaded columns, N = 50) or are not (shaded columns, N = 146) exposed to frequent stock grazing. See Table 2.3 for full names of floristic/structural categories. NS = not significantly different P=0.05, * = 0.01 < P < 0.05, ** 0.001 < P < 0.01, *** = P < 0.001. Tot woody, natural log transformed.

Environmental Relationships of Grassland and Grassy Woodland Vegetation Groups

Geology and Geomorphology

The majority of quadrats across the 14 groups are located on Quaternary riverine alluvium (75%), in particular, groups 3 to 12 are more or less restricted to the Riverine Plain. Group 2 and to a lesser extent group 11, includes a mix of additional non-riverine geological formations such as Tertiary marine sediments (Parilla Sand) and Devonian granitic hills (Table 2.4). Group 13 is almost entirely non-riverine and is restricted to the marine plain west of Boort, a region often referred to as the Gredgwin Ridge. Group 14 likewise is non-riverine and is confined to the peaks of outcropping granite along the Terrick Terrick Range, north of Mitiamo (Table 2.4).

Table 2.4. Number of quadrats occurring in each of the 14 grassland and grassy woodland groups by geology and geomorphology. Source: Cockrane *et. al.* (1991), Macumber (1991).

Groups	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Tot
Granite	-	4	-	-	-	-	-	-	-	-	3	-	-	2	9
Metamorphic	1	-	-	-	1	-	-	-	-	-	2	1	-	-	5
Parilla Sand (marine)	-	11	3	-	-	2	-	-	-	-	3	2	10	-	31
Alluvium (riverine)	1	19	26	27	20	6	6	1	9	1	20	9	1	-	146
Aeolian (lunette)	-	-	1	2	-	-	-	-	-	-	-	-	2	-	5
Total Quadrats	2	34	30	29	21	8	6	1	9	1	28	12	13	2	196

Land Tenure and Management Regime (Stock Grazing)

Grassland and grassy woodland remnants are found anywhere in the landscape that has been little disturbed by post-settlement land use. They are often small, isolated refugia found on miscellaneous public reserves such as cemeteries, parks and water reserves (26% of all quadrats), road reserves (45%), rail reserves (7%) and on private property (22%) (Table 2.5). Public reserves, rail reserves and road reserves are not currently subject to frequent domestic stock grazing (80%, 97% and 100% of quadrats respectively). In contrast, ninety two percent of private property sites are frequently exposed to stock, usually at a regionally light intensity (~1 Dry Sheep Equivalents [DSE]/ha, Diez and Foreman 1995). Whilst many of the broader roadsides are designated stock routes, they are only infrequently used as such - a situation that has prevailed in the region for at least the last few decades (Diez and Foreman 1995). Some rail reserves, primarily in the east, are currently subject to frequent burning in order to perpetuate historical fire protection regimes (Glen Johnson pers. comm.).

Groups 8 to 14 are mainly located on public reserves and road reserves, often where stock grazing is rarely or never present and in many cases actively excluded (Table 2.5). The remaining groups are variously exposed to grazing and are found across all tenure categories. Groups 6 and 7 are primarily restricted to private property exposed to grazing, whereas 90% of group 4 and 5 quadrats occur along roadsides, rail lines and in cemeteries/parks not exposed to stock. Group 2 and 3 quadrats are evenly spread across all land tenures and evenly divided between grazing regimes (Table 2.5).

Table 2.5. Relationship between land tenure and stock grazing frequency in each of the 14 grassland and grassy woodland groups. G = Is (Yes) or Isn't (No) frequently (usually continuously) grazed by stock (sheep or cattle) at various levels of intensity.

Groups	G	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Tot
Public Reserve	Y	-	3	4	1	-	1	-	-	-	-	1	-	-	-	10
	N	1	5	3	4	2	-	-	-	1	-	13	5	4	2	40
totals		1	8	7	5	2	1	0	0	1	0	14	5	4	2	50
Road Reserve	Y	-	-	1	-	-	1	1	-	-	-	-	-	-	-	3
	N	1	11	7	20	11	1	1	1	6	1	12	7	9	-	87
totals		1	11	8	20	11	2	2	1	6	1	12	7	9	0	90
Rail Reserve	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	N	-	4	-	3	2	-	-	-	2	-	2	-	-	-	13
totals		0	4	0	3	2	0	0	0	2	0	2	0	0	0	13
Private Property	Y	-	11	15	1	2	5	5	-	-	-	-	-	-	-	39
	N	-	-	-	-	4	-	-	-	-	-	-	-	-	-	4
totals		0	11	15	1	6	5	5	0	0	0	0	0	0	0	43
Yes totals		0	14	20	2	2	7	5	0	0	0	1	0	0	0	51
No totals		2	20	10	27	19	1	1	1	9	1	27	12	13	2	145
Total Quadrats		2	34	30	29	21	8	6	1	9	1	28	12	13	2	196

The strong link between land tenure and grazing management is reflected in comparisons in the floristics and structure of quadrats between the four major tenure categories (Table 2.6). For instance, compared with all other land, private property has a generally lower perennial element; total woody species (***P<0.001 compared with public and road reserves), indigenous perennial forbs (*P=0.02 compared with rail reserves) and indigenous grasses (***P<0.001), whilst retaining a higher annual component (***P<0.001 - Table 2.6). Of the remaining tenure categories, not generally subject to grazing, rail reserves are richest in indigenous perennial forbs (NS, P=0.02) and indigenous grasses (NS, P<0.001), as well as exotics (NS, P=0.06 compared with road reserves, Table 2.6).

Table 2.6. Comparisons of the floristics and structure of quadrats across tenure categories (private property, public reserves, rail reserves and road reserves). See Table 2.3 for full names of floristic/structure categories. P = F probability, T(superscript) = natural log transformation required to stabilise variances. Not significantly different values within each floristic category have the same superscripts.

Floristic Category	P	Private	Public Res	Rail Res	Road Res	Total
Tot species	-	37.42	40.78	43.85	40.50	
Tot exotic	P=0.06	13.05[a]	12.96[a]	16.31[b]	14.19[ab]	
Tot indigenous	P=0.17	24.37[a]	27.82[a]	27.54[a]	26.31[a]	
Trees	-	0.00	0.58	0.23	0.38	
Tall shrubs	-	0.30	1.46	0.92	1.10	
Low shrubs	-	0.67	1.10	0.69	1.57	
Tot woody	P<0.001[l]	0.98[a]	3.14[bc]	1.85[ab]	3.04[c]	
Ind pere herb	P=0.02	11.63[a]	14.04[ab]	15.85[b]	13.78[ab]	
Ind grass	P<0.001[l]	3.91[a]	6.22[b]	6.54[b]	5.92[b]	
Ann herb	P<0.001	7.86[a]	4.42[b]	3.31[b]	3.57[b]	
VROT	P=0.013	2.14[a]	1.32[b]	1.77[ab]	1.69[ab]	
Quadrat Number		43	50	13	90	196

Soil Types and Drainage

Sixty three percent of all quadrats fell outside the mapped coverage of detailed soil type descriptions within the study area. Soils varied greatly across the range of quadrats from very well drained soils (usually non-riverine) to those with very poor drainage at the lowest elevations. The full range includes skeletal soils and sandy loam surface textures (generally non-riverine landsystems) (14% of quadrats), loamy sand deposits associated with palaeo-channels and lunette complexes (25%), very flat clay loam plains with a deep, heavily textured subsoil (40%) and water logged grey cracking clays (21%) (Table 2.7) (Butler *et. al.* 1942; Skene and Poutsma 1962; Skene 1963; Skene and Harford 1964; Skene 1971).

Groups 11, 12, 13 and 14 mainly occur on the better drained soils with relatively light surface textures occasionally grading into a clay loam where drainage is less impeded by the physical characteristics of the profile than similar soils elsewhere (Skene and Poutsma 1962; Skene 1963; Skene and Harford 1964; Skene and Sargeant 1966; Skene 1971; Sargeant *et. al.* 1978). Groups 6 and 7 occur over the heavier textured soils (clay loam and clay) typical of damp depressions and the northern reaches of the riverine deposits (Table 2.7). Groups 4 and 5 are mainly found on loam and clay loam soils, with the greatest texture range in group 4. Similarly, groups 2 and 3 have moderate drainage characteristics, but still encompass an enormous variation (Table2.7).

Table 2.7. Summary of soil types within each of the 14 grassland and grassy woodland groups. So = reference source, L = Loddon (Skene 1971), R = Rochester (Skene and Harford 1964), D = Deakin (Skene 1963), G = Goulburn (Skene and Poutsma 1962) and M = Murray Valley East (Butler *et. al.* 1942).

Groups	So	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Tot
Skeletal soils	L	-	-	-	-	-	-	-	-	-	-	1	-	-	2	3
Terricks sandy clay loam	L	-	1	-	-	-	-	-	-	-	-	1	-	-	-	2
Terricks sandy loam	L	-	3	-	-	-	-	-	-	-	-	-	-	-	-	3
Woolshed sandy loam	L	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Yarrawalla fine sandy loam	L	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
Sandy loam soils totals		0	4	0	1	0	0	0	0	0	0	2	0	1	2	10
Boosey loam	M	-	-	-	-	-	-	-	-	-	-	2	-	-	-	2
Lemnos loam	G	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Lunette soils (unclass)	D	-	-	-	2	1	-	-	-	-	-	-	-	-	-	3
Lyndger loam	L	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Mologa loam	L	-	-	-	2	1	-	-	-	-	-	-	-	-	-	3
Type 1 prior streams	L	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Wanalta loam	D	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2
Woolshed loam	L	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Wychitella loam	L	-	2	-	-	-	-	-	-	-	-	1	-	-	-	3
Yarrawalla loam	L	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Loam soils totals		0	2	3	6	3	0	0	0	0	0	4	0	0	0	18
Fernihurst clay loam	L	-	-	4	-	-	1	1	-	-	-	-	-	-	-	6
Kinypaniel clay loam	L	-	-	-	5	2	-	-	-	-	-	-	-	-	-	7
Kinypaniel/Fernihurst clay loam	L	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2
Koga clay loam	D	-	-	-	1	2	-	-	-	-	-	-	1	-	-	4
Koyuga clay loam	R	-	1	1	-	5	-	-	-	-	-	-	-	-	-	7
Terrappee clay loam	L	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Wychitella clay loam	L	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2
Clay loam soils totals		0	3	5	8	9	1	1	0	0	0	0	1	1	0	29
Boort clay	L	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Kerang clay	L	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1
Marona clay	L	-	-	-	-	-	-	2	-	-	-	-	-	-	-	2
Restdown clay	R	-	4	-	2	-	-	-	-	-	-	-	-	-	-	6
Restdown/Rochester clay	R	-	1	-	1	-	-	-	-	-	-	-	-	-	-	2
Towangur clay	L	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
Yuga clay	R	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1
Clay soils totals		0	5	2	2	0	1	3	0	0	0	0	0	1	0	15
All soils		0	14	10	18	12	2	4	0	0	0	6	1	3	2	72
Data unavailable		2	20	20	11	9	6	2	1	9	1	22	11	10	0	124
Total Quadrats		2	34	30	29	21	8	6	1	9	1	28	12	13	2	196

Overall, grassy woodland structures dominate on soils with good drainage characteristics and are gradually replaced by grasslands on heavily textured soils with impeded drainage susceptible to water logging in winter and severe cracking over summer (Fig. 2.8).

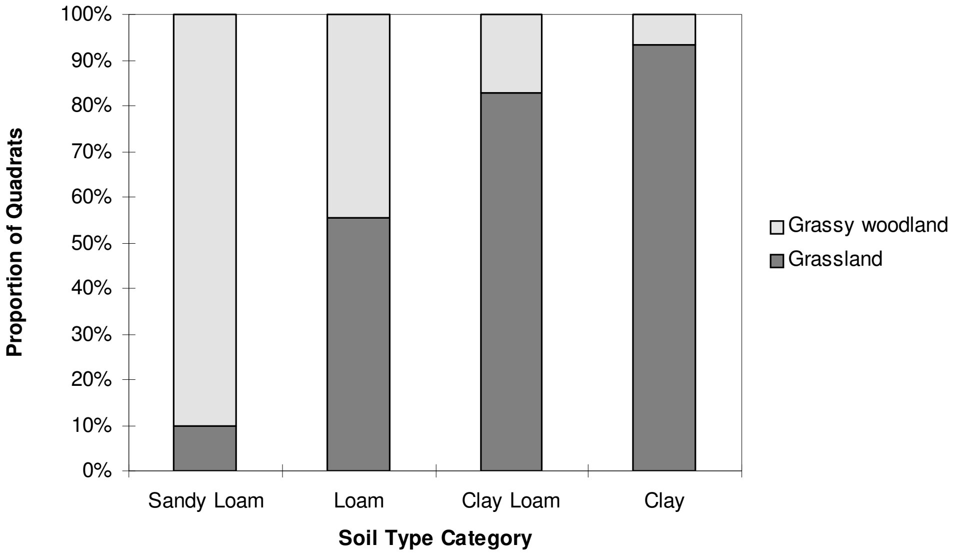


Fig. 2.8. Proportion of grassland and grassy woodland quadrats in four soil type classes graded by surface soil texture.

Mean Annual Precipitation

Except for groups 9 and 11, predicted mean annual rainfall for most of the quadrats oscillates around 400 mm (Fig. 2.9*a*). Groups 9 and 11 have the highest mean annual precipitation (580 mm, * P<0.001 and 466 mm, NS P<0.001 respectively) (Fig. 2.9*b*) because both are well represented in the east of the region (Fig. 2.5). Groups 3, 6 and 7 have a slightly lower mean annual precipitation (NS, P<0.001) than groups 2, 4, 5 and 12 because of the slight northern bias in their distribution (Fig. 2.9*b* and Fig. 2.5).

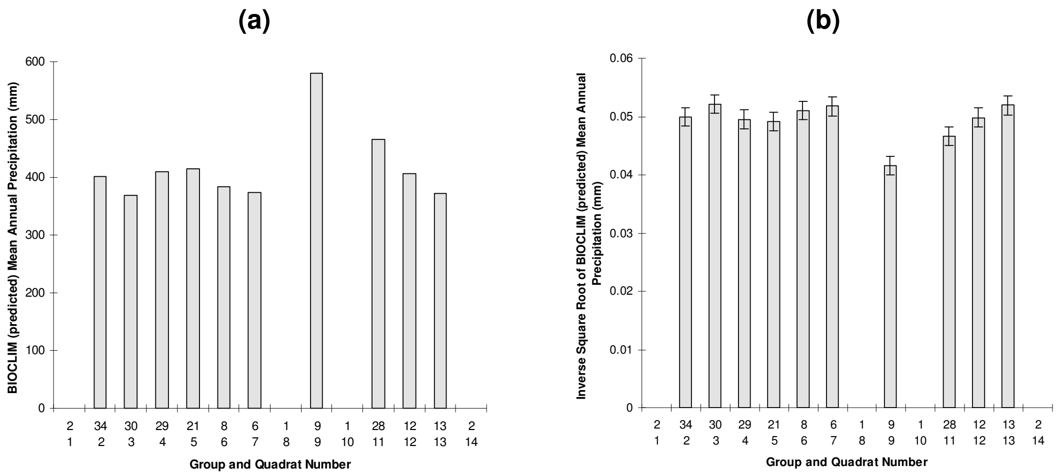


Fig. 2.9. (a) BIOCLIM predicted mean annual precipitation (mm) within 10 of the 14 vegetation groups. (b) Inverse square root transformation to stabilise variances and enable LSD comparison (P<0.001).

Discussion

Grassland and Grassy Woodland Flora of the Northern Plain

The indigenous vascular flora of grasslands and grassy woodlands of the Northern Plain represents 12% (521 taxa) of the total flora of Victoria (Ross 1993) and contains populations of at least 5% (39 taxa) of the state's rare or threatened taxa (Gullan *et.al.* 1990). Because of differences in sampling procedures and survey scope, it is difficult to make species richness (alpha and beta-diversity) comparisons between grassy communities in temperate Australia (Tremont and McIntyre 1994). However, the grassy flora of the Northern Plain, is similar to grassy vegetation elsewhere in south-eastern Australia with respect to total richness and mean richness per sample unit (quadrat) (McDougall and Kirkpatrick 1994; Tremont and McIntyre 1994).

The dominance in particular of the families Poaceae and Asteraceae (and to a lesser extent, Fabaceae and Liliaceae) in the flora is typical of south-eastern Australian grasslands (Stuwe 1986; McDougall and Kirkpatrick 1994). The richness of Chenopodiaceae however, is unusual and is a characteristic feature of the vegetation. The prevalence of this family hints at the close links between the Northern Plain and the arid and semi-arid interior of the continent (McDougall and Kirkpatrick 1994). The only family typical elsewhere in grassy vegetation and under-represented in the Northern Plain is Cyperaceae (McDougall and Kirkpatrick 1994).

Many threatened species, some of national significance, are restricted to the Northern Plain (many are also found in the Riverina of southern NSW). These include taxa from: *Maireana* and *Sclerolaena* (Chenopodiaceae); *Vittadinia*, *Brachyscome* and *Leptorhynchos* (Asteraceae); *Swainsona* (Fabaceae); and *Eryngium* (Apiaceae). However, few taxa are considered endemic to lowland grassland (and probably also grassy woodland) communities of south-eastern Australia (McDougall and Kirkpatrick 1994).

Just under a quarter (23%) of the flora of grasslands and grassy woodlands of the Northern Plain is regarded as exotic in Victoria (Ross 1993), and weeds were present in great abundance at most sites studied. These levels compare with about 35% in grasslands elsewhere in south-eastern Australia (Stuwe 1986; McDougall and Kirkpatrick 1994), 24% in the woodlands and forests of the infertile sedimentary hills of central Victoria (Muir *et. al.*

1995), and 28% across Victoria as a whole (Ross 1993; Carr *et. al.* 1992). The relatively low richness of exotics in the region could be attributed to the slightly drier conditions which fail to support a range of perennials widespread in regions receiving more rain.

Links with Adjacent Ecosystems and Regions

Within the Northern Plain, remnant grassy vegetation has closest floristic links with riparian plains (*Eucalyptus largiflorens*) woodlands best developed in the west of the region (Fig. 2.2). Whilst structurally the latter vegetation is a grassy woodland (with a scattering of medium to low shrubs), floristically it is transitional between grassy vegetation of the higher level riverine plain and wetlands of the active riverine flood plain.

To the south, remnant grassy vegetation directly adjoins and merges with the Box-ironbark vegetation of the Midlands or Goldfields (Fig. 2.2, Muir *et. al.* 1995). With the exception of some exotic plants (annual grasses and herbs), very few species characteristic of the Box-ironbark vegetation of the Goldfields (Muir *et. al.* 1995) were found frequently present in Northern Plain grassy vegetation. In areas at the foot of slopes and on low rises along the interface between the Midlands and the Northern Plain, the vegetation is structurally a grassy woodland whilst floristically transitional with the Midlands. The communities, Low Rises Grassy Woodland and Alluvial Terraces Herb-rich Woodland (Muir *et. al.* 1995) are two documented examples of such vegetation. Further research is required to determine how this vegetation should be classified.

To the west, the Northern Plain merges into the Wimmera Plain. Although a predominantly aeolian landscape (Butler *et. al.* 1973), the Wimmera shares many of the physical and landuse features of the Northern Plain. The distinctive floristic features of the grassy remnant vegetation of the western Wimmera occur in: (1) tree composition - the dominance of *Eucalyptus largiflorens* and *Allocasuarina luehmannii* instead of *E. microcarpa.* In some places mallee eucalypts and mallee boxes (*E. dumosa*, *E. behriana, E. porosa* and *E. odorata*) may also be present as a codominant (Foreman and Bailey 1996); (2) shrub presence and composition - a scattered shrub layer of *Maireana rohrlachii* and *Eutaxia diffusa/microphylla* complex is frequently present; (3) graminoid composition - *Stipa gibbosa* and *Elymus scabrus* are both less common in the western Wimmera, whilst *Stipa blackii* and *Homopholis proluta* are more frequent. *Stipa puberula* is an entirely new species that is relatively common in the Northern Wimmera apparently replacing *S. curticoma*; (4) forb composition - while a great number of species are shared between the two regions there are slight differences in composition and relative frequency - for example the therophyte *Goodenia pusilliflora* is 20% more frequent in the Wimmera (McDougall and Kirkpatrick 1994; Flora Information System 1995). Overall, the grassy flora of the Wimmera and the Northern Plain are very similar.

North of the Murray River, the Riverina biogeographic region extends for hundreds of kilometres into central NSW (Butler *et. al.* 1973; Thackway and Cresswell 1995). The native grassland vegetation of the NSW southern Riverina, particularly in the Jerilderie district, is very similar to that of the Northern Plain in Victoria on the basis of both floristics and structure (Porteners 1993; McDougall and Kirkpatrick 1994; Benson *et.al.* 1996). This floristic affinity is a reflection of the environmental similarities between the two regions (Soil Conservation Service of NSW 1990).

The floristic differences between the grassland flora of the two regions are essentially a consequence of shifts in the relative abundance and frequency of the same species - as virtually all species found in grasslands in Victoria are also found across the Jerilderie Plains (McDougall and Kirkpatrick 1994; Diez and Foreman 1995; Benson *et. al.* 1996). The distinctive floristic features of the grasslands of the Jerilderie Plains are: (1) a generally lower cover of perennial grasses and a greater abundance of seasonal perennial forbs such as *Swainsona murrayana*, *Calotis scabiosifolia* and *Brachyscome chrysoglossa*; (2) *Stipa scabra* is completely replaced by *S. nodosa*; (3) Unlike the grazed grasslands in Victoria especially, the low shrub *Leptorhynchos panaetioides* (syn. *Ixiolaena* spp.) is often visually dominant and abundant along many of the Travelling Stock Routes (TSR); and (4) larger shrubs such as *Acacia omalophylla* and most notably *A. pendula* are also frequently encountered along the TSR grasslands (McDougall and Kirkpatrick 1994; Foreman unpublished data).

Floristics, Structure and Management

With some exceptions grasslands are floristically distinct from grassy woodlands across the Northern Plains, with 8 of the 10 well sampled vegetation groups readily classified as either grassland or non-grassland on the basis of structure (Table 2.2). In groups where mixing occurred, this distinction emerged at slightly lower levels in the TWINSPAN classification (Fig. 2.4). In comparison to grasslands, grassy woodlands supported a greater richness of indigenous taxa because of greater abundance of woody species and to a lesser extent perennial forbs and tussock grasses. The woody element in the grassy woodland vegetation was equally represented by trees and tall to low shrubs. It is speculated that the greater richness of tussock grasses and perennial forbs could be related to an increase in ecological niches created by shading and other physical influences (i.e. the presence of shade tolerant species). In contrast, grassland structures tend to support a greater richness of indigenous annual forbs, perhaps because of the maintenance of an open grassy sward and the lack of tree/shrub shading.

Some of this difference can be explained by tenure and land use management. The vast majority of grassy woodland sites occurred on roadsides, rail reserves and public land that is not subject to frequent grazing and in many cases sites are not subject to any disturbances. This result is consistent with the conclusions drawn for white box woodlands in NSW (Prober and Thiele 1995), where highest indigenous richness was reported in remnants generally not subject to stock grazing. In contrast, over a third of the grassland sites sampled occured in freehold land subject to frequent (but light) stock grazing. Sampling sites on freehold land is unusual in vegetation ecology in south-eastern Australia (except for agricultural research) because most surveys have been systematically biased to all other tenures on the basis of the assumption that little remains under private ownership under stock grazing (Stuwe 1986; McDougall and Kirkpatrick 1994; Prober and Thiele 1995). In fact some of the largest, richest and most significant grassland remnants occur on conservatively managed freehold land (Foreman 1992; Maher and Baker-Gabb 1993).

The relative richness and abundance of indigenous perennials, particularly woody species, in grassy vegetation excluded from grazing, is presumably linked to palatability and habit - clearly some of these perennials are palatable to stock and are sensitive to even light grazing regimes. Frequently grazed paddocks very rarely support tall to low shrubs because the incessant browsing causes continuous defoliation and prevents successful reproduction (either preventing flowering, seed production or seedling establishment). Because the smaller shrubs are relatively short lived (compared to trees), they quickly die out creating a grassland or a grassy woodland devoid of a shrub layer. In due course, if continuous grazing is maintained, the scattering of large and often sensecent trees throughout the region will suffer a similar fate (Hobbs *et. al.* 1993; Bennett *et. al.* 1994; McIntyre and Lavorel 1994; McIntyre *et. al.* 1995). It should be noted, that historically many roadsides and other public land was probably subject to very intense and frequent grazing (Diez and Foreman 1995, Chaper 3) and the populations of woody species present today have likely regenerated after these episodes. It is possible that there were many species that became extinct very early on because they were unable to tolerate such extreme post-settlement disturbances.

Whilst there are some isolated examples of shrubs (such *as Maireana decalvans*) recolonising long-grazed paddocks (pers. obs.), shrubs tend not to invade grasslands if grazing is removed (see Chapter 4). This contrasts with the behaviour of shrubs in the Victorian Alps where the expansion of heath has been linked to disturbance of the grassy sward (resulting from cattle grazing) which allows seedling establishment (Williams 1987). Critical to the success of shrub re-establishment in the Alps is the availablility and dispersal of propagules (Williams 1987), the lack of which could explain the absence of shrub recolonisation in grazing exclosures on the Northern Plain.

In comparison with infrequently grazed grassland vegetation, frequently grazed paddocks support almost double the richness (and a far greater abundance) of a range of indigenous annuals. In fact one such species, *Leptorhynchos scabrus* (annual buttons), was thought to be extinct in Victoria until it was found in tens of thousands across a single paddock near Mitiamo (Foreman 1992). The presence of indigenous therophytes in the grasslands of Northern Victoria is characteristic, being much less developed in grassy ecosystems elsewhere in the state (Willis 1964; Stuwe 1986; John Morgan pers. comm.). Elsewhere, perennial forbs tend to occupy the interstices of the perennial grass matrix, especially where *Themeda triandra* is dominant (Stuwe and Parsons 1977). Presumably the need for disturbance to maintain an open grass sward and provide reproductive opportunities for interstital forbs (Stuwe and Parsons 1977; McDougall 1989; Lunt 1994; Lunt 1995*b*) applies equally on freehold grasslands in Northern Victoria (see Chapter 4). Therefore, stock grazing in annual grasslands of the Northern Plain, probably plays a similar role to fire in the *T. triandra* grasslands of southern Victoria. In this respect, rail sites are closely aligned with roadside vegetation despite the clear differences in post-settlement management (i.e. in the past rail reserves were frequently burnt and roasides were not, Diez and Foreman (1995)), suggesting frequent burning may also diminish the abundance of annuals in grasslands.

This management driven floristic (and structural) divergence is clearly evident in the distinction between groups 2/3 and 4/5 in the TWINSPAN classification. Not only do all four of these groups occupy a very similar geographic range, they are often found in close proximity and occasionally only separated by a fence. The significant and overriding effects of land use in lowland grassy vegetation have been identified elsewhere in the state. Lunt (1995*a*) found a similar floristic divergence between regularly burnt rail reserves and adjacent grazed forests. Not only does this suggest land management (and tenure) can be a good predictor of composition and structure in the vegetation, but also very significant vegetation can be found anywhere in the landscape where post-settlement land management has been relatively conservative.

Within the study area, post-settlement land management history has exerted a profound influence on all indigenous vegetation. The composition of vegetation on either side of a fence will often be significantly different. Whilst irrigation and cultivation usually result in the complete replacement of the indigenous vegetation with exotic species, stock grazing modifies vegetation by increasing the abundance of grazing tolerant species and decreasing that of grazing sensitive species resulting in structural decline, species extinctions and weed invasion. Other anthropogenic factors that have influenced the vegetation include: (a) extinction of indigenous herbivores and the subsequent “replacement” with domestic stock and rabbits, (b) selective clearance (especially plants with fodder and timber value), (c) modification of water movement regimes and (d) exclusion of fire (Moore 1953*a* and 1953*b*;

Connor 1966; Chesterfield *et al.* 1984; Morcom and Westbrooke 1992; Hadden and Westbrooke 1996). These anthropogenic disturbances may have been responsible for the loss of considerable floristic and community diversity in the region (Willis 1962; Frankenberg 1971; Frood and Calder 1987).

Whilst there is evidence to suggest at least some perennials are sensitive to stock grazing, many more are probably quite tolerant of grazing and in some instances species may actually require grazing or at least some kind of disturbance to persist. The annual *Leptorhynchos scabrus* introduced above is a case in point. With the exception of the grazed annual grassland vegetation, the indigenous/exotic division in the flora was coincident with a difference in the predominant type of plant life-cycle. As reported in Prober and Thiele (1995) for grassy white box woodlands in NSW, virtually all natives are perennial and a large proportion of the exotics are annual or biennial.

Interestingly, while exotic species were abundant throughout the vegetation, there was no link between either grazing frequency or soil parent material, and exotic richness. Whilst grazing may well have introduced naturalised flora to the landscape, there is no evidence to suggest grazing exclusion will reduce the richness of the exotic flora, nor that its perpetuation will increase it. In fact, weeds tend to become more abundant if disturbance is removed from a formerly grazed or cultivated remnant (pers. obs.). Vegetation in the east of the study area tended to be richer in exotics (similar to levels recorded across the Victorian Volcanic Plains, Stuwe 1986) because it supported a suite of higher rainfall dependant perennials on top of the typical range of annuals. This observation suggests overall richness of naturalised flora in the region maybe correlated to precipitation.

A similar grazing-neutral parameter was the richness of VROT (Victorian Rare or Threatened) species. In general, vegetation in the west of the study area had a greater average richness of rare or threatened species than that in the east, although they were equally represented in both grasslands and grassy woodlands. This could in part be explained by the distinctiveness of the flora in the west compared with surrounding natural regions (many groups were only found west of the Campaspe River) combined with the general poor level of reservation.

Most of the Northern Plains grassy vegetation occurs exclusively on the Riverine Plain, with only two groups occuring primarily on adjacent formations. Floristically the Riverine Plain has closest links to the Gredgwin Ridge or Marine Plain west of Boort (Fig. 2.1*b*) which is a gently undulating landform with similar soils and landuse history.

Previous classification schemes for the region's vegetation have been based on dominant species composition and structure (LCC 1983). Whilst this study has demonstrated a broad link between floristics and structure, the specific demarcation between the various structural types (eg. Grey Box (4a) and Yellow Box (4b) open forest II - woodland II, in LCC 1983) did not emerge in the present community analysis. Often the different grassy woodland vegetation groups identified could be dominated by a wide range of tree species. Because the majority of the floristic diversity is present in the understorey this conclusion is not unexpected. It is speculated that significant differences may have previously existed between these various structural vegetation types that have been lost under the homogenising influence of post-settlement land management.

All but one of the Northern Plain grassy vegetation communities are well represented in the western half of the region. Whilst to some extent this could be attributed to undersampling in the east, greater vegetation heterogeneity in the west could be the consequence of wider gradients in precipitation, soils and parent material. With the exception of eastern (wet) grassland, grasslands are a feature of the western reaches of the Northern Plain, whilst grassy woodlands are widespread throughout. Because of its close floristic affinities with grassy woodlands and the presence of scattered eucalypts, it is speculated that eastern (wet) grassland was formerly an open woodland partially cleared over the last 160 years of European occupation.

Environmental Relationships

Beyond the influence of post-settlement land management, floristic patterning within the Northern Plain is linked to soil type, geology and geomorphology and precipitation. Despite the fact that the region is essentially defined using geological and geomorphological features

(Conn 1993), vegetation sampling from geological inliers and formations on the periphery of the region exposed some patterning. Two of the 14 floristic groups described occurred exclusively on landforms other than recent alluvium; (a) Parilla Sand (Marine Plain) of the Gredgwin ridge, and (b) outcropping granite of the Terrick Terrick Range (Fig. 2.1*b*) - the two groups with the highest tall to medium shrub component.

Soil type, particularly texture and physical characteristics influencing water movement, was extremely variable between and even within the various floristic groups defined. However, in some instances clear correlations were evident. The shrubland vegetation of the Terrick Terrick Range occurred on very well drained and shallow skeletal soils, whilst in contrast the wet grassland vegetation of group 6 persisted in the depressions of gilgai complexes composed of clays with severely impeded drainage. At a broader level, soil type is correlated to vegetation structure, with grasslands and grassy woodlands (or shrublands) occuring with greater frequency on heavier and lighter textured soils respectively. Heavier textured soils become more prevalent moving north and west across the Northern Plain because of the direction of movement of sediments from the Midlands in prior streams during the region's evolution. "As coarser materials were deposited close to the highlands, there is a gradual fining northward across the Loddon Plain, until a point is reached beyond which stream loads were virtually reduced to suspended load; this allowed a predominantly clay plain to build up" (Macumber 1991). This gradient co-incidently correlates with a gradual decline in annual precipitation. The even representation of both grassland and non-grassland structures on loamy soils could be attributed in part to tree clearance associated with agriculture and the selection of soils with good drainage characteristics for crop and pasture establishment. This pattern has been long acknowledged in the Northern Plain by the agricultural industries.

Published soil surveys of the region recognise that, relative to the prior streams sequence, the treeless plain soils differed in the following ways: (a) slightly heavier texture throughout profile; (b) shallower surface horizons; (c) darker and duller, more intractable subsoil clay structure; (d) the presence of gypsum in deep subsoil; and (e) slightly lower elevation (Skene and Poutsma 1962; Skene 1963; Skene and Harford 1964; Skene and Sargeant 1966; Skene 1971; Sargeant *et. al.* 1978). These poorly drained, non-inundated soils create very difficult conditions for deep-rooted perennial plants. “The combination of relatively low ‘profile of available water storage’ (PAWS) and overall mediocre nutrient status with the limited summer rainfall [of the region], precludes formations of perennial species requiring ready supply of water, and also prevents the vigorous growth of any vegetation during the dry summer” (Gibbons and Rowan 1993). Other important features are the inhibition of root penetration during winter as the sodic clay swells reducing porosity and aeration, and in some soils, the presence of deep cracking also imposes severe mechanical strain on plant roots. Plants which are capable of rapid growth, flowering and seed production during the favourable months of the year and semi-dormancy over the harsh summer period are favoured. Saltbush (*Atriplex* spp. and *Maireana* spp.) tends to occur where soils are sodic, alkaline or salty (Patton 1930; Gibbons and Rowan 1993).

A link between mean annual precipitation and floristics was evident between those groups that were geographically separated particularly in latitude. Because of the proximity of the eastern highlands of Victoria, there is a uniform gradient of decreasing precipitation along a south-east to north-west transect (LCC 1983; Bureau of Meteorology and Walsh 1995). Discrete floristic groups in the extreme east of the region (at the foot of the Warby Ranges) received the highest rainfall. Mean annual precipitation gradually diminished with further distance to the north and west. Whilst there was some variation in the rainfall received by the various groups in the west, vegetation patterning there was more closely linked to soil type and management.

Theoretical Framework for Grassland Dynamics - A Community Divergence Model

The floristic divergence of the dominant grassland groups as a consequence of post-settlement land management which has emerged from this analysis (groups 1/2 compared with groups 3/4) forms the basis of the development of a theoretical framework for understanding the dynamics of grassland vegetation on the Northern Plain. In particular this divergence suggests links between the nature of disturbance and the persistence of specific functional elements in the grassland flora. Although the pattern of post-settlement land management has been complex (see Chapter 2), today frequent versus infrequent disturbance has driven a community divergence by providing appropriate environments for two distinctly different groups of plants: annuals (therophytes) and shrubs. In the context of the current urgent need for conservation via reservation and sustainable/ameliorative management, knowledge of the implications of interventionist practices will be critical to avert disastrous mistakes resulting in habitat deterioration and ultimately further species loss.

Grazing exclosure experiments in similar lowland grassland vegetation in eastern Australia have resulted in a significant reduction in native richness - primarily the herbaceous element. For instance, Tremont (1994; also see McIntyre and Lavorel 1995; McIntyre *et. al.* 1995) recorded that after 16 years of exclosure of a species-rich remnant on the Northern Tablelands of NSW, the richness of the grazed treatment was approximately twice that of the ungrazed treatment. On the basalt plains of western Victoria after only 12 months of exclosure, a formerly species-rich and frequently-grazed native pasture significantly declined in richness after the prolific growth of the dominant grass *Themeda triandra* (Hadden unpublished data) (also see Stuwe 1986; Scarlett and Parsons 1990; Lunt 1991 for similar behaviour in regularly burn rail and roadside refugia).

In contrast, a long term exclosure experiment in a native grassland near Cobar in central-western NSW (non-seasonal rainfall of 325 to 350 mm), resulted in no change in richness after 10 years (Leigh *et al.* 1989). According to the authors, this result suggests grazing has determined the present species composition, and therefore forb richness is more likely to drop rather than increase with further exclosure. This experiment also suggests that compositional change in species-rich grazed grasslands occurs on a far slower time scale in drier environments compared with the higher rainfall temperate regions. International studies in similar ecosystems have also reported similar behaviour and trends: Collins and Barber 1985, Collins 1987 (America); Noy-Meir *et al.* 1989, Noy-Meir 1995 (Middle East); Grubb 1986, Puerto *et. al.* 1990, Montalvo *et al.* 1993 (Europe); and Belsky 1992 (Africa).

With few exceptions, experimental work in Riverina grasslands (mainly in NSW) has been undertaken in species-poor vegetation and focused on the perennial graminoid component of the flora and the dynamics and utility of the vegetation as an agronomic resource (Leigh and Mulham 1964, 1966; Robards *et al.* 1967; Leigh *et al.* 1968; Williams 1968, 1969, 1970;

Williams and Roe 1975; Wilson 1976; Tupper 1978*a*, 1978*b*; Austin *et. al.* 1981). As a consequence such research has limited application to biodiversity conservation.

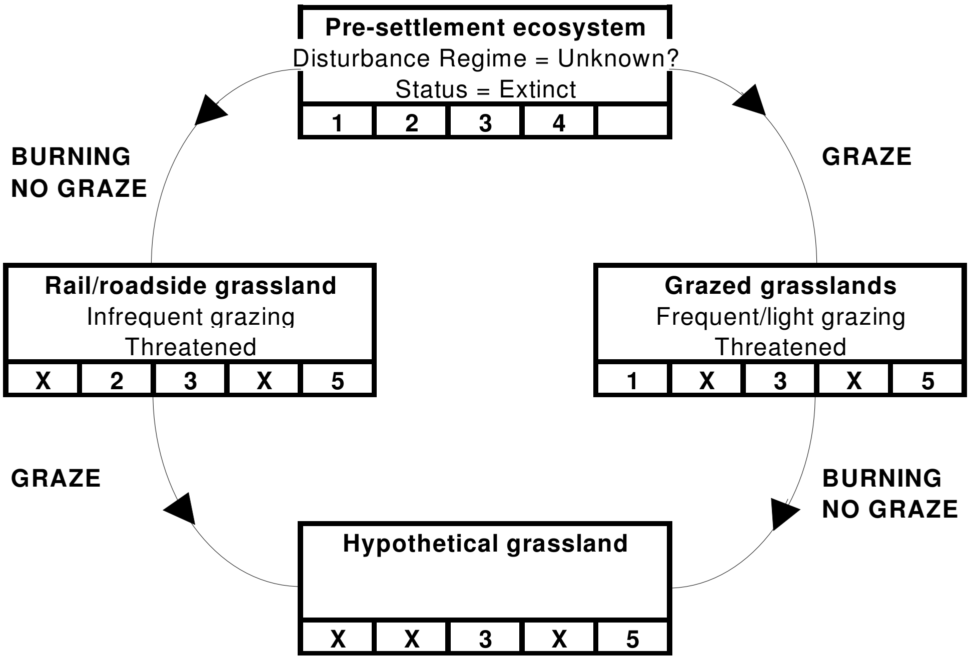


Fig. 2.10. (adapted from Lunt 1995) Generalised model of community divergence in Northern Victorian grassland vegetation. This model assumes the pre-settlement vegetation consisted of 4 broad groups, three of which are still found in remnants today. Group 1 (therophytes) species are generally diminutive annual forbs which have persisted under conservative grazing regimes and largely absent from burnt (rail) or ungrazed (road) remnants (e.g. *Goodenia pusilliflora*, *Triptilodiscus pygmaeus* and *Eriochlamys behrii*). Group 2 (chamaephytes and phanerophytes) species are shrubs and longer living perennial forbs that are sensitive to grazing and variously tolerant of burning (e.g. *Leptorhynchos panaetioides*, *Sclerolaena napiformis*, *Maireana decalvans* and *Pimelea spinescens*). Group 3 (hemicryptophytes and cryptophytes) species are plants that tolerate a wide range of disturbances and are generally shortly lived (seasonal) herbaceous perennials (e.g. *Danthonia* spp., *Convolvulus erubescens*, *Maireana excavata* and *Sida corrugata*). Group 4 species are a largely unknown group of plants which were present in the original vegetation that rapidly become extinct in the alien context of post-settlement land management (e.g. *Atriplex nummularia* and *Acacia pendula* although plants with various life strategies could occur in this group). Group 5 plants are alien species that have been either deliberately or inadvertently introduced and are widespread in remnant vegetation (e.g. various annual grasses, **Romulea* spp., **Hypochoeris* spp. and **Erodium botrys*). Note that the arrows indicate change in one direction only and that in general successional resurrection of the former vegetation is not possible because eliminated species are not represented in the seed bank or anywhere else in the landscape.

The generalised model of community divergence (Fig. 2.10) depicts modification in the composition of grassland vegetation resulting from post-settlement land management as changes in the presence and absence of five discrete groups of plants. The first important changes in the vegetation depicted in the model are: (1) the invasion of aliens and (2) the regional extinction of formerly abundant species. This modification was rapid and all pervasive in the landscape and largely irrevocable. The two broad grassland groups are depicted as floristically distinct as a consequence of a dichotomous disturbance environment and change is shown as unidirectional. Any attempts to manipulate them as shown will necessarily result in further species loss, producing the hypothetical grassland shown. This hypothesis is experimentally tested in Chapter 3.

Conclusions

Grassy vegetation of the Northern Plain is rich in indigenous species, diverse in structure and community composition, and unique in Victoria because of the rich and abundant presence of species of the family Chenopodiaceae and indigenous diminutive annuals (uncommon in grassy vegetation elsewhere in lowland plains). Grasslands and grassy woodlands were found to be broadly distinct floristically, but no correlation exists between floristics and the range of previously described vegetation types defined exclusively on the basis of structure. Within the Northern Plain, grassy vegetation is floristically closest to riparian *Eucalyptus largiflorens* woodlands distributed along major western watercourses. Outside the region, Northern Plain grassy vegetation has very close affinities with that in the Wimmera and across the border into the southern Riverina of NSW. Although there is a transitional or ecotonal region on the lower slopes and rises in the northern reaches of the central Victorian hills, there are few floristic links with the box-ironbark vegetation of the Midlands.

Floristic patterning was linked to both environmental and anthropogenic influences. Post-settlement land management (closely linked to grazing and land tenure) had an important influence on the structure and composition of grasslands in particular. The key environmental factors included geology, soil type (drainage characteristics) and mean annual precipitation.

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Appendix 2.1. Species frequency summary table derived from TWINSPAN classification of 197 grassland and grassy woodland quadrats - percentage frequency of exotic and indigenous taxa by classification group in alphabetical order. Note: only taxa that have a frequency greater than or equal to 50% in any one group are included.

Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Quadrats	**2**	**34**	**30**	**29**	**21**	**8**	**6**	**1**	**9**	**1**	**28**	**12**	**13**	**2**
Acacia deanei (R. Baker) Welch et. al.	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Acacia genistifolia Link	-	-	-	-	-	-	-	-	-	100	-	-	-	-
Agrostis avenacea J.F. Gmelin	-	-	-	3	5	50	-	-	40	-	3	-	-	-
* Aira cupaniana Guss.	-	5	-	3	24	-	-	-	20	-	17	-	8	50
Allocasuarina luehmannii (R. Baker) L. Johnson	-	-	-	-	-	-	-	-	-	-	10	-	77	-
Amphibromus nervosus (J.D.Hook.) Druce	-	-	-	10	10	38	-	-	40	-	-	-	-	-
Amyema quandang (Lindley) Tieghem	-	-	-	-	-	-	-	-	-	-	-	-	-	50
* Aphanes arvensis L.	-	25	3	10	5	13	-	-	-	100	-	-	-	-
* Arctotheca calendula (L.) M. Levyns	50	75	47	80	81	88	33	-	30	100	80	83	38	100
Aristida behriana F. Muell.	-	35	3	7	10	-	-	-	20	-	57	-	15	-
Arthropodium fimbriatum R. Br.	50	25	27	27	24	-	-	-	-	-	53	67	8	-
Arthropodium minus R. Br.	100	35	47	3	29	50	-	-	-	-	20	25	15	50
Asperula conferta J.D. Hook.	100	25	13	40	38	50	17	-	10	-	10	-	46	-
Atriplex leptocarpa F. Muell.	-	-	-	-	-	-	67	-	-	-	-	-	-	-
Atriplex semibaccata R. Br.	-	15	40	60	57	25	33	-	-	-	10	50	31	-
* Avena barbata Pott ex Link	-	10	-	10	5	-	-	-	30	-	43	42	85	50
* Avena fatua L.	-	-	3	3	43	-	-	-	20	-	13	17	-	50
* Brachypodium distachyon (L.) P. Beauv.	50	-	13	3	-	-	-	-	-	-	7	58	77	-
Bracteantha viscosa (DC.) A. Anderb. and L. Haegi	-	-	-	-	-	-	-	-	-	-	-	-	-	50
* Briza maxima L.	-	-	-	-	-	-	-	-	60	100	20	-	-	-
* Briza minor L.	-	15	-	7	29	25	-	-	70	-	30	-	-	-
* Bromus diandrus L.	-	-	-	-	-	-	-	-	20	-	23	17	8	100
* Bromus hordeaceus L.	-	35	17	50	48	13	-	100	50	100	37	33	8	50
* Bromus rubens L.	50	15	30	7	5	-	-	-	-	-	7	42	46	100
Bulbine bulbosa (R. Br.) Haw.	-	40	50	30	62	38	-	-	80	-	43	33	31	-
Bursaria spinosa Cav.	50	-	-	-	-	-	-	-	-	-	7	8	46	-
Calandrinia calyptrata J. D. Hook.	-	-	-	-	-	-	-	-	-	-	-	-	-	50
Calocephalus sonderi F. Muell.	-	-	23	17	5	63	83	-	-	-	-	-	-	-
Calotis scabiosifolia Sonder and F. Muell. ex Sonder	-	15	20	33	48	50	17	-	-	-	3	25	15	-
Calotis scapigera Hook.	-	-	-	-	-	-	-	100	-	-	-	-	-	-
* Centaurea melitensis L.	50	-	-	-	-	-	-	-	-	-	-	17	31	-
* Cerastium vulgare Hartm.	-	-	-	-	-	-	-	-	-	100	-	-	-	-
Chamaesyce drummondii (Bioss.) D. Hassell	-	30	10	47	52	63	50	-	10	-	10	8	23	-
Chenopodium desertorum (J.Black) J. Black	-	-	-	-	-	-	-	-	-	-	10	58	85	-
Chenopodium desertorum sspp. microphyllum Paul. G. Wilson	50	-	7	10	-	-	-	-	-	-	7	50	-	-
Chloris truncata R. Br.	-	10	27	53	10	38	-	-	40	-	23	-	23	-
Chrysocephalum apiculatum (Labill.) Steetz in Lehm.	100	30	33	30	48	25	-	-	10	-	40	8	15	-
Chrysocephalum semipapposum (Labill.) Steetz in Lehm.	100	-	-	-	-	-	-	-	-	-	7	8	31	-
* Cicendia quadrangularis (Dombey ex Lambert) Griseb.	-	70	13	3	48	-	-	-	30	-	17	-	-	-
Clematis microphylla DC.	-	-	-	-	-	-	-	-	-	-	-	-	23	50
Convolvulus erubescens Sims	50	90	23	77	67	-	-	-	-	-	23	17	62	-
Convolvulus remotus R. Br.	-	-	-	-	-	-	-	-	50	-	30	58	8	-
Correa glabra Lindley in T. Mitch.	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Cotula australis (Sieber ex Sprengel) J.D. Hook.	-	-	-	-	-	-	-	-	-	100	-	-	-	50
* Cotula bipinnata Thunb.	-	5	13	53	67	50	67	-	-	-	-	-	-	-
Crassula decumbens Thunb.	-	95	53	77	86	75	83	-	10	100	37	33	8	50
Crassula sieberiana (Schultes and Schultes f.) Druce	50	55	60	17	-	-	17	-	-	-	10	25	-	100
* Critesion marinum (Hudson) A. Love	-	-	13	-	-	38	67	-	-	-	-	-	-	-
* Critesion murinum (L.) A. Love	50	-	-	-	-	-	-	-	-	-	-	-	-	50
* Cucumis myriocarpus Naudin	-	-	-	-	-	-	-	-	-	-	-	-	-	50
* Cyperus tenellus L.f.	-	-	-	-	-	-	-	-	70	-	-	-	-	-
Danthonia auriculata J. Black	-	20	-	3	5	-	-	-	10	-	57	-	-	-
Danthonia caespitosa Gaudich. in Freycinet	-	80	80	60	43	25	50	100	60	-	57	83	62	50
Danthonia duttoniana Cashm.	-	-	3	13	10	38	-	100	50	-	7	-	-	-
Danthonia eriantha Lindley in T. Mitch.	-	5	-	-	10	-	-	-	10	-	53	42	8	50
Danthonia setacea R. Br.	100	75	73	90	100	63	83	-	30	-	50	92	31	-
Daucus glochidiatus (Labill.) Fischer	50	45	63	10	29	50	50	-	-	-	13	33	23	-
Dianella revoluta R. Br.	50	-	-	-	-	-	-	-	20	100	17	8	8	-
Dodonea viscosa sspp. cuneata (Smith) J. West	-	-	-	-	-	-	-	-	-	-	3	8	31	50
Drosera peltata sspp. auriculata (Backh. ex Planchon) Conn	-	50	-	3	-	-	-	-	-	-	-	-	-	-
Drosera peltata sspp. peltata (Backh. ex Planchon) Conn	-	-	-	-	-	-	-	-	70	-	17	-	-	50
Echinopogon ovatus (G. Foster) P. Beauv.	-	-	-	-	-	25	-	-	-	-	-	-	-	50
* Echium plantagineum L.	-	-	-	-	-	-	-	-	-	-	-	-	-	50
* Ehrharta longifolia Smith	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Einadia nutans (R.Br.) A.J. Scott.	100	-	-	3	-	-	-	-	-	-	10	50	69	-
Elymus scabrus (R. Br.) A. Love	50	10	3	13	5	-	-	-	20	-	67	50	8	-
Enchylaena tomentosa R.Br.	100	10	23	13	-	-	-	-	-	-	-	25	85	-
Enteropogon acicularis (Lindley) Lazarides	50	50	53	77	81	88	83	-	-	-	20	50	46	-
Eragrostis elongata (Willd.) J.F. Jacq.	-	-	-	-	-	-	-	-	-	-	-	-	-	50
Eriochlamys behrii Sonder and F. Muell.	-	15	53	20	-	25	33	-	-	-	-	-	-	-
* Erodium botrys (Cav.) Bertol.	-	55	13	50	67	25	33	-	30	-	7	-	-	-
* Erodium cicutarium (L.) L'Her. ex Aiton	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Erodium crinitum Carolin	50	5	-	-	-	-	-	-	-	-	10	8	8	-
Eryngium ovinum Cunn. in B. Field	-	20	-	13	10	25	-	-	50	-	13	-	-	-
Eucalyptus leucoxylon F. Muell.	-	-	-	-	-	-	-	-	-	-	3	25	54	-

Eucalyptus melliodora Cunn. ex Schauer in Walp.	-	-	-	-	-	-	-	-	-	100	13	-	-	-
Eucalyptus microcarpa (Maiden) Maiden	-	-	-	-	-	-	-	-	-	100	37	33	-	-
Galium gaudichaudii DC.	-	-	-	-	-	-	-	-	-	-	-	-	-	50
* Geranium dissectum L.	50	-	-	-	-	-	-	-	-	-	-	-	-	-
Geranium solanderi Carolin	-	-	-	-	-	-	-	-	-	-	-	-	-	50
Gonocarpus elatus (Cunn. ex Fenzel) Orch.	-	-	-	-	-	-	-	-	-	-	13	-	8	100
Goodenia pinnatifida Schldl.	50	-	7	-	19	-	-	-	20	-	20	50	8	-
Goodenia pusilliflora F. Muell.	50	80	77	37	33	13	83	-	-	-	20	33	8	-
* Gynandriris setifolia (L. f.) R. Foster	-	-	7	13	52	-	-	-	-	-	-	-	-	-
Haloragis aspera Lindley in T. Mitch.	50	-	-	-	-	-	-	100	10	-	-	-	23	-
* Hedypnois cretica (L.) Willd.	50	15	20	7	14	38	50	-	-	-	13	25	15	-
* Helminthotheca echioides (L.) Holub	50	10	3	40	29	25	33	100	10	-	7	17	31	-
* Holcus lanatus L.	-	-	-	-	-	-	-	-	20	100	3	-	-	-
* Holcus setosus Trin.	-	-	-	-	-	-	-	-	50	-	-	-	-	-
Homopholis proluta (F. Muell.) R. Webster	-	10	-	27	43	13	-	100	70	-	10	8	38	-
* Hypochoeris glabra L.	50	90	80	77	43	88	83	-	60	-	77	67	46	100
* Hypochoeris radicata L.	-	25	13	33	24	-	33	-	80	100	33	8	23	100
Hypoxis glabella R. Br.	-	-	-	10	52	13	-	-	-	-	-	-	-	-
Indigofera australis Willd.	-	-	-	-	-	-	-	-	-	-	-	-	-	50
Isoetopsis graminifolia Turcz.	-	35	40	13	5	38	67	-	-	-	-	-	-	-
Isotoma axillaris Lindley in Edwards's	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Juncus bufonius L.	-	-	-	13	14	25	-	-	50	-	7	-	-	-
* Juncus capitatus Weigel	-	-	-	-	-	-	-	-	80	-	20	-	-	-
Juncus flavidus L. Johnson	-	-	-	-	-	-	-	100	-	-	-	-	-	-
Juncus subsecundus Wakef.	-	10	7	60	57	88	17	-	60	-	7	8	-	-
* Lactuca serriola L.	-	-	-	-	-	-	-	-	-	-	-	8	23	50
* Lamarckia aurea (L.) Moench	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Leptorhynchos panaetioides sensu J.H. Willis	50	5	-	17	29	13	-	-	-	-	-	-	-	-
Leptorhynchos squamatus (Labill.) Less.	-	45	17	53	48	50	17	-	30	-	43	8	-	-
Linum marginale Cunn. ex Planchon	50	-	3	7	14	25	-	-	30	-	10	-	8	-
* Lolium perenne L.	-	-	-	3	33	38	17	-	10	-	10	42	38	50
* Lolium rigidum Gaud.	50	-	70	33	-	38	17	100	40	-	40	75	31	-
Lomandra effusa (Lindl.) Ewart	0	25	7	13	-	-	-	-	-	-	23	42	62	-
Lomandra filiformis (Thunb.) Britten		-	-	-	-	-	-	-	50	-	37	8	15	-
* Lycium ferocissimum Miers	50	-	-	-	-	-	-	-	-	-	-	-	31	50
Lythrum hyssopifolia L.	-	5	7	37	5	-	-	-	80	-	20	-	-	-
Maireana decalvans (Gand.) Paul G. Wilson	-	-	10	33	38	25	50	-	-	-	-	-	-	-
Maireana enchylaenoides (F. Muell.) Paul G. Wilson	100	85	33	80	62	13	-	-	-	-	40	75	23	-
Maireana excavata (J. Black) Paul G. Wilson	50	70	67	30	52	25	50	-	-	-	13	25	15	-
Maireana pentagona (R. Anderson) Paul G. Wilson	-	45	83	67	81	88	100	-	-	-	-	-	-	-
* Marrubium vulgare L.	-	-	-	-	-	-	-	-	-	-	3	-	54	100
* Medicago minima (L.) Bartel.	50	-	10	-	-	-	-	-	-	-	-	42	8	-
* Medicago polymorpha L.	50	-	-	-	-	-	-	-	-	-	-	-	-	50
Microlaena stipoides (Labill) R. Br.	-	-	-	-	-	-	-	-	-	100	-	-	-	-
Minuria leptophylla DC.	50	-	20	-	-	-	-	-	-	-	7	25	46	-
Myriocephalus rhizocephalus (DC.) Benth.	-	10	3	-	14	88	-	-	-	-	-	-	-	-
Oxalis perennans Haw.	100	65	47	83	67	25	17	-	30	100	67	67	85	-
Oxalis radicosa A. Rich.	-	-	-	-	-	-	-	-	-	-	-	-	-	50
Pachymitus cardaminoides (F. Muell) O. Schulz	-	-	-	-	-	-	-	-	-	-	-	-	-	50
* Parentucellia latifolia (L.) Caruel in Parl.	-	60	17	3	33	38	17	-	10	-	30	-	-	-
Parietaria debilis G. Foster	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Paspalidium constrictum (Domin) C.E.Hubb.	-	-	-	-	-	-	-	-	-	-	-	-	23	50
* Paspalum dilatatum Poiret in Lam.	-	-	-	-	-	-	-	100	30	-	-	-	-	-
* Petrorhagia velutina (Grus.) P. Ball and Heyw.	-	15	10	-	-	-	-	-	10	-	20	17	8	50
Pimelea curviflora/micrantha	50	-	-	-	-	-	-	-	-	-	23	8	-	-
Pimelea linifolia Smith	-	-	-	-	-	-	-	-	-	-	-	-	-	50
Plantago gaudichaudii Barneoud	-	10	-	33	43	63	-	-	-	-	-	-	-	-
* Plantago lanceolata L.	-	-	-	-	-	-	-	100	40	-	-	-	8	-
Plantago varia R. Br.	50	5	3	13	-	-	-	-	-	-	-	-	-	-
* Poa annua L.	-	-	-	-	-	-	-	-	-	100	-	-	-	-
Poa labillardieri Steudel	50	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonolepis muelleriana (Sonder) P. Short	-	10	47	-	-	13	67	-	-	-	-	-	-	-
Pratia concolor (R. Br.) Druce	-	-	-	-	-	-	-	100	30	-	-	-	-	-
Prostanthera nivea Cunn. ex Benth.	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Ptilotus exaltatus Nees in Lehm.	100	20	30	13	43	-	-	-	-	-	13	42	77	-
Pycnosorus globosus (Bauer ex Benth.) Benth.	-	-	-	50	48	50	-	-	20	-	7	-	-	-
Rhodanthe corymbiflora (Schldl.) Paul G. Wilson	100	15	47	37	48	88	67	-	-	-	3	67	62	-
Rhodanthe pygmaea (DC.) Paul G. Wilson	-	55	67	-	5	-	17	-	-	-	-	-	-	-
* Romulea minutifora Klatt	-	95	73	77	48	3	50	-	-	-	13	17	-	-
* Romulea rosea (L.) Ecklon	50	25	7	70	95	-	-	100	100	100	77	58	8	-
* Rumex crispus L.	-	-	-	-	-	-	-	-	-	100	-	-	-	-
* Salvia verbenaca L.	-	-	7	7	5	-	-	-	-	-	7	17	62	-
Sclerolaena diacantha (Nees) Benth.	50	10	20	10	10	-	33	-	-	-	-	42	62	-
* Scorzonera laciniata L.	-	-	-	7	38	63	50	100	10	-	3	17	31	-
Sida corrugata Lindley in T. Mitch	100	95	77	97	86	100	100	-	20	-	60	100	85	-
* Solanum nigrum L.	-	-	-	-	-	-	-	-	-	-	-	-	-	50
* Sonchus oleraceus L.	50	40	27	70	33	-	-	-	-	-	7	25	85	100
* Spergularia rubra (L.) J. and C. Presl	-	-	33	20	14	50	33	-	-	-	7	17	23	-
Sporobolus caroli Mez	-	-	7	3	-	-	50	-	-	-	-	-	-	-
* Stellaria media (L.) Cirillo	-	-	-	-	-	-	-	-	-	100	-	-	-	50
Stipa bigeniculata Hughes	50	5	13	17	10	-	-	-	-	-	-	-	-	-
Stipa blackii C.E. Hubb.	50	-	7	-	10	-	-	-	-	-	17	33	77	-
Stipa elegantissima Labill.	100	-	-	-	-	-	-	-	-	-	7	25	77	-
Stipa eremophila Reader	50	-	7	-	-	-	-	-	-	-	7	50	15	-
Stipa gibbosa Vick.	50	60	10	17	19	-	-	-	20	-	40	33	15	-

Stipa scabra Lindley in T. Mitch	-	85	90	40	-	-	17	-	10	100	67	75	38	100
Stuartina muelleri Sonder	-	60	-	3	-	-	-	-	-	-	-	-	-	-
Stypandra glauca R. Br.	-	-	-	-	-	-	-	-	-	-	-	-	-	100
Swainsona plagiotropis F. Muell.	-	30	7	37	76	63	-	-	-	-	-	-	-	-
Swainsona procumbens (F. Muell.) F. Muell.	-	5	27	10	10	75	-	-	30	-	13	-	-	-
Teucrium racemosum R. Br.	50	5	10	23	14	38	-	-	-	-	10	8	31	-
* Trifolium angustifolium L.	50	75	20	87	29	-	17	-	-	-	87	8	15	-
* Trifolium arvensis L.	50	80	37	23	14	13	-	-	40	-	70	50	8	100
* Trifolium campestre Schreber	-	40	10	23	5	-	-	-	40	-	50	8	15	-
* Trifolium dubium Sibth.	-	-	-	-	-	-	-	-	70	-	7	-	-	-
* Trifolium fragiferum L.	-	-	-	-	-	-	-	100	-	-	-	-	-	-
* Trifolium glomeratum L.	50	75	57	67	19	13	33	-	50	-	70	42	8	-
* Trifolium repens L.	-	-	-	-	-	-	-	-	-	100	-	-	-	-
* Trifolium striatum L.	-	20	-	27	48	13	-	-	40	-	30	8	-	-
* Trifolium subterraneum L.	-	5	3	7	29	13	-	-	80	-	37	-	-	50
* Trifolium tomentosa L.	-	-	3	-	-	13	50	-	-	-	0	-	-	-
Triptilodiscus pygmaeus Turcz.	-	40	53	-	14	38	-	-	10	-	20	-	8	-
Velleia paradoxa R. Br.	-	10	-	-	-	-	-	-	-	-	10	-	8	-
Vittadinia cuneata DC.	100	40	17	20	10	-	-	-	-	-	23	33	54	-
Vittadinia gracilis (J. D. Hook) N. Burb.	-	40	17	13	10	-	-	-	-	-	27	50	62	50
* Vulpia bromoides (L.) Gray	-	-	-	-	76	25	17	-	80	-	37	33	8	-
* Vulpia myuros (L.) C. Gmelin	-	10	7	-	-	-	17	-	10	-	33	33	77	50
Wahlenbergia luteola P.J. Smith	50	15	-	7	-	-	-	-	30	-	47	25	31	-
Wurmbea dioica (R. Br.) F. Muell.	50	10	7	3	38	50	-	-	20	-	13	17	8	-
Wurmbea latifolia T.D. Macfarlane	-	60	37	17	14	13	17	-	-	-	-	-	-	-

Appendix 2.2. Summary of key environmental and floristic features of each grassland and grassy woodland group, except groups 1, 8 and 10.

Group No: 2	**Group name: annual grassland and grassy woodland (south)**	**Quadrat No: 34**

Structure: Open woodland, tall shrubland or grassland.
Dominant species: *Eucalyptus microcarpa*, *E. melliodora*, *Allocasuarina luehmannii* and *Callitris glaucophylla*, mallee eucalypts or a range of medium to tall shrubs. Grassland: *Danthonia* spp. and *Stipa* spp.and *Enteropogon acicularis.*
Floristics: (Indigenous) Trees (see above), tall to low shrubs (*Acacia* spp. and *Atriplex semibaccata*.), perennial forbs (*Sida corrugata, Oxalis perennans, Convolvulus erubescens, Arthropodium* spp., *Wurmbea latifolia, Bulbine bulbosa* and *Chrysocephalum apiculatum*, *Maireana excavata* and *M. enchylaenoides*) perennial tussock grasses (see above) and annual forbs (*Goodenia pusilliflora, Rhodanthe pygmaea, Triptilodiscus pygmaeus, Stuartiana muelleri, Isoetopsis graminifolia, Daucus glochidiatus, Eriochlamys behrii* and *Pogonolepis muelleriana*). (Exotics) Apart from the ubiquitous geophyte **Romulea minutiflora*, the coexistent exotic species are annual grasses and herbs.
Geographic distribution: Southern latitudes (south of 36^{o}10’00”, but not further than 36^{o}25’00”) west of the Campaspe River.
Geology/geomorphology: Riverine alluvium, marine Parilla sand and igneous granite.
Mean annual precipitation: 401 mm.
Soil types and drainage: Wide range of drainage characteristics: Terricks sandy loam through Wychitella loam and Koyuga clay loam to Restdown/Rochester clay.
Tenure/management history: Both frequently grazed (private property) and ungrazed (road reserves, rail reserves and public reserves). Most sites have not been subject to cultivation.

Group No: 3	**Group name: annual grassland (north)**	**Quadrat No: 30**

Structure: Open woodland (grassy), low-open shrubland and grassland.
Dominant species: *Allocasuarina luehmannii* and *Eucalyptus* spp. Shrubland*: Nitraria billardierei* (and others). Grassland: *Danthonia* spp. and *Stipa* spp. and *Enteropogon acicularis*
Floristics: (Indigenous) Trees (see above), tall to low shrubs (*Acacia* spp., *Maireana decalvans* and *Atriplex semibaccata*.), perennial forbs (*Sida corrugata, Oxalis perennans, Convolulus erubescens, Arthropodium* spp., *Wurmbea latifolia, Bulbine bulbosa* and *Chrysocephalum apiculatum*, *Maireana pentagona* and *M. excavata*) perennial tussock grasses (see above) and annual forbs (*Goodenia pusilliflora, Rhodanthe pygmaea, Triptilodiscus pygmaeus, Isoetopsis graminifolia, Daucus glochidiatus, Eriochlamys behrii* and *Pogonolepis muelleriana.* Note: *Leptorhynchos scabrus* was the only species exclusive to this group, although it only survives on one property). (Exotics) Apart from the ubiquitous geophyte **Romulea minutiflora*, the coexistent exotic species are annual grasses and herbs.
Geographic distribution: Northern latitudes (north of 36^{o}10’00”) west of the Campaspe

River.
Geology/geomorphology: Riverine alluvium and marine Parilla sand.
Mean annual precipitation: 369 mm.
Soil types and drainage: Wide range of drainage characteristics from prior stream loam and Woolshed loam through Fernihurst clay loam to Towangar clay.
Tenure/management history: Both frequently grazed (private property) and ungrazed (road reserves, rail reserves and public reserves). Most sites have not been subject to cultivation.

Group No: 4	Group name: perennial grassland 1	Quadrat No: 29

Structure: Grassland (occassionally a low open shrubland).
Dominant species: *Danthonia* spp. and *Stipa* spp. and *Enteropogon acicularis.*
Floristics: (Indigenous) Tall to low shrubs (*Maireana decalvans*, *Atriplex semibaccata* and *Leptorhynchos panaetioides*) tussock grasses (see above and Chloris truncata) perennial forbs (*Convolvulus erubescens, Juncus subsecundus, Leptorhynchos squamatus, Maireana enchylaenoides, M. pentagona, Oxalis perennans, Pycnosorus globosus, Sida corrugata* and *Swainsona plagiotropis*) annual forbs infrequent and low abundance - generally <35% frequency and <5% cover (*Chamaesyce drummondii* and *Crassula decumbens*) (Exotics) annuals and perennials (**Arctotheca calendula, *Bromus* spp., **Cotula bipinnata, *Erodium botrys, *Hypochoeris glabra, *Romulea rosea, *R. minutiflora, *Sonchus oleraceus, *Trifolium* spp.)
Geographic distribution: Central latitudes (south of 36°10’00”) between the Goulburn and Loddon Rivers.
Geology/geomorphology: Riverine alluvium.
Mean annual precipitation: 409 mm.
Soil types and drainage: Generally loam and clay loam soils, but occassionally sandy loam or a clay soil.
Tenure/management history: Road reserves, public reserves and rail reserves not subject to stock grazing, rarely on grazed private property.
Notes: At least 28 species of tall to low shrubs have been recorded from similar vegetation along roadsides in the region, although most are now present in low numbers because of past over grazing.

Group No: 5	Group name: perennial grassland 2	Quadrat No: 21

Structure: Grassland (occassionally a low open shrubland).
Dominant species: *Danthonia* spp., *Stipa* spp. and *Enteropogon acicularis.*
Floristics: (Indigenous) Tall to low shrubs (*Maireana decalvans*, *Atriplex semibaccata* and *Ixiolaena* spp. syn. *Leptorhynchos panaetioides*) tussock grasses (see above), perennial forbs (*Bulbine bulbosa, Convolvulus erubescens, Calotis scabiosifolia, Hypoxis glabella, Juncus subsecundus, Maireana enchylaenoides, M. excavata, M. pentagona, Oxalis perennans, Sida corrugata* and *Swainsona plagiotropis*) annual forbs infrequent and low abundance - generally <35% frequency and <5% cover (*Chamaesyce drummondii* and *Crassula decumbens*) (Exotics) (**Arctotheca calendula, *Bromus* spp., **Erodium botrys, *Gynandriris setifolia, *Romulea rosea, *Vulpia bromoides*)
Geographic distribution: Central regions (south of Lat 36°10’00”) between the Goulburn and Loddon Rivers.
Geology/geomorphology: Riverine alluvium.
Mean annual precipitation: 415 mm.
Soil types and drainage: Restricted to clay loam and loam soils - Koyuga, Koga and Fernihurst clay loams.
Tenure/management history: Road reserves, public reserves and rail reserves not subject to stock grazing, rarely on grazed private property.

Group No: 6	Group name: western wet grassland	Quadrat No: 8

Structure: Grassland.
Dominant species: *Danthonia duttoniana, Stipa* spp.*, Agrostis avenacea, Amphibromus spp.* or *Homopholis proluta.*
Floristics: (Indigenous) Medium to low shrubs (*Maireana decalvans* and *Atriplex*

semibaccata, rarely *Muehlenbeckia florulenta* and *M. horrida*) perennial and annual forbs (*Calotis anthemoides, Myriocephalus rhizocephalus, Swainsona procumbens* and *Pycnosorus globosus)* perennial tussock grasses (see above and *Stipa aristiglumis*). (Exotics) annual forbs and grasses.
Geographic distribution: Northern latitudes (north of 36°10'00") west of the Campaspe River
Geology/geomorphology: Riverine alluvium (Shepparton Formation).
Mean annual precipitation: 384 mm.
Soil types and drainage: Poorly drained clay soils usually in microtopographical depressions and subject to flooding episodes in winter and intense drying and cracking over summer (gilgai complexes): Yuga clay and Fernihurst clay loam.
Tenure/management history: Private property and occasionally road reserves and public reserves subject to frequent stock grazing.
Notes: Grazing has resulted in degradation of this vegetation because the soils become extremely vulnerable to pugging and weed invasion when saturated - consequently this grassland form is rarely found undisturbed. Wet grassland only accounts for the flora of the depressions in gilgai and related environments and does not include the flora of the associated puffs which is often drastically different (Williams 1955). In many areas *Stipa aristiglumis* dominates gilgai puffs and could represent the remnants of an extinct vegetation community that has long been displaced by weed invasions encouraged by the dynamic behaviour of the friable clay soils.

Group No: 7	**Group name: northern (species-poor) grassland**	**Quadrat No: 6**

Structure: Open shrubland (grassy) or grassland.
Dominant species: *Nitraria billardierei* (occassionally also *Maireana decalvans* and *Lawrencia squarrosa*) or a combination of *Danthonia* spp. and *Stipa* spp.
Floristics: (Indigenous) Medium to low shrubs (see above plus *Atriplex leptocarpa, Sclerolaena diacantha* and *Sida trichopoda*), perennial forbs are rare (*Sida corrugata* and *Oxalis perennans*), perennial tussock grasses (see above plus *Sporobolus caroli*) annual forbs (*Calocephalus sonderi*, *Goodenia pusilliflora*, *Isoetopsis graminifolia*, *Pogonolepis muelleriana*) (Exotics) annual forbs (**Cotula bipinnata* and **Hedypnois cretica*).
Geographic distribution: Northern latitudes (north of 36°10'00") west of the Campaspe River
Geology/geomorphology: Riverine alluvium.
Mean annual precipitation: 374 mm.
Soil types and drainage: poorly drained (but not flooded) clay soils: Fernihurst clay loam, Kerang clay and Marcona clay.
Tenure/management history: Private property and occasionally roadsides generally subject to frequent stock grazing.
Notes: The region covered by this vegetation is increasingly being adversely affected by groundwater salinity. Indigenous species richness lowest in study area.

Group No: 9	**Group name: eastern wet grassland**	**Quadrat No: 9**

Structure: Grassland or occasionally an open grassy woodland.
Dominant species: A combination of *Danthonia* spp. and *Stipa* spp. or *Themeda triandra*. Woodland of *E. microcarpa*, *E. melliodora*, *E. albens* or *E. camaldulensis.*
Floristics: (Indigenous) Trees (see above), tall shrubs (*Acacia* spp.) perennial tussock grasses very rich - wet and dry elements (see above plus *Amphibromus nervosus, A. macrorhinus, Agrostis avenacea, Deyeuxia quadriseta*, *Homopholis proluta*, *Chloris truncata, Bothriochloa macra* and *Elymus scabrus*) perennial forbs - wet and dry elements (*Bulbine bulbosa, Lomandra filiformis, Convolvulus remotus, Wahlenbergia luteola, Leptorhynchos squamatus, Lythrum hyssopifolia, Pycnosorus globosus, Schoenus apogon, Eryngium ovinum, Juncus* spp., *Calotis anthemoides, Eleocharis acuta* and *Isolepis* spp.) annual forbs generally absent. (Exotic) rise in dominance of perennial tussock grasses (**Holcus* spp. **Paspalum dilatatum* and **Phalaris* spp.)
Geographic distribution: Extreme eastern edge of the region surrounding the Warby Ranges and the Ovens River.
Geology/geomorphology: Riverine alluvium (Shepparton Formation).
Mean annual precipitation: 580 mm.
Soil types and drainage: Data unavailable.
Tenure/management history: Road reserves and rail reserves not subject to stock grazing -

generally a history of burning.

Group No: 11	Group name: perennial grassy woodland (south)	Quadrat No: 28

Structure: Open woodland (grassy), occassionally a grassland.
Dominant species: *Eucalyptus microcarpa* and on occasions *E. melliodora*, *E. albens*, *E. leucoxylon, Callitris glaucophylla* and *Allocasuarina luehmannii.* Grasses: *Danthonia* spp. and *Stipa* spp. (rarely an open to closed shrubland dominated by mallee eucalypts).
Floristics: (Indigenous) Trees (see above) tall and low shrubs (*Acacia acinacea, A. pycnantha, Bursaria spinosa, Pimelea micrantha/curviflora* and *Atriplex semibaccata*) perennial tussock grasses (*Aristida behriana, Elymus scabrus, Danthonia* spp., *Stipa* spp., *Themeda triandra* and *Chloris truncata*) perennial forbs (*Oxalis perennans, Sida corrugata, Lomandra filiformis, Arthropodium spp., Calocephalus citreus, Bulbine bulbosa, Leptorhynchos squamatus, Convolvulus remotus, Goodenia pinnatifida, Solenogyne dominii, Chrysocephalum apiculatum* and *Vittadinia* spp., *Stackhousia monogyna, Cheilanthes sieberi, Velleia paradoxa, Thysanotus patersonii, Tricoryne elatior, Gonocarpus elatus* and *Minuria leptophylla*) annual forbs usually present in low numbers (*Daucus glochidiatus*, *Goodenia pusilliflora* and *Triptilodiscus pygmaeus*) (Exotic) mainly annual grasses and forbs (**Arctotheca calendula*, **Avena* spp., **Bromus* spp., **Hypochoeris* spp., **Lolium* spp., **Romulea rosea*, **Trifolium* spp. and **Vulpia* spp.)
Geographic distribution: Spans the full width of the region from the Ovens River in the east to the Avoca River in the west. In the western half, generally in southern latitudes (south of 36^{o}10'00").
Geology/geomorphology: Marine Parilla sand, Riverine alluvium, Granite (igneous and metamorphic).
Mean annual precipitation: 466 mm.
Soil types and drainage: Well drained loamy soils of the riverine plain (siliceous deposits of palaeo-stream channels or source bordering dunes) and associated low rises: Wychitella loam, Lyndger loam and Boosey loam.
Tenure/management history: Public reserves, road reserves, and occassionally road reserves not subject to stock grazing.
Notes: Some of the wet elements from group 9 are also occasionally present which is an indication of the close geographic and floristic links between these two vegetation forms. The consistent presence of chenopods in low abundance is a significant contrast to the groups to the west.

Group No: 12	Group name: Perennial grassy woodland (north west)	Quadrat No: 12

Structure: Open woodland (grassy), occasionally a grassland.
Dominant species: *Eucalyptus microcarpa*, *E. melliodora*, *Allocasuarina luehmannii* and *Callitris* spp. Grasses: *Danthonia* spp. and *Stipa* spp.
Floristics: (Indigenous) Trees (see above) Tall to low shrubs (*Acacia acinacea, Bursaria spinosa, Atriplex semibaccata* and *Chenopodium desertorum* sspp. *microphyllum*) perennial and annual forbs (*Ptilotus exaltatus, P. spathulatus, Lomandra effusa, Rhodanthe corymbiflora* and *Minuria leptophylla*) perennial grasses (see above plus *Enteropogon acicularis, Aristida behriana* and *Elymus scabrus)* (Exotics) manily annual grasses and forbs (**Arctotheca calendula*, **Brachypodium distachyon*, **Avena* spp., **Bromus* spp., **Hypochoeris* spp. **Trifolium* spp. **Lolium* spp. and **Romulea rosea*)
Geographic distribution: Generally west of the Campaspe River at latitudes north of 36^{o}10'00" - some sites near Barmah Forest.
Geology/geomorphology: Marine Parilla sand, Riverine alluvium, Granite (igneous and metamorphic).
Mean annual precipitation: 406 mm.
Soil types and drainage: Data unavailable.
Tenure/Management history: Public reserves (parks and cemeteries) and road reserves not subject to either stock grazing or burning.

Group No: 13	Group name: marine plain (shrubby) woodland	Quadrat No: 13

Structure: Woodland (shrubby and grassy).
Dominant species: *Allocasuarina luehmannii, Eucalyptus leucoxylon* and *E. largiflorens*, plus

occasionally: *Callitris* spp. and *E. microcarpa* or a shrubland of mallee eucalypts such as *Eucalyptus dumosa*.
Floristics: (Indigenous) Trees (see above) tall shrubs (*Bursaria spinosa, Acacia acinacea, A. pycnantha, A. osswaldii, Senna artemisioides, Dodonea viscosa, Pittosporum phylliraeoides, Hakea tephrosperma, Rhagodia spinescens, Maireana rohrlachii* and *Eutaxia diffusa*) low shrubs (*Atriplex semibaccata, Sclerolaena diacantha, Chenopodium desertorum* sspp. *microphyllum* and *Einadia nutans*) perennial grasses (*Danthonia* spp., *Stipa* spp., *Aristida behriana, Homopholis proluta, Elymus scabrus* and *Enteropogon acicularis*) perennial forbs (*Asperula conferta, Lomandra effusa, Convolvulus erubescens, Ptilotus exaltatus, Oxalis perennans, Sida corrugata,* and *Vittadinia* spp.) annual forbs are uncommon (*Rhodanthe corymbiflora*) (Exotics) annual grasses and forbs (**Arctotheca calendula*, **Brachypodium distachyon*, **Sonchus oleraceus, *Marrubium vulgare, *Salvia verbenaca*, **Avena* spp., **Bromus* spp., **Hypochoeris* spp. **Trifolium* spp. and **Lolium* spp.)
Geographic distribution: Restricted to the Gredgwin Ridge west of Boort and the Loddon River in the extreme west of the study area.
Geology/geomorphology: Marine Parilla sand.
Mean annual precipitation: 372 mm.
Soil types and drainage: wide range: Woolshed sandy loam, Terrappee clay loam and Boort clay.
Tenure/management history: Public reserves and road reserves not subject to either stock grazing or burning.

Group No: 14	Group name: granite outcrop shrubland	Quadrat No: 2

Structure: Tall Shrubland
Dominant species: *Acacia deanei* sspp. *paucijuga, Correa glabra and Prostanthera nivea.*
Floristics: (Indigenous) Tall shrubs (see above) over perennial forbs (*Stypandra glauca, Gonocarpus elatus* and *Isotoma axillaris*), perennial tussock grasses (*Danthonia spp. Stipa scabra*) and annual forbs (*Crassula sieberiana*). (Exotics) Annual forbs and grasses (**Arctotheca calendula, *Bromus* spp. **Ehrharta longifolia, *Erodium cicutarium, *Hypochoeris* spp. **Sonchus oleraceus, *Marrubium vulgare and *Lamarckia aurea*).
Geographic distribution: Restricted to outcropping granite rock peaks along the Terrick Terrick Range, north of Mitiamo.
Geology/geomorphology: Granite (igneous).
Mean annual precipitation: 389 mm.
Soil types and drainage: Well drained skeletal soils (shallow and gravelly).
Tenure/management history: Public reserve not current subject to stock grazing, but a history of both stock and rabbit degradation.