Date of Publication:
July 2022

# Cunninghamia

A journal of plant ecology for eastern Australia

ISSN 0727-9620 (print) • ISSN 2200-405X (Online)

# Potential for conservation and restoration following long-term pastoral use in a temperate forest-woodland-grassland mosaic on the Southern Tablelands, New South Wales

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***Abstract****:* We document the transitioning of a 50 ha paddock from production grazing to conservation land use. Observations include: i) a quantitative ground layer vegetation baseline survey; ii) the species assemblage and iii) an estimate of the species dynamics in terms of colonization and local extinctions over a 15 year period. We interpreted site productivity to be the major factor influencing species composition, followed by moisture availability. The two vegetation types present, grassy woodland and sclerophyll forest, were floristically distinct but the lower slopes of the sclerophyll forest had a similar richness of native grassy ecosystem species to that of grassy woodland. The spontaneous colonization rate was one species per year (25% native, 75% exotic). Eradication efforts and spontaneous losses of species with small populations over the 15 years resulted in a net loss of one native and three exotic species. However, assisted colonization resulted in 17 local native species becoming naturalised. Our results demonstrate that significant native plant diversity (256 species, including 39 geophytes, 31 annuals and 187 other grassy ecosystem species) can persist under heavy livestock grazing if pasture improvement is limited. Moreover, the potential for introduction of additional species with active restoration is high. Conservation of grassland species would be better served if the significance of the grassy woodland-sclerophyll forest interface was recognized in conservation practice.

**Key words:** Southern Tablelands NSW, grassy eucalypt woodland, colonization, species turnover, species richness, nutrient response, slope position, NMDS ordination

***Cunninghamia* (2022) 22: 027–044**
**doi: 10.7751/cunninghamia.2022.003**

## Introduction

Unfenced grazing by livestock on the Southern Tablelands of New South Wales began in the 1820s when the first flocks of sheep were driven westwards from the Sydney region (Wyatt 1941; Lea-Scarlett 1972). Shepherding of flocks prevailed until secure tenures were established; cropping, internal fencing and tree clearing followed. Pasture improvement surged in the mid-twentieth century (Alexander & Williams 1986). These exogenous disturbances coincided with the dispossession of indigenous peoples and the cessation of their longstanding management regimes. Together with the persecution of certain native animals such as bettongs (Short 1998) and koalas (Lea-Scarlett 1972), and the importation of exotic flora and fauna, these factors have modified the diversity, structure and function of the grassland, woodland and forest vegetation that still occupies the bioregion. All but the most inaccessible parts of the Tablelands have been affected by this kaleidoscope of changes, but agricultural intensification has resulted in the greatest loss of vegetation on the fertile soils, where the grasslands and grassy woodlands have been seriously depleted (Keith 2004). While the less fertile sclerophyll forests are notionally more intact, past tree clearing, misguided attempts at pasture improvement, and on-going grazing have also seriously affected the condition of vegetation and soil in these forests (Jenkins 2000; Keith 2004).

The Ordovician sediments of the Southern Tablelands support a mosaic of Southern Tableland Dry Sclerophyll Forest and Southern Tableland Grassy Woodland which has been converted to derived grassland and open woodland over significant areas (Jenkins 2000; Keith 2004) and, in places, now supports dense tree regrowth in previously cleared areas. These regional vegetation types and their typical structural modifications are represented in the study site. Our benchmark vegetation description marks the endpoint of 200 years of pastoralism, and the beginning of a transition towards restoration with a biodiversity conservation objective. For this we provide a baseline vegetation assessment at two temporal scales (1 year and 15 years):

i) Sampled vegetation stratified over the floristic and structural habitats across a 50 ha landscape assessed over 2.5 months in spring-summer 2005 providing a snapshot of vegetation composition within one year of the removal of long-term sheep grazing;

ii) A full floristic inventory over the entire 50 ha based on repeated searching over a 15 year period.

We used the data to characterize the ground layer vegetation in relation to landscape position, and the presence of tree canopies in grassy woodland, sclerophyll forest and derived grassland (Figure 1). The conservation significance of vegetation with this type of land use history is considered in relation to its total flora, species richness and the presence of several vulnerable groups, namely grassland and grassy woodland species, native geophytes and native annual species. The potential for achieving significant ecological restoration is considered in terms of our estimates of species turnover in time, at the 50 ha scale, the rates of new exotic and native colonization, and the potential for assisted colonization to augment species diversity.

a)

b)

c)

**Figure 1.** Three major vegetation types occurring at the study site on the southern tablelands of NSW; a) Dry sclerophyll forest; b) *Eucalyptus melliodora* grassy woodland and c) Derived grassland with scattered eucalypts, showing the convergence of two incised drainage lines in the foreground.

## Methods

### *Study area characteristics and history*

The study area is located on undulating hills and minor flats of the Yass River valley, on the New South Wales Southern Tablelands. Permanent plots were established across a 50 ha study area comprising a single paddock (centre 34°58'30"S, 149°12'23"E) with an altitudinal range of 50 m (585-635 m). The soil parent materials are Ordovician sediments (Jenkins 2000) and the clay-loam soils are acidic (pH 4 - 5), nutrient-poor and highly erodible. The mean annual temperature is 20°C (maximum) and 6.5°C (minimum). Annual rainfall averages 644 mm, with monthly averages ranging from 45 mm (in May, June, July) to 66 mm (November). Extremely wet or dry conditions may be experienced in any month of the year and winter frosts are frequent. The study area has a 200-year history of livestock grazing. Stocking in the 25 years prior to the first vegetation assessment (2005) was 100 wethers, reduced to 65 from 2000-04 during the Millennium Drought. While this stocking rate of 2 Dry Sheep Equivalent/ha is mid-range carrying capacity for native grassland in the region (Langford *et al.* 2004) one third of the paddock was dry sclerophyll forest, which suggests higher grazing pressures.

Over the 50 ha, the vegetation comprises roughly equal amounts of Southern Tableland Dry Sclerophyll Forest (hereafter sclerophyll forest), Southern Tableland Grassy Woodland (hereafter grassy woodland) (Keith 2004), and grassland-open woodland mosaic derived from tree clearing. While there is evidence of past ringbarking, most of the open areas resulted from pasture development in 1972-74. Trees were bulldozed into windrows and burnt. The areas were chisel-ploughed, superphosphate applied and sown to *Trifolium* spp. The entire site was burnt by wildfire in 1975. There have been no further pasture inputs, and soil sampling in 2006 indicated that available soil phosphorus had returned to 'native' levels (Colwell P, 5 $mg.kg^{-1}$; see McIntyre 2008). Conversion from pastoral use to conservation management was initiated at the end of 2004 with the permanent removal of all livestock.

From the start of the study (January 2005), the site continued to be grazed by macropods: *Macropus giganteus*, *Macropus rufogriseus* and *Wallabia bicolor* which moved freely within and beyond the site. The latter two species were present in low numbers in the forest and woodland. Hares were also present in very low numbers but their grazing impact was not evident, and rabbits were absent. The grazing regime after the removal of livestock was overall lighter and more selective, resulting in spatially variable grazing pressure. The upper slopes were the most severely grazed part of the landscape before and during the study, with 30-40 *Macropus giganteus* frequently sighted in this more open area. They also camped in the sclerophyll forest where total grazing/browsing pressure was high. Rainfall variation resulted in grazing pressure also varying in time, although even at the extreme of the 2017-19 drought, grassland on the upper slopes supported an average biomass in the order of 1,500 $kg.ha^{-1}$.

### *Floristic inventory*

Plant species records between 2005 and 2020 were amassed through regular formal and informal observations, at fine and broad spatial scales, by two people (SM, JL) with plant identification skills. Observations included five plot surveys (650 hours), fine- and broad-scale weeding (estimated 2,800 hours) and walking all parts of the site (estimated 2,400 hours), spread evenly over the 15 years of observation. This intensive level of scrutiny enabled estimates of species population sizes, identification of new incursions, extirpation of exotic incursions, detection of cryptic species and observations of intermittently emerging species.

### *Plot survey design*

We established 73 permanently marked plots (5 x 6 m) and assessed the ground layer vegetation in 2005, 12 months after the removal of sheep. While five surveys of these plots were conducted between 2005 and 2020 and these contributed to the floristic inventory, we report the details of the 2005 baseline survey only in this paper. Plot (= site) locations were stratified to sample the range of environments over the 50 ha study area. These were categorised in terms of vegetation structure, tree species and landscape position (Table 1), and numbers of plots were roughly proportional to the representation of the area of the habitats, although 'Sheep Camps' were over-represented. All but the 'Forest' category were sites located in grassy woodland or derived grassland broadly associated with grassy woodland eucalypts:

1) Forest - in sclerophyll forest with continuous tree canopy characterised by *Eucalyptus rossii* and *Eucalyptus mannifera* on the mid- and upper slopes and by *Eucalyptus macrorhyncha* and *Eucalyptus polyanthemos* on the mid-and lower slopes;
2) Open - grass-dominated sites away from tree canopies;
3) Tree - under a well-developed canopy of a eucalypt (*Eucalyptus macrorhyncha*, *Eucalyptus polyanthemos* or *Eucalyptus melliodora*) in a scattered tree or woodland setting;

   For habitats 1-3, upper slopes included hill crests and shoulders, lower slopes included break of slope and flats, while mid-slopes were intermediate locations;

4) Sheep camp - these were physically equivalent to upper slope 'Tree' habitat but carried a nutrient legacy from their previous use by sheep as locations for habitual resting (Nui et al. 2009), as evident from accumulated dung;
5) Drainage line - intermittent watercourses (1st and 2nd order) with scour ponds and incised sections (as described in Eyles 1977). 'Slope position' for drainage lines was determined from the overall altitude at the study site as follows: upper (1st order drainage lines, >615 m), mid- (1st order, 600 – 615 m) and lower (2nd order drainage line, <600 m). Trees were largely absent from the drainage line sites.

**Table 1. Stratification of survey plots across habitat and landscape position. The 73 permanently marked plots (6 x 5m) were assessed in 2005, one year after destocking.**

| | Slope position | | | Total |
|---|---|---|---|---|
| Habitat | Upper | Mid | Lower | (n = 73) |
| Open | 8 | 10 | 9 | 27 |
| Tree | 4 | 3 | 4 | 11 |
| Forest | 6 | 7 | 4 | 17 |
| Drainage line | 4 | 4 | 6 | 14 |
| Sheep camp | 4 | 0 | 0 | 4 |

*Survey methods*

All herbaceous species (except cryptogams) and shrubs with a potential growth height up to 1.5 m were included in the survey. The 2005 plot survey (and subsequent surveys) comprised two assessments: i) in early spring to detect the presence of geophytes and early finishing annuals, and ii) in late spring-early summer to record all additional species and their relative abundance. In 2005 the timing of the two assessments was early October and late November-early December. For relative abundance, the top ten plant species were ranked by biomass. The two assessments were merged in the final data set, with species recorded in early spring being recorded as present, or included in the rankings if they persisted into late spring.

*Data analysis*

The 73 site by 205 species matrix was used as input to a Non-metric Multidimensional Scaling Ordination (NMDS). Abundance was scored as follows: 1st ranked = 11; 2nd ranked = 10; 3rd ranked = 9, and so on, down to species that were ranked 11th onwards scored as 1. This scoring method is the equivalent of an arc sine, square-root transformation of relative biomass ('t Mannetje & Haydock 1963). The similarity matrix for the NMDS was obtained by using the Bray and Curtis coefficient (Oksanen *et al.* 2019). The function metaMDS (Oksanen *et al.* 2019) was used to generate an ordination solution using the default options which implies that the function monoMDS (Oksanen *et al.* 2019) was used with the model set to 'global' (equivalent to Kruskal's (1964 a,b) original NMDS). The minimum and maximum number of iterations was set to 1000 which gives a minimum number of random starts ensuring that a global rather than a local optimum solution has been found. The treatment of ties was set to be TRUE, meaning that where equal observed dissimilarities occur, they are allowed to have different fitted values.

The three-axis solution (stress value 0.11) was accepted (Figure 2) as it represented a compromise between an easily displayed two axes solution and one with four axes which had a stress value of less than 0.1 (0.092). Stress represents a goodness-of-fit measure of the NMDS ordination and is the proportion of the sum of the differences between the squared between-plot distances in the original data and in the NMDS ordination, relative to the sum of the squared distances in the original data (Kruskal 1964b). Stress can take values that range from zero to one where a value close to zero represents an ordination that has very little distortion relative to the original data and values above 0.3 suggest that the ordination has performed poorly. All analyses were performed in the R language and environment (R Core Team 2021).

The position of the sites was displayed in two-dimensional scatter plots (Figure 2). As there were 205 species in the input data matrix, it was not feasible to display their positions in the multidimensional space as a biplot. Rather, the distribution of the species coded as annual, native, exotic and grassy ecosystem species were displayed in the ordination space (Figure 3) defined by the first two NMDS axes (Figure 2).

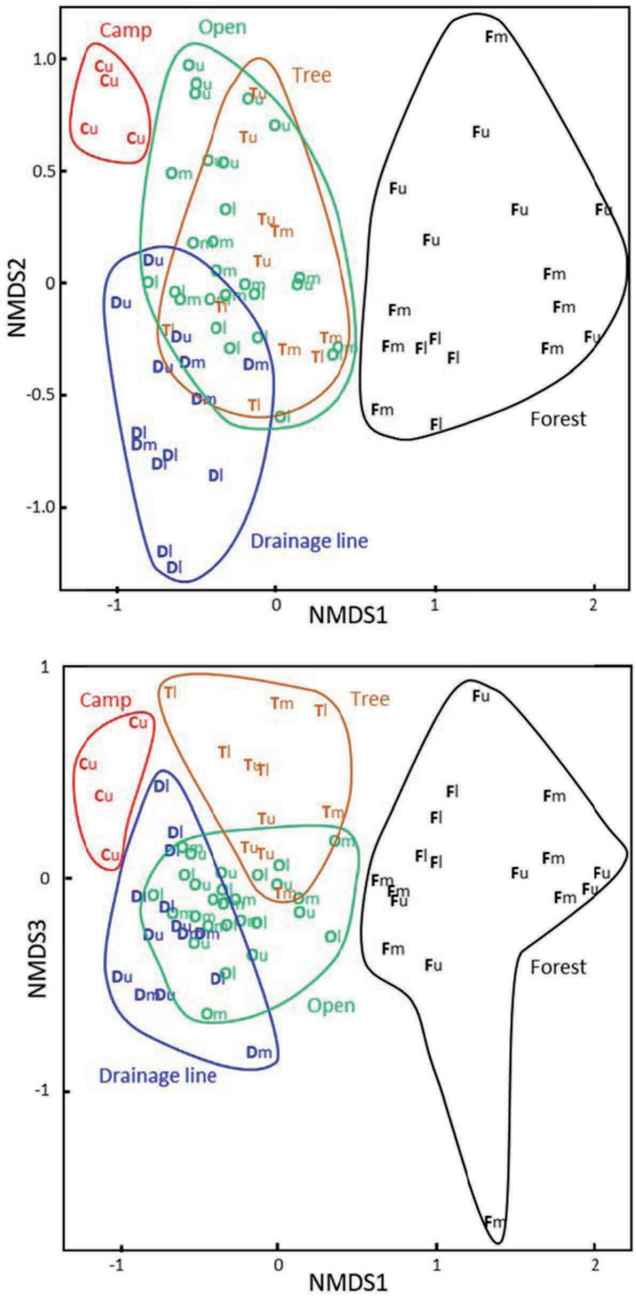


**Figure 2.** The distribution of the 73 plots in the three axes NMDS ordination space. Primary habitat coded as C = historical sheep camp, T = under tree canopy in grassy vegetation, O = open grassy vegetation, D = drainage line, F = dry sclerophyll forest and slope position coded as u, m and l for upper, mid- and lower slope respectively.

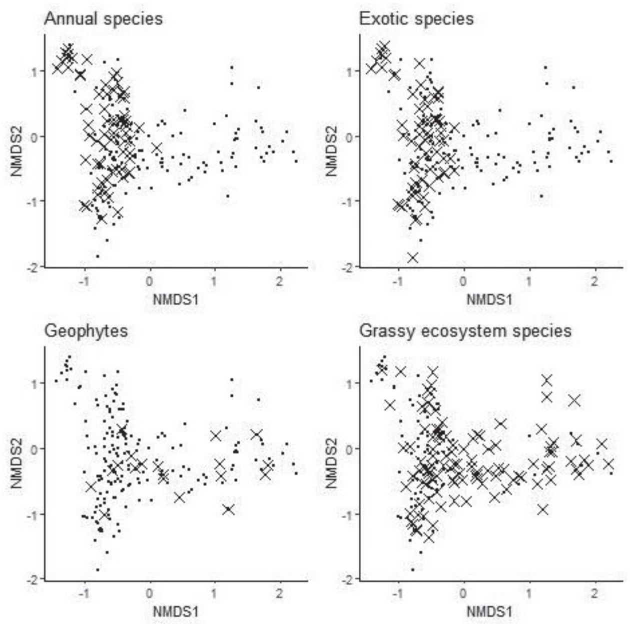


**Figure 3.** Distribution of the 205 species recorded in the 73 survey plots in the first two axes of the NMDS ordination space (as presented in Figure 2). Annual species, native species, geophytes, and native grassy ecosystem species are highlighted as 'x' with other species represented by small points. NMDS1 is negatively correlated with site productivity while NMDS2 is positively correlated with site dryness (higher slope position) as indicated in Figure 2.

## Results

### *General features of the species assemblage and rates of change*

A total of 370 species was recorded over the entire 50 ha between 2005 and 2020 (Appendix 1). The majority were native perennials, followed by exotic annuals, then similar numbers of native annuals and exotic perennials (Table 2). Half of the total comprised native species associated with grasslands or grassy woodlands (hereafter "grassy ecosystem species" as defined in Appendix 1) and there was a diversity of native geophytes, primarily orchids (27 of the 39 species). Population estimates made for 342 species (Appendix 1) indicate that 65% of the native species were present in numbers greater than 100, and that greatest proportion of species with an extremely large population (>10,000 plants) were exotic annuals.

**Table 2. Summary of origin and life-form of 370 species recorded at the 50 ha study site between 2005 – 2020. Grassy spp. = native grassy ecosystem species. Full details in Appendix 1.**

| | Native | Exotic |
|---|---|---|
| Total | 256 | 114 |
| Annual | 31 | 85 |
| Perennial | 225 | 29 |
| Geophyte | 39 | 3 |
| Grassy spp. | 187 | - |

Our sustained level of observation provides some estimates of the gains and losses of species over the 50 ha between 2005 and 2020, although a level of uncertainty is unavoidable. Lags in recognition of existing species can be due to various factors e.g. dormancy of seed or storage organs, appearances related to rainfall, incomplete searching. Context is important for interpretation. For example, flowering *Caleana minor* appeared on two stony ridges in forest in the very wet spring of 2016; the remote location of plants and their simultaneous appearance at two sites suggest their small single leaves were absent or undetected, even in previously searched permanent plots, and they were not considered colonizers. In contrast, the appearance of previously unrecorded species near vehicle tracks, places of habitation or earthworks were assumed to be the result of introduction via vehicles, which are major vectors for seed dispersal (Wace 1977). Two species were introduced via illegally dumped garden waste. Fifteen species were identified as having colonised (approximately one per year) of which six exotics and one non-local native were eradicated (or at least provisionally eradicated) and eight are established or naturalised (three native, five exotic) (Table 3). Each of the two colonising native shrub species are represented by only one individual.

There has been spontaneous local extinction of eight exotic species and four native species, all of which were represented by one or a few plants at the commencement of the observations. In summary, over the 15 years, there has been a net loss of one native species and a net loss of three exotic species. In addition to these species, assisted colonisation through direct seeding and planting by the authors (SM, JL) has resulted in the naturalisation of an additional 17 indigenous native species (6 forbs, 8 shrubs, 3 aquatics, Table 3). The species were sourced locally, if available, or commercially. If these introductions are included, there has been a net gain of 16 native species.

**Table 3. Gains and losses of species between 2005 and 2020 over the entire 50 ha study site.**
*** denotes exotic species. Abbreviations: s = shrub, ah = annual herb, ag = annual grass, aq = aquatic herb, ph = perennial herb, pg = perennial grass.**

| Life-form | Colonised spontaneously, established |
|---|---|
| s | *Pultenaea spinosa* |
| s | *Acacia verniciflua* |
| ah | *Gnaphalium indutum* |
| ah | **Lotus angustissumus* |
| ah | **Pentameris aeroides* |
| ag | **Psilurus incurvus* |
| ag | **Digitaria ischaemum* |
| ag | **Digitaria sanguinalis* |
| | Colonised spontaneously, provisionally eradicated |
| s | *Acacia boormanii* |
| ah | **Crepis foetida* |
| ah | **Senecio madagascariensis* |
| ph | **Romulea rosea* |
| ph | **Nothoscordium borbonicum* |
| ph | **Galium aparine* |
| pg | **Eragrostis curvula* |

| | Spontaneous local extinction |
|---|---|
| ah | *Brachyscome perpusilla* |
| ah | **Sisyrinchium rosulatum* |
| ah | **Echium plantagineum* |
| ah | **Vicia sativa* |
| ah | **Polygonum aviculare* |
| ah | **Tragopogon dubius* |
| ag | *Aristida behriana* |
| ag | **Bromus catharticus* |
| ag | **Bromus rubens* |
| ph | *Cynoglossum suaveolens* |
| ph | *Cassytha pubescens* |
| pg | **Puccinellia sp.* |
| | Actively introduced, subsequently naturalised |
| s | *Acacia buxiflolia* |
| s | *Daviesia latifolia* |
| s | *Indigofera australis* |
| s | *Grevillea lanigera* |
| s | *Kunzea ericoides* |
| s | *Melaleuca parvistaminea* |
| s | *Bursaria spinosa* |
| s | *Dodonaea viscosa* |
| ph | *Eryngium ovinum* |
| ph | *Calocephalus citreus* |
| ph | *Linum marginale* |
| ph | *Chrysocephalum semipapposum* |
| ph | *Leucochrysum albicans* |
| ph | *Vittadinia gracilis* |
| aq | *Ottelia ovalifolia* |
| aq | *Schoenoplectus tabernaemontani* |
| aq | *Typha domingensis* |

## *Plot survey*

The plot survey recorded 205 species or taxonomic entities, a little over half (55%) of the species recorded in the overall site, despite sampling less than 1% of the total area. All the species with large populations (>10,000, Appendix 1) were recorded, with progressively fewer of the smaller populations represented, so that only 24% of the species with populations of ≤ 100 were recorded. Twelve of the 14 most frequent and dominant taxa were native (Table 4), with annual grasses (*Aira*, *Vulpia*, *Briza*) and *Hypochoeris* spp. being the most dominant exotic taxa.

**Table 4. Integrated list of 28 species, representing the 20 most dominant (RA = relative abundance) and 20 most frequent (Freq.) species/taxa in all 73 x 30m² plots assessed in 2005. Bold indicates species that meet both criteria (dominant and frequent); underlining indicates where a taxon met one, but not both of the criteria, * indicates exotic taxa.**

| All sites | RA | Freq. |
|---|---|---|
| ***Rytidosperma* spp.** | **5.4** | **0.6** |
| ***Themeda triandra*** | **5.1** | **0.5** |
| ****Aira elegantissima*** | **4.4** | **0.6** |
| ***Lomandra filiformis*** | **4.3** | **0.6** |
| *Rytidosperma pallidum* | 3.1 | 0.3 |
| ***Microlaena stipoides*** | **2.7** | **0.5** |
| ****Aira caryophyllea*** | **2.0** | **0.4** |
| *Aristida ramosa* | 1.8 | 0.3 |
| *Melichrus urceolatus* | 1.8 | 0.3 |
| *Poa sieberiana* | 1.7 | 0.3 |
| ***Gonocarpus tetragynus*** | **1.5** | **0.5** |
| *Acacia genistifolia* | 1.4 | 0.1 |
| ***Goodenia hederacea*** | **1.4** | **0.4** |
| *Dillwynia phylicoides* | 1.4 | 0.1 |
| ****Vulpia myuros*** | **1.4** | **0.4** |
| ****Hypochaeris glabra*** | **1.3** | **0.6** |
| **Poa bulbosa* | 1.3 | 0.2 |
| *Dianella revoluta* | 1.2 | 0.2 |
| *Carex appressa* | 1.1 | 0.1 |
| ****Briza maxima*** | **1.1** | **0.4** |
| *Triptilodiscus pygmaeus* | 1.0 | 0.4 |
| **Briza minor* | 1.0 | 0.5 |
| **Vulpia bromoides* | 0.97 | 0.4 |
| **Hypochaeris radicata* | 0.85 | 0.4 |
| *Hypericum gramineum* | 0.78 | 0.4 |
| *Solenogyne dominii* | 0.78 | 0.4 |
| *Drosera peltata* | 0.73 | 0.4 |
| *Oxalis perennans* | 0.58 | 0.4 |
| *Microtis unifolia/parviflora* | 0.51 | 0.4 |

The ordination of the 73 sites revealed differences between the forest sites and the four other habitats, with slope position and the presence of tree canopies also influencing ground layer composition (Figure 2). The first axis separated sites along a soil productivity gradient, with sheep camps and drainage lines representing the fertile end, sclerophyll forest sites representing low productivity sites, with tree canopy and open habitats being intermediate. The second axis is suggestive of a moisture gradient, with sites being sorted by landscape position within their habitat type. Thus the driest sites were i) sheep camps which are located under trees on the highest parts of the study area, ii) the ridge tops of the forest and iii) the exposed open grassland also on the highest parts. The wettest sites were the mid- and lower drainage lines. Intermediate sites on the moisture gradient were tree canopy, open, and forest habitats (mid- and lower slopes), and upper drainage lines. The third axis separated tree canopy sites on the lower and mid-slopes from open sites. Sites under tree canopies on the upper slopes (where trees were widely scattered) had affinities to open sites on the lower slopes (where a woodland structure predominated).

The nature of these habitat differences is summarised in terms of species with the highest relative abundances and frequencies in these micro-habitats (Table 5). Grasses and graminoids were important dominants, but varied across habitats. *Rytidosperma pallidum* was the outstanding dominant in the forest while a suite of eleven *Rytidosperma* spp. (Appendix 1) were most important in grassy woodland habitats. These were sampled and analysed separately as the individual species could not be ranked in the field, but varied in their ecology (see McIntyre *et al.* 2022). Other important native perennial graminoids were *Themeda triandra* (open sites low in the landscape), *Microlaena stipoides* (shaded and open sites), *Poa sieberiana* (low in the landscape), *Aristida ramosa* (upper and mid-slopes) and *Carex apressa* (drainage lines). The most important native forbs were *Lomandra filiformis* and *Gonocarpus tetragynus* (in all dry habitats), *Goodenia hederacea* (varied habitat) and *Dianella revoluta* (treed habitat). Native shrubs were frequent dominants in forest sites (*Acacia genistifolia*, *Dillwynia phylicoides*, *Brachyloma daphnoides*, *Daviesia leptophylla*, *Melichrus urceolatus*), with some present in other habitats (Table 5).

**Table 5. Most frequent (Freq.) and abundant (RA) species in five habitats and relevant combinations of slope position within each habitat. The number of sites per particular habitat/slopes combinations are given in brackets, * indicates exotic taxa; underlining indicates native grassland or grassy ecosystem species as defined and identified in Appendix 1; shaded species are those considered indicative of Southern Tableland Dry Sclerophyll Forest (Keith 2004).**

| OPEN | | |
|---|---|---|
| **All open sites (27)** | **RA** | **Freq.** |
| Rytidosperma spp. | 8.0 | 1.0 |
| *Aira elegantissima | 7.7 | 1.0 |
| Lomandra filiformis | 6.7 | 1.0 |
| *Aira caryophyllea | 2.9 | 0.7 |
| *Tolpis barbata | 2.4 | 0.9 |
| Microlaena stipoides | 2.2 | 0.8 |
| Triptilodiscus pygmaeus | 2.2 | 1.0 |
| *Hypochaeris glabra | 2.1 | 0.9 |
| Gonocarpus tetragynus | 1.8 | 0.9 |
| Solenogyne dominii | 1.2 | 0.8 |
| Goodenia hederacea | 1.2 | 0.6 |
| Hypericum gramineum | 1.1 | 0.7 |
| *Centaurium tenuiflorum | 0.9 | 0.8 |
| **Open upper slopes (8)** | | |
| Austrostipa scabra | 6.0 | 0.8 |
| *Poa bulbosa | 4.1 | 0.8 |
| *Vulpia myuros | 2.4 | 1.0 |
| **Open mid- & upper slopes (18)** | | |
| Aristida ramosa | 4.6 | 0.7 |
| Panicum effusum | 1.5 | 0.7 |
| **Open mid-slopes (10)** | | |
| *Briza maxima | 1.8 | 0.8 |
| **Open mid- & lower slopes (19)** | | |
| Themeda triandra | 10 | 0.9 |
| Melichrus urceolatus | 2.3 | 0.5 |
| *Briza minor | 1.9 | 0.9 |
| Drosera peltata | 1.3 | 0.9 |
| Microtis spp. | 0.9 | 0.9 |
| **Open lower slopes (9)** | | |
| Poa sieberiana | 2.6 | 0.7 |
| *Hypochaeris radicata | 0.8 | 0.8 |
| **DRAINAGE LINE** | | |
| **All drainage sites (14)** | **RA** | **Freq.** |
| Themeda triandra | 9.6 | 1.0 |
| Carex appressa | 5.9 | 0.6 |
| *Aira elegantissima | 4.9 | 1.0 |
| Schoenus apogon | 3.9 | 0.9 |
| Juncus subgen. Genuini. | 1.6 | 1.0 |
| *Briza minor | 1.5 | 1.0 |
| *Hypochaeris glabra | 1.1 | 0.8 |
| Drosera peltata | 1.1 | 0.9 |
| Euchiton japonicus | 0.9 | 0.8 |
| Hypericum gramineum | 0.8 | 0.8 |
| **Drainage line upper slopes (4)** | | |
| Solenogyne domini | 3.3 | 1.0 |
| *Aira caryophyllea | 2.5 | 0.8 |
| Alternanthera sp. A | 2.3 | 1.0 |
| **Drainage line mid- & upper slopes (8)** | | |
| Rytidosperma spp. | 7.7 | 1.0 |
| Eragrostis brownii | 6.5 | 0.8 |
| Microlaena stipoides | 4.1 | 0.9 |
| Daviesia genistifolia | 2.8 | 0.5 |
| *Isolepis levynsiana | 1.8 | 0.9 |
| **Drainage line mid- slopes (4)** | | |
| *Hypochaeris radicata | 3.3 | 1.0 |
| Goodenia hederacea | 2.5 | 0.5 |
| **Drainage line mid- & lower slopes (10)** | | |
| *Trifolium dubium | 3.4 | 1.0 |
| *Briza maxima | 3.3 | 1.0 |
| *Holcus lanatus | 2.7 | 0.8 |
| Haloragis heterophylla | 2.4 | 0.9 |
| *Gamochaeta americana | 1.1 | 0.9 |
| Hydrocotyle sibthorpioides | 0.9 | 0.8 |
| **Drainage line lower slopes (6)** | | |
| Craspedia variabilis | 3.5 | 0.5 |
| Poa labillardieri | 3.5 | 0.7 |
| Isotoma fluviatilis | 2.8 | 1.0 |
| Elaeocharis plana | 1.8 | 0.3 |
| **TREE CANOPY** | | |
| **All tree canopy sites (11)** | **RA** | **Freq.** |
| Rytidosperma spp. | 6.4 | 1.0 |
| Microlaena stipoides | 5.8 | 0.9 |
| Lomandra filiformis | 5.6 | 1.0 |
| Gonocarpus tetragynus | 2.5 | 1.0 |
| Anthosachne scabra | 1.7 | 0.9 |
| *Aira caryophyllea | 3.7 | 0.7 |
| Themeda triandra | 3.3 | 0.7 |
| **Tree canopy upper slopes (4)** | | |
| *Poa bulbosa | 4.3 | 1.0 |
| *Petrorhagia nanteuilii | 2.3 | 1.0 |
| Austrostipa scabra | 1.8 | 0.5 |
| Panicum effusum | 1.0 | 1.0 |

(Table 5 cont.)

| TREE CANOPY | | |
|---|---|---|
| **All tree canopy sites (11)** | **RA** | **Freq.** |
| **Tree canopy mid- & upper slopes (7)** | | |
| *Rytidosperma pallidum* | 5.5 | 0.6 |
| **Aira elegantissima* | 4.9 | 0.6 |
| *Melichrus urceolatus* | 4.4 | 0.8 |
| **Vulpia myuros* | 4.3 | 0.7 |
| **Vulpia bromoides* | 4.2 | 0.9 |
| **Trifolium subterraneum* | 1.0 | 1.0 |
| **Tree canopy mid- slopes (3)** | | |
| **Rumex acetosella* | 3.3 | 1.0 |
| *Lomandra multiflora* | 1.0 | 1.0 |
| *Luzula densiflora* | 1.0 | 1.0 |
| **Tree canopy mid- & lower slopes (7)** | | |
| *Poa sieberiana* | 5.4 | 1.0 |
| *Hydrocotyle laxiflora* | 5.1 | 1.0 |
| *Dianella revoluta* | 2.7 | 0.6 |
| **Briza maxima* | 2.2 | 1.0 |
| **Hypochaeris radicata* | 2.0 | 0.7 |
| **Tree canopy lower slopes (4)** | | |
| *Plantago varia* | 6.0 | 0.8 |
| *Geranium solanderi* | 4.5 | 1.0 |
| *Scutellaria humilis* | 4.5 | 0.5 |
| *Acacia genistifolia* | 2.8 | 0.3 |
| **Lolium perenne* | 2.5 | 0.8 |
| *Oxalis perennans* | 1.8 | 1.0 |
| *Daucus glochidiatus* | 1.3 | 1.0 |
| **CAMP (all upper slopes)** | | |
| **All camp sites (4)** | **RA** | **Freq** |
| **Poa bulbosa* | 8.3 | 1.0 |
| **Arctotheca calendula* | 7.0 | 1.0 |
| **Hordeum glaucum* | 6.3 | 0.8 |
| *Rytidosperma* spp. | 6.3 | 1.0 |
| **Spergularia rubra* | 5.8 | 1.0 |
| **Vulpia myuros* | 5.5 | 1.0 |
| **Rumex acetosella* | 4.3 | 0.8 |
| **Trifolium glomeratum* | 3.8 | 0.8 |
| **Lolium perenne* | 3.5 | 0.5 |
| **Poa annua* | 3.3 | 0.8 |
| **Bromus racemosus* | 2.8 | 0.8 |
| **Aira elegantissima* | 2.0 | 1.0 |
| **FOREST** | | |
| **All forest sites (17)** | **RA** | **Freq.** |
| *Rytidosperma pallidum* | 9 | 0.9 |
| *Acacia genistifolia* | 5.2 | 0.6 |
| *Dillwynia phylicoides* | 5.2 | 0.6 |
| *Brachyloma daphnoides* | 3.9 | 0.6 |
| *Daviesia leptophylla* | 3.7 | 0.7 |
| *Dianella revoluta* | 3.7 | 0.6 |

| FOREST | | |
|---|---|---|
| **All forest sites (17)** | **RA** | **Freq.** |
| *Lomandra filiformis* | 3.2 | 0.6 |
| *Melichrus urceolatus* | 3.1 | 0.6 |
| *Goodenia hederacea* | 2.9 | 0.8 |
| *Microlaena stipoides* | 2.1 | 0.7 |
| *Hovea heterophylla* | 2 | 0.7 |
| *Hibbertia obtusifolia* | 2 | 0.7 |
| *Gonocarpus tetragynus* | 1.5 | 0.6 |
| *Stylidium graminifolium* | 0.9 | 0.5 |
| **Forest mid- & upper slopes (13)** | | |
| *Aristida ramosa* | 2.7 | 0.4 |
| *Hibbertia riparia* | 2.2 | 0.3 |
| *Lomandra multiflora* | 1.6 | 0.6 |
| *Patersonia sericea* | 1.5 | 0.4 |
| *Astrotrica ledifolia* | 1.3 | 0.1 |
| **Forest mid- & lower slopes (11)** | | |
| *Poa sieberiana* | 4.4 | 0.7 |
| *Pultenaea subspicata* | 2.4 | 0.3 |
| *Dillwynia sericea* | 1.2 | 0.3 |
| **Forest lower slopes (4)** | | |
| *Dichelachne rara* | 2.0 | 0.3 |
| *Cheiranthera linearis* | 1.0 | 1.0 |
| *Microseris walteri* | 1.0 | 1.0 |
| *Hypericum gramineum* | 1.0 | 1.0 |
| **Hypochaeris glabra* | 1.0 | 1.0 |
| **Aira elegantissima* | 1.0 | 1.0 |
| *Glossodia major* | 0.3 | 0.8 |
| *Dichelachne hirtella* | 0.2 | 0.8 |

Native species richness at the plot scale was lowest on the sclerophyll forest upper slopes and sheep camps and highest in the open sites and drainage lines (Table 6). Exotic species richness was highest on the sheep camps and in the drainage lines. The upper and mid-slopes of the forest habitat were the most species poor, but the lower slopes supported high densities of native species, 'grassy ecosystem' species, comparable with open and treed grassy habitats (Table 6). Forest lower slopes also had the highest density of native geophytes, and the lowest density of exotics when compared with open and treed grassy habitats. These patterns are supported by the distribution of the 205 survey species in the NMDS ordination space (Figure 3) where exotic species and annuals are clustered towards the negative end of axis 1, where the fertile drainage line and sheep camp sites occurred (Figure 2). Also notable is the wide spread of the grassy ecosystem species on both axis 1 and 2, which is consistent with their association with sclerophyll forest as well as grassy habitats. Geophytes were associated with the range of habitat fertilities (across axis 1) but were missing from the driest and wettest sites (the extreme ends of axis 2).

**Table 6. Average numbers of species recorded in 75 plots (5 x 6 m) in 2005 in a 50 ha paddock comprising dry sclerophyll forest, grassy woodland and derived grassland (+/- standard errors). Plots are classified by habitat type and slope position within habitat type.**

| | Habitat type | | | | | |
|---|---|---|---|---|---|---|
| | Camp (n = 4) | Drainage (n = 14) | Forest (n = 17) | Open (n = 27) | Tree (n = 11) | All sites (n = 73) |
| **a) All species** | | | | | | |
| **All slopes** | **35 ± 1.5** | **48 ± 2.4** | **22 ± 3.0** | **42 ± 1.7** | **39 ± 2.4** | **37 ± 1.5** |
| Lower slope | - | 42 ± 2.6 | 33 ± 2.4 | 45 ± 2.0 | 39 ± 3.5 | - |
| Mid-slope | - | 48 ± 3.9 | 22 ± 5.0 | 46 ± 2.4 | 41 ± 3.5 | - |
| Upper slope | 35 ± 1.5 | 58 ± 2.0 | 14 ± 3.4 | 33 ± 2.0 | 37 ± 5.8 | - |
| **b) Native species** | | | | | | |
| **All slopes** | **11 ± 1.5** | **28 ± 1.7** | **19 ± 2.4** | **26 ± 1.2** | **23 ± 1.9** | **24 ± 1.0** |
| Lower slope | - | 25 ± 1.7 | 29 ± 1.8 | 29 ± 1.2 | 23 ± 1.6 | - |
| Mid-slope | - | 27 ± 3.9 | 19 ± 3.9 | 28 ± 1.8 | 25 ± 5.0 | - |
| Upper slope | 11 ± 1.5 | 34 ± 2.2 | 13 ± 3.2 | 20 ± 1.8 | 23 ± 4.2 | - |
| **c) Exotic species** | | | | | | |
| **All slopes** | **23 ± 1.0** | **20 ± 1.2** | **2.2 ± 0.7** | **16 ± 0.9** | **15 ± 1.4** | **14 ± 0.9** |
| Lower slope | - | 17 ± 1.9 | 4.5 ± 0.6 | 16 ± 1.7 | 15 ± 3.4 | - |
| Mid-slope | - | 21 ± 1.6 | 2.6 ± 1.3 | 18 ± 1.6 | 16 ± 2.0 | - |
| Upper slope | 23 ± 1.0 | 24 ± 0.8 | 0.3 ± 0.2 | 13 ± 0.7 | 14 ± 1.7 | - |
| **d) Grassy ecosystem species (Grassland and/or grassy woodland)[1]** | | | | | | |
| **All slopes** | **10 ± 1.2** | **24 ± 1.5** | **18 ± 2.2** | **25 ± 1.2** | **23 ± 1.8** | **22 ± 0.9** |
| Lower slope | - | 21 ± 1.4 | 26 ± 1.5 | 29 ± 1.0 | 23 ± 1.6 | - |
| Mid-slope | - | 24 ± 3.5 | 18 ± 3.6 | 27 ± 1.7 | 24 ± 4.3 | - |
| Upper slope | 10 ± 1.2 | 29 ± 2.2 | 12 ± 2.7 | 19 ± 1.8 | 23 ± 4.2 | - |
| **e) Native geophytes** | | | | | | |
| **All slopes** | **0** | **3.3 ± 0.4** | **2.2 ± 0.5** | **2.6 ± 0.3** | **1.8 ± 0.5** | **2.4 ± 0.2** |
| Lower slope | - | 3.3 ± 0.6 | 4.8 ± 0.8 | 4.0 ± 0.4 | 2.0 ± 0.7 | - |
| Mid-slope | - | 3.0 ± 0.9 | 1.9 ± 0.7 | 2.8 ± 0.3 | 2.3 ± 1.4 | - |
| Upper slope | 0 | 3.8 ± 0.6 | 0.8 ± 0.4 | 0.7 ± 0.2 | 1.2 ± 0.7 | - |

1. Listed in either Eddy *et al.* (1998) or the EPBC List of species of White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland: http://www.environment.gov.au/epbc/publications/white-box-yellow-box-blakelys-red-gum-grassy-woodlands-and-derived-native-grasslands.

## Discussion

### *Axes of floristic variation*

The critical importance of a productivity gradient in determining ground layer composition, suggested by the first axis of the ordination (NMDS1, Figure 2), is consistent with other reports of primary effects of nutrients (natural or added) on composition, in the same district (McIntyre 2008; McIntyre *et al.* 2010), and elsewhere in eastern Australia (Chalmers 1996; McIntyre & Martin 2002; Reseigh 2004; Dorrough *et al.* 2006; Dorrough & Scroggie 2008; Driscoll & Strong 2018). The stony ridges of the forest habitat were dominated by coarse tussocks of *Rytidosperma pallidum* and shrubs, many of which were are identified as indicative of Southern Tableland Dry Sclerophyll Forest by Keith (2004) and the Grass/shrub forest (5b) of Gellie (2005). The combined effects of grazing, thin rocky soils and high tree densities in the forest contributed to a very sparse ground layer, as well as a notable lack of exotic species amongst the forest dominants, particularly on the mid- and upper-slopes (Table 5, 6). At the other end of the productivity gradient are the drainage line and sheep camp habitats, herbaceous communities whose productivity is relatively higher as a result of past nutrient deposition (camps), or water and nutrient flows (drainage lines). These are strongly associated with annual exotic species (Figure 3). While sustained high soil moisture contributes to elevated nutrients, axis 2 appeared related specifically to moisture as it further separated the productive drier habitats from the moister ones and sorted the upper-slopes sites from mid- and lower slopes within habitats (NMDS2, Figure 2). The exotic-dominated sheep camps and open upper slopes shared *Vulpia myuros* and *Poa bulbosa* as dominants, in contrast to the waterlogging-tolerant native dominants of the lower drainage lines (Table 5). Although trees were not present at all sites, the ground layer floristics of the non-forest sites and the presence of *Eucalyptus melliodora* indicate they are Southern Tablelands Grassy Woodland as defined by Keith (2004) and Gellie (2005), although the absence of *Eucalyptus blakelyi* and the numbers of *Eucalyptus macrorhyncha* and *Eucalyptus polyanthemos* (Appendix 1) suggest they are at the infertile end of the scale, and some sites may be ecotonal with sclerophyll forest.

*Species diversity and richness*

The benchmark survey data presented here represent the culmination of over a century of commercial livestock grazing plus one earlier attempt at pasture sowing, before the switch to conservation management. The most obvious outcome of the land-use history is the large number of exotic species (representing about a third of the flora), and the predominance of annual species, particularly in the open areas of the upper slopes where cultivation, fertilisation and legume sowing took place in the 1970's (Tables 2, 4, 5). Despite this, comparisons of species richness in other comparable settings suggest that the ground layer is diverse at both the site and plot scale. An earlier study (McIntyre & Martin 2001) identified sub-tropical grassy woodlands as being exceptionally diverse in native species compared with the NSW northern tablelands. A comparison of four studies is now possible, which confirms the high native richness of grazed sub-tropical grassland, but which also suggests that a native component of the grassland in this study has been resilient to the effects of pasture 'improvement' three decades prior and that richness is similar or greater than temperate sites with no fertiliser history (Table 7). While the total species recorded in our 73 quadrats is less than that recorded in the other three studies, the geographical range sampled and number of quadrats is markedly more limited (Table 7). A prolonged and full search of the species present over our entire study site (0.5 km$^2$) revealed 370 species (Table 2), as many as recorded in the other surveys ranging over areas up to 10,000 km$^2$. Also notable is the consistency with which the exotic component of the species assemblage in all four studies represents approximately a third of the total (Table 6). Whether this is indicative of a wider pattern, or of any biological significance would require further investigation.

For native species, the drainage lines were the most species-rich overall and, within these, upper slope drainage lines were richer in both native and exotic species. We attribute this diversity to their variously incised state, in which the banks and gully walls were dry, and the bed of the drainage lines were variously moist, waterlogged and/or ponded. All these microhabitats were represented in the plots, with more heterogeneity in the upper slope plots.

**Table 7. Summary of four studies of grassy woodland vegetation in variegated landscapes using the same quadrat size (5 x 6m) and sampling a comparable range of enrichment, disturbance and grazing intensities. Means and standard errors given where available.**

| | This study | Reseigh (2004) | McIntyre & Martin (2001); McIntyre et al. (2002) | McIntyre et al. (1993); McIntyre & Lavorel (1994) |
|---|---|---|---|---|
| Region | NSW ST | NSW NT | SE Qld | NSW NT |
| Lithologies | Sediment | Basalt, granite, sediments, metamorphics, | Sandstone, granite, metamorphics | Basalt, granite, sediments |
| Sampled area (km$^2$) | 0.5 | 6,400 | 27 | ~10,000 |
| No. quadrats surveyed | 73 | 373 | 212 | 120 |
| Total species (% exotic) | 205 (33%) | 321 (30%) | 337 (28%) | 371 (29%) |
| Spp. density (30m$^{-2}$) all sites | | | | |
| Exotic | 14 ± 0.9 | 7 ± 0.2 | 10 ± 0.3 | 9 ± 0.8 |
| Native | 24 ± 1.0 | 14 ± 0.3 | 31 ± 0.9 | 19 ± 0.8 |
| Total | 38 ± 1.5 | 21 ± 0.3 | 41 ± 1.0 | 28 ± 0.7 |
| Native richness in 'natural' pasture | 26 ± 1.2[1] | ~17[2] | 36 ± 1.0[3] | 23 ± 1.8[4] |

1. open sites all slope positions, single fertilisation; 2. Unfertilised, sheep grazed; 3. Unfertilised, cattle grazed; 4. Grazed reserve (no fertiliser use).

*Sclerophyll forest as a refuge for grassland species*

An unexpected finding of the survey was the degree of overlap between the ground flora of the sclerophyll forest and the 187 species considered to be characteristic of grassy ecosystems. Although separated in the ordination by their dominant species, Figure 3 points to the occurrence of grassy ecosystem species across both vegetation formations. Moreover, the density of grassland species and native geophytes on the lower slopes of the forest, equalled that of the grassy woodland habitats (Table 6). *Microseris walteri* and *Glossodia major* were among the dominants, and the only known populations of *Calochilus platychilus*, *Patersonia sericea*, *Coronidium scorpioides* and *Stackhousia monogyna* occurred here. The lower slopes of forest also supported the largest populations of *Dichelachne* spp. (Table 5). It appears that this habitat may have provided a refuge for grassland and grassy woodland species during the century of livestock grazing and pastoral development. We suggest the infertility of the soil has contributed to reduced weed competition, while the associated sclerophylly in the ground layer creates a population of unpalatable species with high dry matter content (McIntyre 2008) which provide a biotic refuge (Milchunas & Noy-Meir 2002). There is strong experimental evidence of the negative effect of macropod grazing on the establishment and persistence of grassland forbs at our study site (McIntyre *et al.* 2018) and field observations point to *Rytidosperma pallidum* and *Melichrus urceolata* in particular assisting the survival of palatable grassland species (Figure 4).

a)

b)

c)

**Figure 4.** a) Interface of grassy woodland and dry sclerophyll forest with *Microseris walteri* occurring across both vegetation types; b) Example of a biotic refuge from herbivore grazing with *Diuris sulphurea* being protected by a large tussock of the unpalatable *Rytidospema pallidum* and c) *Walhenbergia* being protected by *Melichrus urceolatus*.

*Species turnover and potential for ecological restoration*

We acknowledge that the determination of species gains and losses is difficult. There are time lags to detection that might confuse a late emergence with a new arrival, and uncertainties about notional local extinctions, whether spontaneous or through eradication attempts. These are due to the low levels of apparency or enduring representation as only soil seed or dormant buds. Nonetheless we argue that detailed, frequent, thorough and long-term searching and documentation by two skilled observers has provided a reasonable estimate of species change at the 50 ha scale (Table 3). The plant colonisation rate was approximately one species per year, and 25% of these were native, the rest exotic. Although vehicle traffic was minimised whenever possible, maintenance of utilities and erosion works required some activity and likely accounted for most of the colonisation events. Illegal garden waste dumping and run-off from an adjacent property were other vectors. Of the four spontaneously colonising native species, one non-local species was eradicated owing to its potential invasiveness (*Acacia boormanii*), two are represented by only one individual (*Pultenaea spinosa*, *Acacia verniciflua*) and one is well established (*Gnaphalium indutum*). Of the 11 exotic species that colonised during the observation period, intensive management prevented six of these establishing. Taking into account the attrition of four existing native species (all with very small populations) there has been a net loss of one native species in 15 years. Despite the widespread adoption of biodiversity offsetting, there is great uncertainty around the expected improvement of vegetation subjected to conservation management (Dorrough *et al.* 2019). Assumptions of significant spontaneous improvement in the species assemblage with the removal of grazing are not supported by our observations. Nonetheless, the successful introduction of 17 shrubs and herbs have increased native species numbers by 7%.

*Conservation significance and restoration potential*

As individual species, grassy ecosystem forbs are rarely listed as endangered owing to their wide distribution, which tends to be weighed more heavily than their sparse occurrence (McIntyre 1992) but collectively they are important to the vegetation formations in which they occur, which are themselves endangered. Thus the high density and large populations of found in this study are of significance, even if they are ecotonal with sclerophyll forest. We argue that the skeletal nature of the soils, their susceptibility to erosion and the belated recognition that they are not suitable for pasture improvement has enabled the persistence of many species that are considered rare. For example, the native annuals of the Victorian basalt grasslands are considered to be of particular concern due to their recent decline (Sinclair *et al.* 2021). Yet 15 of the 35 species identified by these authors have been recorded at the study site including significant populations (>1,000) of *Daucus glochidiatus*, *Euchiton sphaericus*, *Stuartina muelleri*, *Triptilodiscus pygmaeus*, *Poranthera microphylla*, *Aphanes australiana* and *Sebaea ovata*, all considered to be occasional, very rare or now absent from Victorian grasslands. The factor not identified by Sinclair *et al.* that we consider to be important is the combination of heavy grazing and low fertility occurring at our study site.

Our results confirm the far great importance of nutrients over livestock grazing when it comes to historical land use effects on plant diversity. Areas that are considered marginal as grassy woodlands may in fact be the most significant when it comes to conserving a diversity of grassland species, yet the focus is often on the better soils which are generally the most altered by past land use. The evidence provided here, and in previous experimental work (McIntyre *et al.* 2018), demonstrates that this marginal grassy vegetation is quite amenable to the (re-)introduction of indigenous species, and point to an under-recognised conservation resource occurring in pastures with a limited history of pasture 'improvement'. In this district, our site is not exceptional in its land use history or the level of plant diversity. However, the predominance of private land in the area has allowed its significance to be overlooked.

## Acknowledgements

This work has received no external funding. Brendan Lepschi, David Mallinson and David Albrecht assisted with plant identifications.

## References

Alexander, G. and Williams, O.B. (1986) (eds) The pastoral industries of Australia: practice and technology of sheep and cattle production. Sydney University Press, Sydney NSW.

Chalmers, A.C. (1996) Plant strategies in herbaceous vegetation in relation to soil disturbance, fertilisation and sowing on the Northern Tablelands of NSW. PhD thesis, University of New England, Armidale.

Dorrough, J., Moxham, C., Turner, V. and Sutter, G, (2006) Soil phosphorus and tree cover modify the effects of livestock grazing on plant species richness in Australian grassy woodland. *Biological Conservation* 130: 394-405.

Dorrough, J. and Scroggie MP (2008) Plant responses to agricultural intensification. Journal of *Applied Ecology* 45: 1274-1283.

Dorrough, J., Sinclair, S.J. and Oliver, I. (2019) Expert predictions of changes in vegetation condition reveal perceived risks in biodiversity offsetting. *PLOS ONE* 14: e0216703.

Driscoll, D.A. and Strong, C. (2018) Covariation of soil nutrients drives occurrence of exotic and native plant species. *Journal of Applied Ecology* 55: 777-785.

Egan, J., Wood, T., Farrow, R. and Hayashi, T. (2020) Field Guide to Orchids of the Southern Tablelands of NSW Including the ACT. Inkpen Press Canberra.

Eddy, D., Mallinson, D., Rehwinkel, R. and Sharp, S. (1998) Grassland Flora: a field guide for the Southern Tablelands (NSW & ACT). Environment ACT, Australian Capital Territory.

Eyles ,R.J. (1977) Birchams Creek: the transition from a chain of ponds to a gully. *Australian Geographical Studies* 15: 146-157.

Fensham, R.J., and Laffineur B. (2019) Defining the native and naturalised flora for the Australian continent. *Australian Journal of Botany* 67: 55-69.

Gellie, N.J.H. (2005) Native vegetation of the Southern Forests: South-east Highlands, Australian Alps, South-west Slopes and SE Corner bioregions. *Cunninghamia* 9: 219-253.

Jenkins, B.R. (2000) Soil landscapes of the Canberra 1:100 000 sheet. Dept. of Land and Water Conservation, Sydney.

Keith, D.A. (2004) Ocean shores to desert dunes: the native vegetation of New South Wales and the ACT. Department of Environment and Conservation (NSW).

Kruskal, J.B. (1964a) Multidimensional scaling by optimising goodness-of-fit to a nonmetric hypothesis. *Psychometrika* 29: 1–28.

Kruskal, J.B. (1964b) Nonmetric multidimensional scaling: a numerical method. *Psychometrika* 29: 115–129.

Langford, C.M., Simpson, P.C., Garden, D.L., Eddy, D.A., Keys, M.J., Rehwinkel, R. and Johnston, W.H. (2004) Managing native pastures for agriculture and conservation. New South Wales Department of Primary Industries.

Lea-Scarlett, E. (1972) Gundaroo. Roebuck Society Publication No. 10, Canberra, ACT.

t' Mannetje, L. and Haydock, K.P. (1963) The Dry-Weight-Rank Method for the botanical analysis of pasture. *Journal of the British Grassland Society* 18: 268-275.

McIntyre, S. (1992) Risks associated with the setting of conservation priorities from rare plant species lists. *Biological Conservation* 60: 31-37.

McIntyre, S, (2008) The role of plant leaf attributes in linking land use to ecosystem function and values in temperate grassy vegetation. *Agriculture, Ecosystems and Environment* 128; 251-258.

McIntyre, S., Heard, K.M. and Martin, T.G. (2002) How grassland plants are distributed over five human-created habitats typical of eucalypt woodlands in a variegated landscape. *Pacific Conservation Biology* 7: 274-285.

McIntyre, S., Huang, Z. and Smith, A.P. (1993) Patterns of abundance in grassy vegetation of the New England Tablelands: identifying regional rarity in a threatened vegetation type. *Australian Journal of Botany* 41: 49-64.

McIntyre, S., Müller, W. and Lewis, J. (2022) Habitat distributions of 12 co-occurring wallaby grasses (*Rytidosperma* spp., Poaceae) and their response to a transition from pastoral to conservation land use. *Australian Journal of Botany* 70: 131-145.

McIntyre, S. and Lavorel, S. (1994) Predicting richness of native, rare and exotic plants in response to habitat and disturbance variables across a variegated landscape. *Conservation Biology* 8: 521-531.

McIntyre, S. and Martin, T.G. (2001) Biophysical and human influences on plant species richness in grasslands - comparing variegated landscapes in sub-tropical and temperate regions. *Austral Ecology* 26: 233-245.

McIntyre, S. and Martin, T.G. (2002) Managing intensive and extensive land uses to conserve grassland plants in sub-tropical eucalypt woodlands. *Biological Conservation* 107: 241-252.

McIntyre, S., Nicholls, A.O., Graff, P. and Stol, J. (2018) Experimental reintroduction of three grassland forbs to assess climate-adjusted provenancing, grazing protection and weed control. *Australian Journal of Botany* 66: 628-639.

McIntyre, S., Stol, J., Harvey, J., Nicholls, A.O., Campbell, M., Reid, A., Manning, A.D., Lindenmayer, D. (2010) Biomass and floristic patterns in the ground layer vegetation of box-gum grassy eucalypt woodland in Goorooyarroo and Mulligans Flat Nature Reserves, Australian Capital Territory. *Cunninghamia* 11: 319-357.

Milchunas, D.G. and Noy-Meir, I. (2002) Grazing refuges, external avoidance of herbivory and plant diversity. *Oikos* 99: 113 - 130.

Niu, Y., Li, G., Li, L., Chan, K.Y. and Oates, A. (2009) Sheep camping influences soil properties and pasture production in an acidic soil of New South Wales, Australia. *Canadian Journal of Soil Science* 89: 235–244.

Oksanen, J., Guillaume Blanchet, F., Friendly, M., Kindt, R. Legendre, P., McGlinn D., Minchin P.R., O'Hara R.B., Simpson G.L., Solymos P., Stevens, M.H.H., Szoecs E. and Wagner H. (2019) vegan: Community Ecology Package. R package version 2.5-6. https://CRAN.R-project.org/package=vegan.

R Core Team (2021) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Reseigh, J. (2004) Grazing management and environmental determinants of the diversity and composition of ground-storey vegetation on the Northern Tablelands, NSW. PhD Thesis, University of New England, Armidale, New South Wales.

Short, J. (1998) The extinction of rat-kangaroos (Marsupialia:Potoroidae) in New South Wales, Australia. *Biological Conservation* 86: 365-377.

Sinclair, S.J., Scott-Walker, G., Batpurev, K., Morgan, J.W., Just, K. and Cook, D. (2021) The forgotten annual forbs of Victoria's basalt plains grassland. *Ecological Management & Restoration* 22: 126-133.

Wace, N. (1977) Assessment of dispersal of plant species - the car-borne flora in Canberra. *Proceedings of the Ecological Society of Australia* 10: 166-186.

Wyatt, R.T. (1941) The history of Goulburn, N.S.W. Municipality of Goulburn, Goulburn, N.S.W.

Manuscript accepted 18 May 2022

**Appendix 1. All plant species recorded at the 50 ha study site between 2005 and 2020.**

Nomenclature after the Australian Plant Census https://biodiversity.org.au/nsl/services/search/taxonomy

Except for *Thelymitra* which follows Egan *et al*. (2020).

**O =** Origin: native or exotic as defined by NSW flora, or Fensham & Laffineur (2019)

**LF =** Life-form: a = annual (incl. biennial, short-lived perennial) p = perennial, g = geophyte (native or exotic)

**GL =** Grassy ecosystem species. Native species listed in either Eddy *et al*. (1998) (g); EPBC List of species found in White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland (gw) or both (ggw).

**S =** recorded in 2005 survey as a species (s) or species combination (sc).

**C =** Changes in status between 2005-20: pn = actively introduced and subsequently naturalised; cn = colonised spontaneously and established; ce = eradication achieved or imminent; wc = existing populations being systematically controlled over entire property but not eradicated; le = spontaneous local extinction.

**P =** Population estimate (genet or ramet): 1 = 1-10; 2 = 11-100; 3 = 101-1000; 4 = 1001-10,000; 5 = >10,000 ("-" indicates unknown population size dues to difficulty with species identifications or ramet delineation. Note for annuals, estimates represent largest population observed between 2005 and 2020.

**()** = indicates a combined taxonomic entity used where species identification in the surveys was not possible.

| | O | LF | GL | S | C | P |
|---|---|---|---|---|---|---|
| **Ferns and allies** | | | | | | |
| **Ophioglossaceae** | | | | | | |
| *Ophioglossum lusitanicum* | n | p | ggw | s | | 4 |
| **Pteridaceae** | | | | | | |
| *Cheilanthes sieberi* | n | p | ggw | s | | 4 |
| **Monocots** | | | | | | |
| **Alliaceae** | | | | | | |
| *Nothoscordum borbonicum* | e | pg | | | ce | 1 |
| **Asparagaceae** | | | | | | |
| *Arthropodium minus* | n | pg | ggw | s | | 4 |
| *Lomandra filiformis* | n | p | ggw | s | | 5 |
| *Lomandra longifolia* | n | p | ggw | | | 3 |
| *Lomandra multiflora* | n | p | ggw | s | | 4 |
| *Thysanotus patersonii* | n | pg | ggw | | | 3 |
| *Thysanotus tuberosus* | n | pg | ggw | s | | 3 |
| **Asphodelaceae** | | | | | | |
| *Bulbine bulbosa* | n | pg | ggw | | | 3 |
| **Colchicaceae** | | | | | | |
| *Wurmbea dioica* | n | pg | ggw | s | | 5 |
| **Cyperaceae** | | | | | | |
| *Carex appressa* | n | p | g | s | | 4 |
| *Carex breviculmis* | n | p | g | | | 2 |
| *Carex inversa* | n | p | ggw | s | | 3 |
| *Cyperus eragrostis* | e | p | | s | | 2 |
| *Cyperus gunnii* | n | p | | s | | 2 |
| *Cyperus sphaeroideus* | n | p | | | | 2 |
| *Eleocharis plana* | n | p | | s | | - |
| *Isolepis levynsiana* | e | a | | s | | 4 |
| *Isolepis marginata* | n | a | | | | 4 |
| *Isolepis multicaulis* | n | a | gw | | | 4 |
| *Lepidosperma laterale* | n | p | gw | | | 2 |
| *Schoenoplectus tabernaemontani* | n | p | | | pn | - |
| *Schoenus apogon* | n | a | ggw | s | | 5 |
| **Hemerocallidaceae** | | | | | | |
| *Caesia calliantha* | n | pg | gw | s | | 2 |
| *Dianella revoluta* | n | p | ggw | s | | 5 |
| *Tricoryne elatior* | n | pg | ggw | s | | 3 |
| **Hypoxidaceae** | | | | | | |
| *Hypoxis hygrometrica* | n | pg | g | s | | 4 |
| **Iridaceae** | | | | | | |
| *Patersonia sericea* | n | p | gw | s | | 3 |
| *Romulea rosea* | e | pg | | | ce | 1 |
| *Sisyrinchium rosulatum* | e | a | | s | le | 1 |
| **Juncaceae** | | | | | | |
| *Juncus australis* | n | p | gw | | | - |
| (*Juncus* subgen. *Genuini*) | n | p | ggw | sc | | 3 |
| *Juncus bufonius* | n | a | ggw | s | | 4 |
| *Juncus capitatus* | e | a | | | | 4 |
| *Juncus flavidus* | n | p | gw | s | | - |
| *Juncus fockei* | n | p | | | | 2 |
| *Juncus homalocaulis* | n | p | gw | | | 1 |
| *Juncus planifolius* | n | p | | | | 1 |
| *Juncus subsecundus* | n | p | ggw | | | - |
| *Luzula densiflora* | n | p | ggw | s | | 4 |
| *Luzula ovata* | n | p | ggw | | | 3 |
| **Orchidaceae** | | | | | | |
| *Caladenia carnea* | n | pg | | | | 3 |
| *Caladenia fuscata* | n | pg | | | | 3 |
| *Caladenia moschata* | n | pg | | s | | 3 |
| (*Caladenia* spp.) | n | pg | | sc | | - |
| *Caleana minor* | n | pg | | | | 1 |
| *Calochilus platychilus* | n | pg | gw | s | | 2 |
| *Cyanicula caerulea* | n | pg | | | | 3 |
| *Dipodium roseum* | n | pg | | | | 2 |
| *Diuris behrii* | n | pg | ggw | | | 1 |
| *Diuris chryseopsis* | n | pg | ggw | | | 3 |
| *Diuris pardina* | n | pg | | s | | 3 |

| | O | LF | GL | S | C | P |
|---|---|---|---|---|---|---|
| *Diuris sulphurea* | n | pg | ggw | s | | 3 |
| *Eriochilus cucullatus* | n | pg | ggw | s | | 4 |
| *Genoplesium clivicola* | n | pg | | | | - |
| *Genoplesium cornutum* | n | pg | | | | - |
| (*Genoplesium* spp.) | n | pg | | sc | | 2 |
| *Glossodia major* | n | pg | gw | | | 3 |
| *Microtis parviflora* | n | pg | ggw | | | - |
| *Microtis unifolia* | n | pg | ggw | | | - |
| (*Microtis* spp.) | n | pg | ggw | sc | | 5 |
| *Pterostylis bicolor* | n | pg | ggw | | | 2 |
| *Pterostylis nutans* | n | pg | | | | 2 |
| *Pterostylis pedunculata* | n | pg | | | | 2 |
| *Pterostylis revoluta* | n | pg | | | | 2 |
| *Pterostylis rubescens* | n | pg | | | | 2 |
| *Pterostylis truncata* | n | pg | | | | 4 |
| *Thelymitra carnea* | n | pg | | | | 1 |
| *Thelymitra megcalyptra* | n | pg | g | | | 2 |
| *Thelymitra pauciflora* | n | pg | g | | | 4 |
| *Thelymitra peniculata* | n | pg | gw | | | 2 |
| (*Thelymitra* spp.) | n | pg | gw | sc | | - |
| **Poaceae** | | | | | | |
| *Agrostis capillaris* | e | p | | s | | 2 |
| *Aira caryophyllea* | e | a | | s | | 5 |
| *Aira elegantissima* | e | a | | s | | 5 |
| *Amphibromus nervosus* | n | p | | s | | 2 |
| *Anthosachne scabra* | n | p | ggw | s | | 4 |
| *Aristida behriana* | n | p | gw | | le | 1 |
| *Aristida ramosa* | n | p | ggw | s | | 5 |
| *Austrostipa densiflora* | n | p | ggw | | | 3 |
| *Austrostipa scabra* | n | p | ggw | s | | 5 |
| *Avena barbata* | e | a | | | wc | 2 |
| *Bothriochloa macra* | n | p | gw | s | | 3 |
| *Briza maxima* | e | a | | s | | 5 |
| *Briza minor* | e | a | | s | | 5 |
| *Bromus catharticus* | e | a | | s | le | 1 |
| *Bromus diandrus* | e | a | | s | | 1 |
| *Bromus hordeaceus* | e | a | | s | | 5 |
| *Bromus rubens* | e | a | | | le | 1 |
| *Chloris truncata* | n | p | ggw | s | | 3 |
| *Cynodon dactylon* | n | p | | | | - |
| *Cynosurus echinatus* | e | a | | s | | 3 |
| *Deyeuxia quadriseta* | n | p | gw | s | | 2 |
| *Dichelachne crinita* | n | p | gw | | | - |
| (*D. crinita/micrantha*) | n | p | gw | sc | | 4 |
| *Dichelachne hirtella* | n | p | gw | s | | 3 |
| *Dichelachne inaequiglumis* | n | p | gw | | | 3 |
| *Dichelachne micrantha* | n | p | gw | | | - |
| *Dichelachne rara* | n | p | gw | s | | 3 |
| *Dichelachne sieberiana* | n | p | | s | | 3 |
| *Digitaria ischaemum* | e | a | | | cn | 2 |
| *Digitaria sanguinalis* | e | a | | | cn | 2 |
| *Echinopogon ovatus* | n | p | gw | | | 1 |
| *Eleusine tristachya* | e | a | | | | 2 |
| *Enneapogon nigricans* | n | p | ggw | | | 2 |
| *Eragrostis brownii* | n | p | | s | | 4 |
| *Eragrostis curvula* | e | p | | | ce | 1 |
| *Eragrostis trachycarpa* | n | p | | | | 3 |
| *Festuca pratensis* | e | p | | s | | 3 |
| *Hemarthria uncinata* | n | p | | s | | - |
| *Holcus annuus* | e | a | | | | 3 |
| *Holcus lanatus* | e | p | | s | | 4 |
| *Hordeum glaucum* | e | a | | s | | 3 |
| *Lachnagrostis filiformis* | n | a | g | s | | 3 |
| *Lolium perenne* | e | p | | s | | 3 |
| *Lolium rigidum* | e | a | | | | 3 |
| *Microlaena stipoides* | n | p | ggw | s | | - |
| *Nassella trichotoma* | e | p | | s | wc | 4 |
| *Panicum effusum* | n | p | ggw | s | | 4 |
| *Parapholis incurva* | e | a | | | | 2 |
| *Paspalum dilatatum* | e | p | | s | | 3 |
| *Pentameris airoides* | e | a | | | cn | 2 |
| *Pentapogon quadrifidus* | n | a | | s | | 3 |
| *Phalaris aquatica* | e | p | | s | | 1 |
| *Poa annua* | e | a | | s | | 3 |
| *Poa bulbosa* | e | p | | s | | 4 |
| *Poa labillardierei* | n | p | ggw | s | | 3 |
| *Poa sieberiana* | n | p | ggw | s | | 4 |
| *Psilurus incurvus* | e | a | | | cn | 4 |
| *Puccinellia sp.* | e | p | | | le | 1 |
| *Rytidosperma auriculatum* | n | p | gw | | | - |
| *Rytidosperma caespitosum* | n | p | gw | | | - |
| *Rytidosperma carphoides* | n | p | gw | | | - |
| *Rytidosperma erianthum* | n | p | gw | | | - |
| *Rytidosperma laeve* | n | p | gw | | | - |
| *Rytidosperma monticola* | n | p | gw | | | - |
| *Rytidosperma pallidum* | n | p | ggw | s | | 4 |
| *Rytidosperma penicillatum* | n | p | | | | - |
| *Rytidosperma pilosum* | n | p | gw | | | - |
| *Rytidosperma racemosum* | n | p | gw | | | - |
| *Rytidosperma setaceum* | n | p | gw | | | - |
| (*Rytidosperma* spp. except *R. pallidum*) | n | p | gw | sc | | 5 |
| *Rytidosperma tenuius* | n | p | | | | - |
| *Setaria viridis* | e | a | | s | | 2 |
| *Themeda triandra* | n | p | ggw | s | | 5 |
| *Thinopyrum elongatum* | e | p | | | | 1 |
| *Vulpia bromoides* | e | a | | s | | 5 |
| *Vulpia myuros* | e | a | | s | | 5 |
| **Typhaceae** | | | | | | |
| *Typha domingensis* | n | p | | | pn | - |
| **Xanthorrhoeaceae** | | | | | | |
| *Xanthorrhoea glauca* | n | p | | s | | 2 |
| **Eudicots** | | | | | | |
| **Amaranthaceae** | | | | | | |
| *Alternanthera* sp. A | n | p | | s | | 3 |
| **Apiaceae** | | | | | | |
| *Centella asiatica* | n | p | gw | s | | 3 |
| *Daucus glochidiatus* | n | a | ggw | s | | 5 |
| *Eryngium ovinum* | n | ng | | | pn | 2 |

| | O | LF | GL | S | C | P |
|---|---|---|---|---|---|---|
| **Araliaceae** | | | | | | |
| *Astrotricha ledifolia* | n | p | gw | s | | 3 |
| *Hydrocotyle laxiflora* | n | p | ggw | s | | 5 |
| *Hydrocotyle sibthorpioides* | n | p | | s | | 5 |
| **Asteraceae** | | | | | | |
| *Arctotheca calendula* | e | a | | s | | 5 |
| *Brachyscome perpusilla* | n | a | | s | le | 1 |
| *Calocephalus citreus* | n | p | ggw | | pn | 3 |
| *Carduus tenuiflorus* | e | a | | s | | 2 |
| *Cassinia sifton* | n | p | gw | s | wc | 3 |
| *Cassinia longifolia* | n | p | gw | | | 1 |
| *Centipeda cunninghamii* | n | p | | | | 2 |
| *Centipeda elatinoides* | n | a | | | | 2 |
| *Chondrilla juncea* | e | p | | s | | 3 |
| *Chrysocephalum apiculatum* | n | p | ggw | s | | 4 |
| *Chrysocephalum semipapposum* | n | p | ggw | s | pn | 3 |
| *Cirsium vulgare* | e | a | | s | wc | 2 |
| *Coronidium gunnianum* | n | p | g | | | 1 |
| *Coronidium scorpioides* | n | p | ggw | s | | 3 |
| *Cotula australis* | n | a | gw | s | | 3 |
| *Cotula coronopifolia* | e | a | | | | 2 |
| *Craspedia variabilis* | n | p | ggw | s | | 4 |
| *Crepis foetida* | e | a | | | ce | 1 |
| *Cymbonotus lawsonianus* | n | p | ggw | s | | 3 |
| *Erigeron bonariensis* | e | a | | | wc | 3 |
| *Erigeron canadensis* | e | a | | | wc | 3 |
| *Erigeron sumatrensis* | e | a | | | wc | 4 |
| *Euchiton japonicus* | n | p | ggw | s | | 5 |
| *Euchiton sphaericus* | n | a | ggw | s | | 4 |
| *Gamochaeta americana* | e | a | | s | | 4 |
| *Gamochaeta calviceps* | e | a | | | | 3 |
| *Gnaphalium indutum* | n | a | | | cn | 3 |
| *Hypochaeris glabra* | e | a | | s | | 5 |
| *Hypochaeris radicata* | e | p | | s | | 5 |
| *Isoetopsis graminifolia* | n | a | ggw | s | | 3 |
| *Lactuca serriola* | e | a | | | | 1 |
| *Leontodon saxatilis* | e | p | | s | | 4 |
| *Leptoryhnchos squamatus* | n | p | ggw | s | | 3 |
| *Leucochrysum albicans* | n | p | | | pn | 4 |
| *Logfia gallica* | e | a | | s | | 2 |
| *Microseris walteri* | n | ng | ggw | s | | 4 |
| *Pseudognaphalium luteoalbum* | n | a | gw | | | 3 |
| *Senecio bathurstianus* | n | a | | | | 1 |
| *Senecio madagascariensis* | e | a | | | ce | 1 |
| *Senecio quadridentatus* | n | p | gw | s | | 4 |
| *Solenogyne dominii* | n | p | ggw | s | | 4 |
| *Soliva sessilis* | e | a | | s | | 3 |
| *Sonchus asper* | e | a | | | | 2 |
| *Sonchus oleraceus* | e | a | | s | | 3 |
| *Stuartina muelleri* | n | a | gw | s | | 4 |
| *Taraxacum sp.* | e | p | | s | | 2 |
| *Tolpis barbata* | e | a | | s | | 5 |
| *Tragopogon dubius* | e | a | | | le | 1 |
| *Triptilodiscus pygmaeus* | n | a | ggw | s | | 5 |
| *Vellereophyton dealbatum* | e | a | | s | | 3 |
| *Vittadinia gracilis* | n | p | | | pn | 2 |
| *Vittadinia muelleri* | n | p | ggw | | | 4 |
| *Xerochrysum viscosum* | n | a | ggw | | | 3 |
| **Boraginaceae** | | | | | | |
| *Cynoglossum suaveolens* | n | p | ggw | | le | 1 |
| *Echium plantagineum* | e | a | | | le | 1 |
| *Myosotis discolor* | e | a | | s | | 5 |
| **Brassicaceae** | | | | | | |
| *Cardamine hirsuta* | e | a | | | | 3 |
| *Erophila verna* | e | a | | | | 3 |
| *Lepidium africanum* | e | a | | | | 1 |
| **Campanulaceae** | | | | | | |
| *Isotoma fluviatilis* | n | p | | s | | - |
| *Lobelia gibbosa* | n | p | gw | | | 1 |
| *Wahlenbergia capillaris* | n | p | ggw | s | | 3 |
| *Wahlenbergia multicaulis* | n | p | ggw | s | | 4 |
| *Wahlenbergia planiflora* | n | p | gw | s | | 2 |
| *Wahlenbergia stricta* | n | p | ggw | s | | 3 |
| **Caryophyllaceae** | | | | | | |
| *Cerastium glomeratum* | e | a | | s | | 3 |
| *Moenchia erecta* | e | a | | s | | 5 |
| *Paronychia brasiliana* | e | p | | s | | 3 |
| *Petrorhagia nanteuilii* | e | a | | s | | 5 |
| *Sagina apetala* | e | a | | s | | 4 |
| *Scleranthus biflorus* | n | p | ggw | | | 2 |
| *Silene gallica* | e | a | | | | 1 |
| *Spergularia rubra* | e | a | | s | | 3 |
| *Stellaria media* | e | a | | | | 2 |
| *Stellaria pallida* | e | a | | s | | 1 |
| **Casuarinaceae** | | | | | | |
| *Allocasuarina verticillata* | n | p | gw | | | 1 |
| **Celastraceae** | | | | | | |
| *Stackhousia monogyna* | n | p | ggw | s | | 4 |
| **Centrolepidaceae** | | | | | | |
| *Centrolepis strigosa* | n | a | gw | | | 4 |
| **Chenopodiaceae** | | | | | | |
| *Dysphania multifida* | e | p | | | | 1 |
| *Dysphania pumilio* | n | a | gw | s | | 2 |
| *Einadia nutans* | n | p | gw | | | 3 |
| **Convolvulaceae** | | | | | | |
| *Convolvulus angustissimus* | n | p | gw | s | | 2 |
| *Dichondra repens* | n | p | gw | s | | 2 |
| **Crassulaceae** | | | | | | |
| *Crassula decumbens* | n | a | | s | | 3 |
| *Crassula sieberiana* | n | a | gw | s | | 5 |
| **Dilleniaceae** | | | | | | |
| *Hibbertia obtusifolia* | n | p | ggw | s | | 4 |
| *Hibbertia riparia* | n | p | ggw | s | | 3 |
| **Droseraceae** | | | | | | |
| *Drosera auriculata* | n | ng | | | | 2 |
| *Drosera peltata* | n | ng | ggw | s | | 5 |
| **Elaeocarpaceae** | | | | | | |
| *Tetratheca bauerifolia* | n | p | | s | | 3 |

| | O | LF | GL | S | C | P |
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| **Ericaceae** | | | | | | |
| *Brachyloma daphnoides* | n | p | ggw | s | | 4 |
| *Leucopogon virgatus* | n | p | gw | s | | 3 |
| *Melichrus urceolatus* | n | p | ggw | s | | 4 |
| **Euphorbiaceae** | | | | | | |
| *Euphorbia drummondii* | n | p | ggw | s | | 3 |
| **Fabaceae** | | | | | | |
| *Acacia boormanii* | n | p | | | ce | 1 |
| *Acacia buxifolia* | n | p | | | pn | 3 |
| *Acacia dealbata* | n | p | ggw | | | 3 |
| *Acacia genistifolia* | n | p | ggw | s | | 4 |
| *Acacia gunnii* | n | p | ggw | s | | 3 |
| *Acacia mearnsii* | n | p | ggw | | | 1 |
| *Acacia parramattensis* | n | p | gw | | | 2 |
| *Acacia rubida* | n | p | gw | s | | 3 |
| *Acacia verniciflua* | n | p | gw | | cn | 1 |
| *Bossiaea buxifolia* | n | p | gw | s | | 3 |
| *Bossiaea prostrata* | n | p | gw | s | | 3 |
| *Daviesia genistifolia* | n | p | ggw | s | | 3 |
| *Daviesia latifolia* | n | p | gw | s | pn | 2 |
| *Daviesia leptophylla* | n | p | gw | s | | 4 |
| *Daviesia mimosoides* | n | p | gw | | | 1 |
| *Desmodium varians* | n | p | ggw | s | | 4 |
| *Dillwynia phylicoides* | n | p | | s | | 4 |
| *Dillwynia sericea* | n | p | | s | | 4 |
| *Glycine clandestina* | n | p | ggw | | | 2 |
| *Glycine tabacina* | n | p | ggw | | | 2 |
| *Gompholobium huegelii* | n | p | gw | s | | 4 |
| *Gompholobium minus* | n | p | | | | 2 |
| *Hardenbergia violacea* | n | p | gw | s | | 2 |
| *Hovea heterophylla* | n | p | ggw | s | | 3 |
| *Indigofera australis* | n | p | gw | | pn | 1 |
| *Lotus angustissimus* | e | p | | | cn | 3 |
| *Pultenaea setulosa* | n | p | | s | | 2 |
| *Pultenaea spinosa* | n | p | gw | | cn | 1 |
| *Pultenaea subspicata* | n | p | gw | s | | 3 |
| *Trifolium angustifolium* | e | a | | s | | 3 |
| *Trifolium arvense* | e | a | | s | | 4 |
| *Trifolium campestre* | e | a | | s | | 4 |
| *Trifolium cernuum* | e | a | | s | | 3 |
| *Trifolium dubium* | e | a | | s | | 5 |
| *Trifolium glomeratum* | e | a | | s | | 4 |
| *Trifolium repens* | e | a | | s | | 3 |
| *Trifolium striatum* | e | a | | s | | 3 |
| *Trifolium subterraneum* | e | a | | s | | 5 |
| *Vicia sativa* | e | a | | | le | 2 |
| **Gentianaceae** | | | | | | |
| *Centaurium erythraea* | e | a | | s | | 5 |
| *Centaurium tenuiflorum* | e | a | | s | | 5 |
| *Cicendia quadrangularis* | e | a | | s | | 4 |
| *Sebaea ovata* | n | a | gw | | | 4 |
| **Geraniaceae** | | | | | | |
| *Erodium botrys* | e | a | | | | 2 |
| *Erodium crinitum* | n | a | | | | 3 |
| *Erodium moschatum* | e | a | | s | | 2 |
| *Geranium solanderi* | n | a | ggw | s | | 4 |

| | O | LF | GL | S | C | P |
|---|---|---|---|---|---|---|
| **Goodeniaceae** | | | | | | |
| *Goodenia hederacea* | n | p | ggw | s | | 5 |
| *Goodenia pinnatifida* | n | p | ggw | | | 3 |
| **Haloragaceae** | | | | | | |
| *Gonocarpus tetragynus* | n | p | ggw | s | | 5 |
| *Haloragis heterophylla* | n | p | g | s | | 3 |
| *Myriophyllum verrucosum* | n | p | | | | - |
| **Hydrocharitaceae** | | | | | | |
| *Ottelia ovalifolia* | n | p | | | pn | 2 |
| **Hypericaceae** | | | | | | |
| *Hypericum gramineum* | n | p | ggw | s | | 5 |
| *Hypericum perforatum* | e | p | | | wc | 2 |
| **Lamiaceae** | | | | | | |
| *Ajuga australis* | n | p | ggw | s | | 3 |
| *Mentha diemenica* | n | p | gw | | | 1 |
| *Scutellaria humilis* | n | p | gw | s | | 3 |
| **Lauraceae** | | | | | | |
| *Cassytha pubescens* | n | p | | | le | 1 |
| **Linaceae** | | | | | | |
| *Linum marginale* | n | p | ggw | | pn | 3 |
| *Linum trigynum* | e | a | | s | | 2 |
| **Loranthaceae** | | | | | | |
| *Amyema miquelii* | n | p | | | | 3 |
| **Lythraceae** | | | | | | |
| *Lythrum hyssopifolia* | n | a | | s | | 3 |
| **Malvaceae** | | | | | | |
| *Malva parviflora* | e | a | | s | | 1 |
| **Myrtaceae** | | | | | | |
| *Calytrix tetragona* | n | p | gw | | | 1 |
| *Eucalyptus cinerea* | n | p | gw | | | 2 |
| *Eucalyptus dives* | n | p | gw | | | 2 |
| *Eucalyptus macrorhyncha* | n | p | gw | | | 4 |
| *Eucalyptus mannifera* | n | p | gw | | | 4 |
| *Eucalyptus melliodora* | n | p | ggw | | | 4 |
| *Eucalyptus polyanthemos* | n | p | ggw | | | 4 |
| *Eucalyptus rossi* | n | p | gw | | | 4 |
| *Kunzea ericoides* | n | p | gw | | pn | 2 |
| *Leptospermum multicaule* | n | p | | s | | 3 |
| *Melaleuca parvistaminea* | n | p | gw | | pn | 2 |
| **Onagraceae** | | | | | | |
| *Epilobium hirtigerum* | n | p | | s | | 2 |
| **Orobanchaceae** | | | | | | |
| *Orobanche minor* | e | pg | | s | wc | 3 |
| *Parentucellia latifolia* | e | a | | | | 4 |
| **Oxalidaceae** | | | | | | |
| *Oxalis perennans* | n | p | ggw | s | | 4 |
| **Phrymaceae** | | | | | | |
| *Glossostigma diandrum* | n | a | | s | | 1 |
| **Phyllanthaceae** | | | | | | |
| *Poranthera microphylla* | n | a | gw | s | | 4 |
| **Pittosporaceae** | | | | | | |
| *Billardiera scandens* | n | p | gw | | | 1 |
| *Bursaria spinosa* | n | p | gw | | pn | 2 |
| *Cheiranthera linearis* | n | p | ggw | s | | 4 |
| *Rhytidosporum procumbens* | n | p | gw | s | | 2 |

| | O | LF | GL | S | C | P |
|---|---|---|---|---|---|---|
| **Plantaginaceae** | | | | | | |
| *Gratiola peruviana* | n | p | gw | | | 2 |
| *Linaria pelisseriana* | e | a | | s | | 5 |
| *Plantago lanceolata* | e | p | | | | 3 |
| *Plantago varia* | n | p | ggw | s | | 4 |
| *Veronica arvensis* | e | a | | | | 2 |
| *Veronica calycina* | n | p | gw | | | 3 |
| *Veronica gracilis* | n | p | gw | | | 3 |
| **Polygonaceae** | | | | | | |
| *Polygonum aviculare* | e | a | | | le | 1 |
| *Rumex acetosella* | e | p | | s | | 4 |
| *Rumex brownii* | n | p | ggw | s | | 3 |
| *Rumex crispus* | e | p | | | wc | 2 |
| **Portulacaceae** | | | | | | |
| *Montia fontana* | n | a | | | | 4 |
| **Primulaceae** | | | | | | |
| *Lysimachia arvensis* | e | a | | s | | 3 |
| *Lysimachia minima* | e | a | | | | 2 |
| **Proteaceae** | | | | | | |
| *Persoonia rigida* | n | p | | | | 1 |
| *Grevillea lanigera* | n | p | ggw | | pn | 2 |
| **Ranunculaceae** | | | | | | |
| *Ranunculus inundatus* | n | p | | | | 1 |
| *Ranunculus lappaceus* | n | p | ggw | s | | 3 |
| *Ranunculus sessiliflorus* | n | a | | | | 2 |
| **Rhamnaceae** | | | | | | |
| *Cryptandra amara* | n | p | ggw | | | 3 |
| *Pomaderris andromedifolia* | n | p | | | | 2 |

| | O | LF | GL | S | C | P |
|---|---|---|---|---|---|---|
| **Rosaceae** | | | | | | |
| *Acaena echinata* | n | p | gw | s | | 3 |
| *Rosa rubiginosa* | e | p | | s | | 2 |
| *Rubus* sp. | e | p | | | wc | 1 |
| *Aphanes australiana* | n | a | ggw | s | | 4 |
| **Rubiaceae** | | | | | | |
| *Asperula conferta* | n | p | ggw | s | | 3 |
| *Galium aparine* | e | a | | | ce | 2 |
| *Galium divaricatum* | e | a | | s | | 5 |
| *Galium gaudichaudii* | n | p | gw | | | 2 |
| *Opercularia hispida* | n | p | gw | s | | 3 |
| *Sherardia arvensis* | e | a | | s | | 3 |
| **Rutaceae** | | | | | | |
| *Boronia nana* | n | p | | s | | 3 |
| **Santalaceae** | | | | | | |
| *Choretrum pauciflorum* | n | p | | | | 2 |
| *Exocarpos cupressiformis* | n | p | gw | | | 1 |
| **Sapindaceae** | | | | | | |
| *Dodonaea viscosa* | n | n | gw | | pn | 2 |
| **Solanaceae** | | | | | | |
| *Solanum nigrum* | e | p | | | wc | 2 |
| **Stylidiaceae** | | | | | | |
| *Stylidium graminifolium* | n | p | ggw | s | | 4 |
| **Thymelaeaceae** | | | | | | |
| *Pimelea curviflora* | n | p | gw | s | | 3 |
| *Pimelea linifolia* | n | p | g | s | | 2 |
| **Violaceae** | | | | | | |
| *Viola betonicifolia* | n | p | ggw | s | | 3 |