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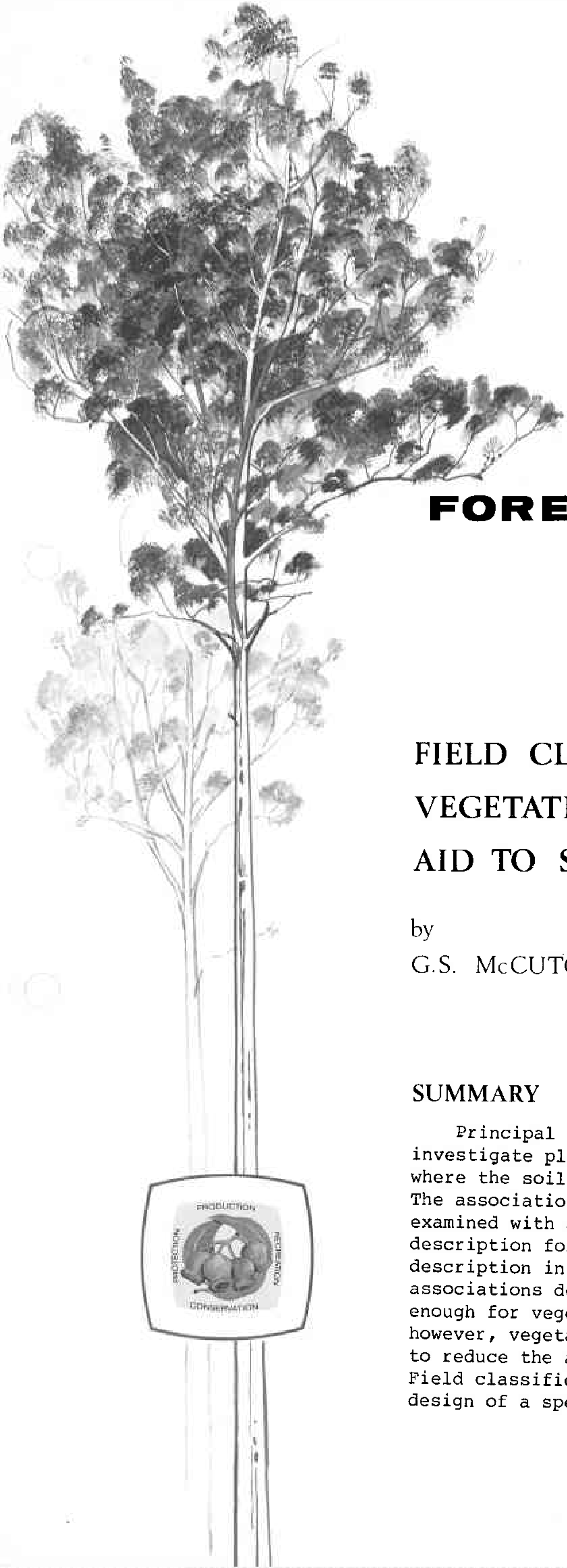

FORESTS DEPARTMENT
OF WESTERN AUSTRALIA

FIELD CLASSIFICATION OF VEGETATION TYPES AS AN AID TO SOIL SURVEY

by
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SUMMARY

Principal components analysis was used to investigate plant groupings in 1990 ha of jarrah forest where the soil had already been intensively surveyed. The association of plant groups and soil types was examined with a view to substituting vegetation description for the more arduous soil profile description in a broad-scale forest site survey. The associations detected were not found to be constant enough for vegetation description alone to be reliable; however, vegetation description could certainly be used to reduce the amount of soil inspection required. Field classification was made practicable by the design of a special form for recording data.

INTRODUCTION

A method of relating vegetation to site and of using this relationship to predict the success of establishment of *Pinus pinaster* plantations was developed for the northern Swan Coastal Plain of Western Australia by Havel (1968). In the planning of a broad-scale reconnaissance to delineate land suitable for plantations of *Pinus radiata* in the Donnybrook Sunkland in the extreme south-west of Western Australia it was considered desirable to make similar use of vegetation as an indicator of site characteristics and of site potential. Since the vegetation of the Sunkland is structurally more uniform than that of the northern Swan Coastal Plain (McCutcheon, 1978) it was recognized that vegetation structure would be of limited use in aerial photo interpretation for site mapping. However, it was hoped that vegetation assessment could be substituted for laborious soil profile description on field traverses for control of the interpretation.

An intensive soil survey had been carried out on an area of 1990 ha as a preliminary to the planned reconnaissance, and the soil profiles recorded had been classified for mapping purposes into seven soil types (McCutcheon, 1978, and Appendix I).

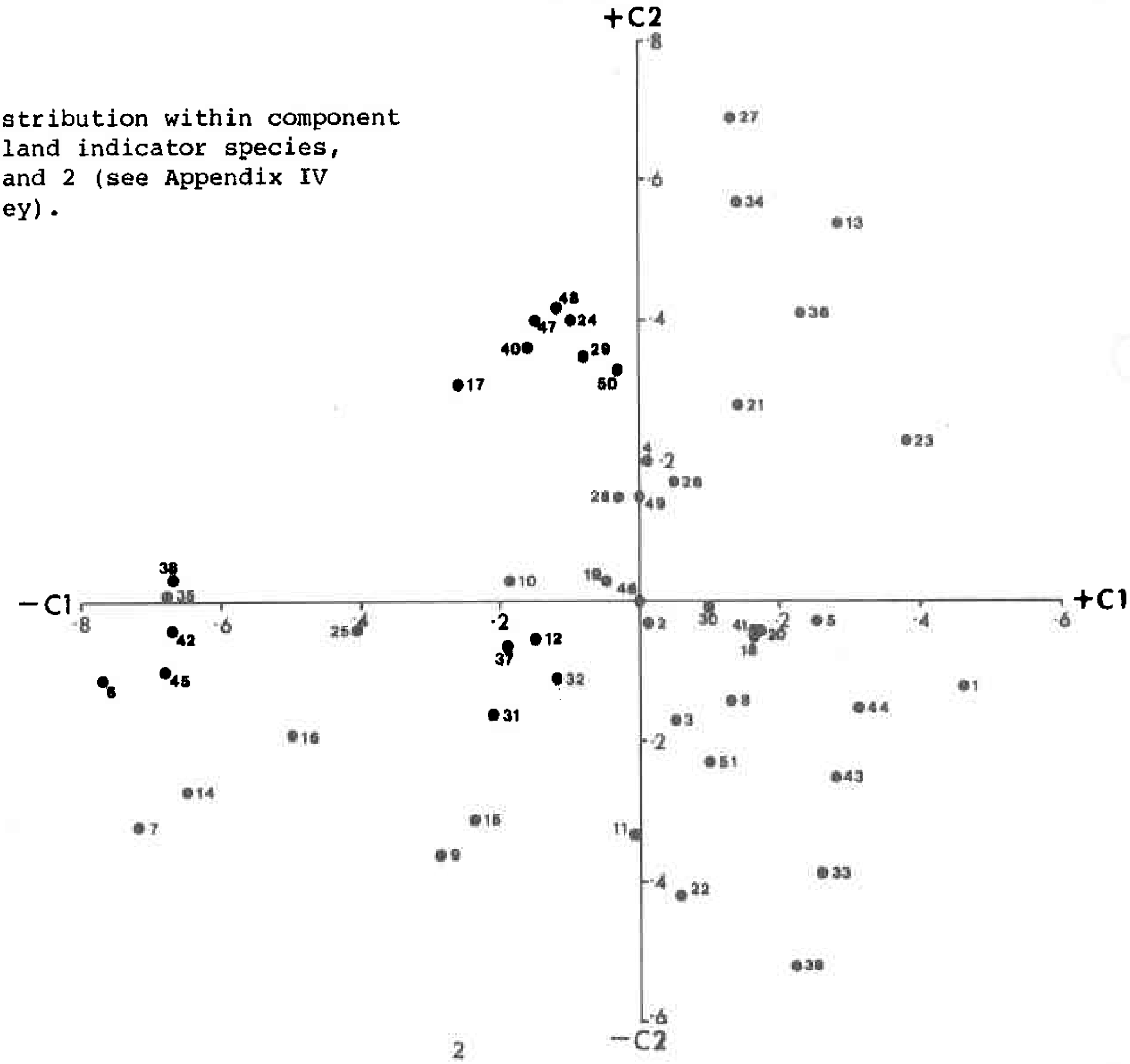
Concurrently with this soil survey, the vegetation was assessed in terms of the following abundance scale. (Trees were assessed within a 20 m radius and shrubs within a 10 m radius.)

1. Rare occurrence
2. Not common
3. 30%; common but not present all around
4. 30-50%; present all around
5. > 50%; predominant all around

Seventy-two species commonly present on the area were recorded. The resulting data were analysed by means of principal components analysis. On the basis of this analysis, six vegetation types were identified.

A second intensive soil survey was then

FIGURE 1: Distribution within component space of Sunkland indicator species, components 1 and 2 (see Appendix IV for species key).



carried out over 920 ha to sample in particular soil type 6 (a soil type not well represented in the first survey) and to collect further vegetation data. Some parameters and some coded, non-parametric characteristics of the soils were included in the principal components analysis of these data.

This paper first reports the relationship between vegetation type and site conditions evident from the analysis of the first intensive survey, and then describes the application of this relationship, modified by the results of the analysis of the second survey, to the development of a special form for recording site description in the field.

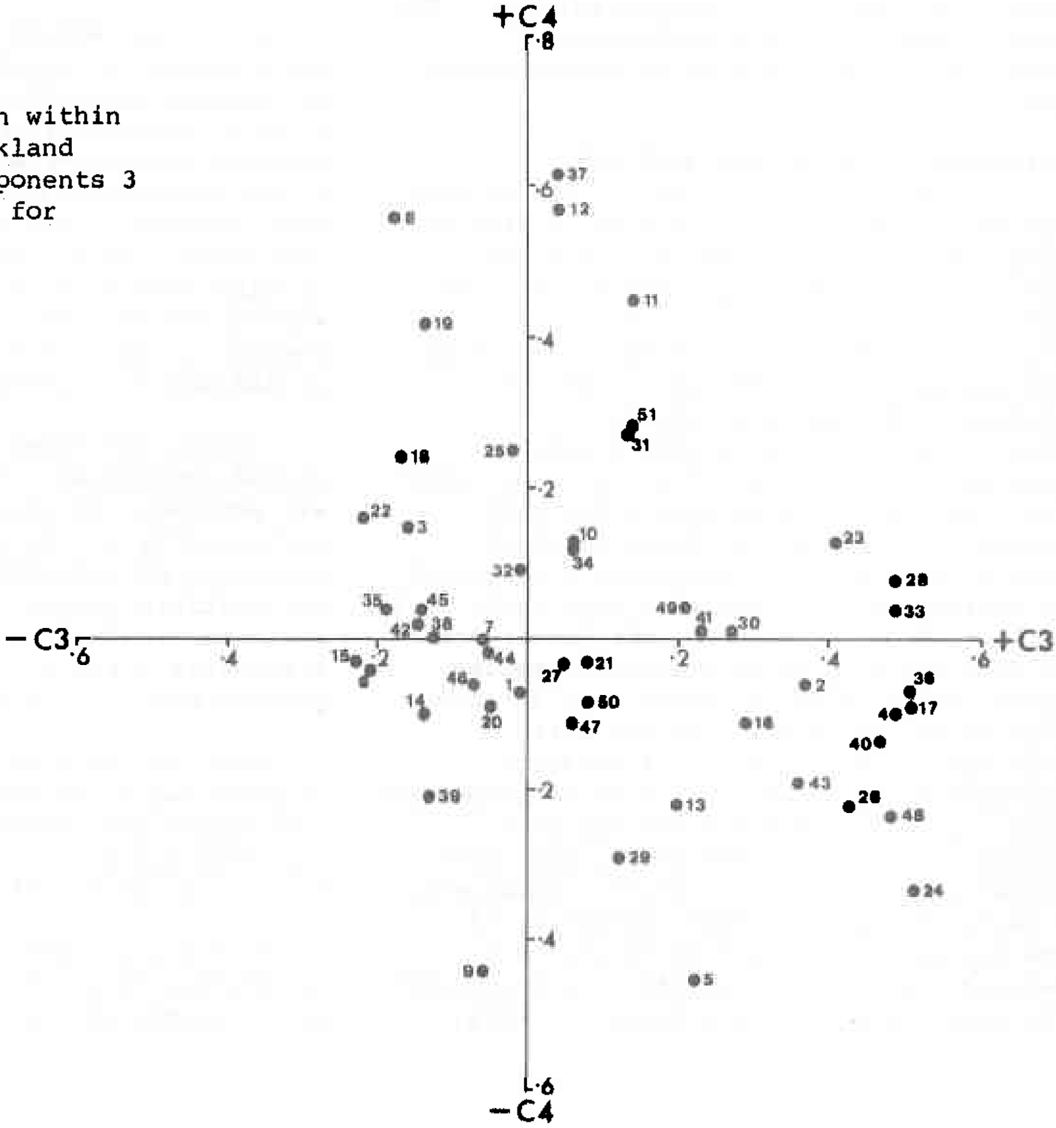
ANALYSES AND RESULTS

Vegetation types

The numerical output of the principal components analysis can be converted by an auxiliary computer program developed by Havel (1975) into a two-dimensional diagram illustrating the distribution of the sample plots in relation to two components, which may or may not be ecological gradients. In this study, components 1 and 2 and components 3 and 4 were considered jointly. The distribution of individual plant species within this framework was used to establish six species groups or types (Appendix II), members of each of which were more frequently associated with each other than with the members of other groups. The groups were not considered sufficiently discrete to be called associations, but were seen as segments of a continuum. The component loadings, which relate individual species to each other on the basis of their joint occurrence, also helped in the formation of these groups.

Examples of the relationships of species to each other in terms of component loadings are given in Figures 1 and 2, which are graphs constructed using the computer output from a later analysis.

FIGURE 2: Distribution within component space of Sunkland indicator species, components 3 and 4 (see Appendix IV for species key).



These loadings were also used to construct a four-dimensional model (Havel, 1975), which represented in a more immediately comprehensible way the relationships between the species.

Once the species whose occurrence was obligatory or permissible in each vegetation type had been decided upon, the species groupings recorded at each of the initial survey sites were assigned vegetation-type codes and were plotted on an overlay to the soil plan so that the distribution of soil and vegetation types could be compared.

Only 25% of sites were listed as supporting pure types. Vegetation at most sites was typified by combinations of letters; the need to use combinations arises out of the fact that the vegetation forms a continuum, which does not lend itself to simple subdivision. The convention was adopted that the dominant vegetation type would be shown by the first letter and the less important influences by the succeeding letters. The most common secondary influence in combination was the type G, occurring on 47% of all sites.

Affinities of vegetation and soil

The relationship of vegetation to soil was then investigated. The affinities of some species for particular soils are easily observable in the field, and such observations provided the first exploration of the gradients displayed by the analysis. On component 1 of the analysis, species segregation distinguished in particular a group of species found on deep, leached sandy soils from species on shallower, iron-oxide-coated sandy soils overlying laterite. Species alignment on component 2 appeared to correspond to a gradient from sandy soils to loamy soils. However, the latter end of this gradient also exhibited species occurring on gravelly soils with stronger iron oxide colouration of the soil particles. The component 3 gradient appeared to be associated with a trend from drier sites to wetter sites and from gravelly to gravel-free sites, with pale colour as a secondary feature. Component 4 seemed to be a further expression of the difference evident on component 1 between the leached, gravel-free soils and the more fertile of the gravelly soils.

These deductions as to the ecological gradients represented by the mathematically derived components were tested by constructing simple linear regressions between edaphic attributes and the corresponding component scores at individual sample points. Attributes such as colour and texture, which could not be described in quantitative terms, were ranked and a number code was assigned to them (Appendix III).

The sample points were grouped and the data for each group averaged before attempting correlation analysis. Each group consisted of the sample points represented on a column or row corresponding to a component score on the two-dimensional diagram earlier described. Negative component scores were eliminated by taking the extreme negative score as the point of origin (zero).

The correlations between component scores and various edaphic characteristics are shown in Table 1.

A further method of studying the distribution of vegetation was to assess an average vegetation type for each group of sites displayed on the two-dimensional diagrams mentioned above. This was done by subjectively combining the vegetation-type codes that had been assigned to the individual sites. Figure 3 is the result of this procedure for components 1 and 2, and illustrates that vegetation types overlap in distribution (in the same way as did species distributions).

Where the types at a group of sites varied considerably a multiple coding was adopted. It should be noted that, particularly at the centre of the continuum on components 1 and 2, some of the multiple coding (for example DGC, FGD) would be resolved on the basis of components 3 and 4. Some multiple coding cannot, however, be avoided.

The various studies of the relationships between individual species and soil types and between groups of species and soil types gave rise to the series of generalizations listed in Table 2.

Using these generalizations as standards, it was found that many of the sites supported vegetation types that did

TABLE 1

Correlations between edaphic characteristics and vegetation distributional gradients (components)

Edaphic characteristic: Name	Expression	Vegetational gradients	Measures of correlation: r	t	d.f.
'Soil volume' (max)	$\frac{D\ max.\ (100-G\%)}{121}$	C1	-0.9812***	27.37	18
'Soil volume' (min)	$\frac{D\ min.\ (100-G\%)}{121}$	C1	-0.9723***	17.68	18
'Soil volume' (min)	[Sites limited by laterite or heavy gravel only]	C1	-0.9722***	17.61	18
Minimum depth	[to a limiting horizon (a)]	C1	-0.9618***	14.91	18
Gravel %		C1	0.8241***	6.17	18
Limiting horizon (a)		C1	0.7796***	5.28	18
'Soil volume' (min)	[Sites limited by laterite excluded]	C1	-0.5999*	2.49	11
'Soil volume' (min)	[Shallow sites not limited by laterite]	C1	-0.1148 N.S.		
Texture (a)	[Average of upper and lower A_2]	C2	0.7565***	4.77	17
Texture (a)	[Lower A_2 only]	C2	0.7332***	4.45	17
Gravel %		C2	0.624*	2.57	17
Colour (a)		C2	0.5968**	3.07	17
'AlFe factor'	$\frac{G\%\ x\ 121}{Min.\ depth\ to\ concretions}$	C3	-0.7578*	2.84	6
'AlFe factor'	$\frac{G\%\ x\ 121\ x\ T_2\ x\ C_2\ (a)}{Min.\ depth\ to\ limiting\ horizon}$	C4	0.9562 **	6.53	4

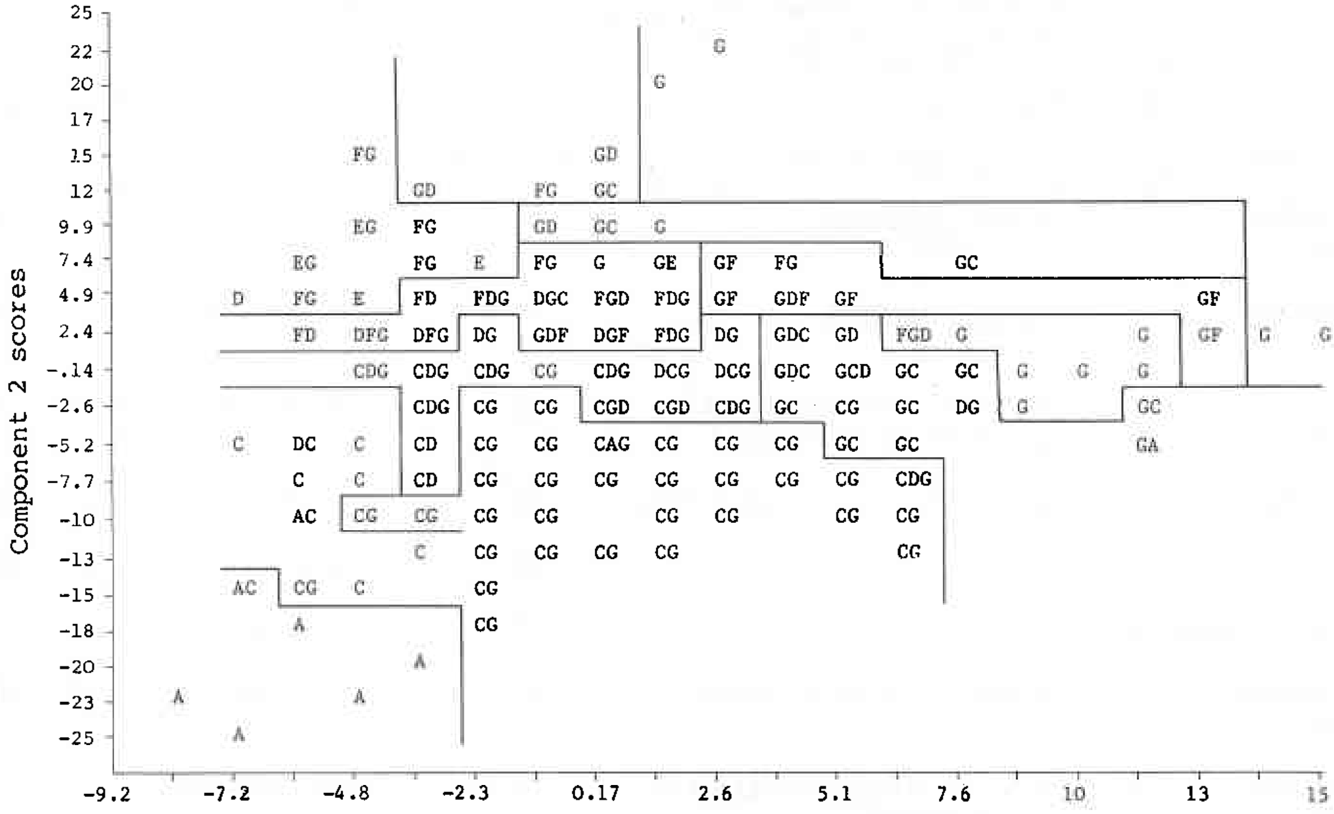
(a) for rank codes, see Appendix III.

G = gravel
T = texture
C = colour

r = correlation coefficient
t = Student's t
d.f. = degrees of freedom

D max. and D min. are respectively the maximum and minimum depths obtained in three probings at a site, to a physically limiting horizon.

FIGURE 3: Vegetation type distribution in relation to plot scores* on components 1 and 2 (based on two-dimensional diagram of plot distribution).



* Plot component scores are derived from program CORD (Havel, 1975)

TABLE 2

Edaphic affinities of Sunkland vegetation types

Vegetation type	Edaphic characteristics
A	Deep sands (> 1210 mm); highly leached; well drained
C	Deep sands; highly leached; moister
D	Deep sands; slightly more fertile; prone to excessive wetness in winter
E	Deep, heavier-textured soils (including silts); may be more fertile; associated with fairly well drained gully soils; some species tolerant of high iron content in soil
F	Soils of intermediate depth; heavier texture than for A to D; generally poorly drained; iron content of soil may be high
G	Gravelly soils; species may vary according to soil texture and drainage

not conform to the mapped soil type. The most frequent discrepancy was the occurrence of species indicative of gravel on sites where no gravel had been mapped. However, a study of profile descriptions explained most of these discrepancies as the result of variations in profile normally accepted in soil mapping and of the inclusion of small enclaves within rationalized larger areas on the plan. Sites where this explanation could not be applied amounted to 27% of all sites.

A summary of the occurrence of vegetation types on the various soil types is given in Table 3, along with subjective assessments of goodness of fit.

It can be seen that the vegetation usually occurred as mixed rather than pure types and that the same combination could occur on different soil types, but that there was bias in the frequency of occurrence, certain vegetation types being more frequently found on certain soil types.

It was concluded that vegetation could be used as an aid to the recognition of soil type but would in many cases need to be supplemented by description of one or two soil profile features. The need for this would be decided on site.

Field recording form

Recording of survey data in a field book and of species abundances on a form bearing an alphabetic list (such as that in Appendix II) was considered unduly cumbersome. Furthermore, the use of a transparent overlay to the recording form indicating the obligatory, probable, permissible and prohibited species for each vegetation type would have been awkward and time-consuming in field work. Accordingly, a form that would facilitate recording and assessment of vegetation type was designed. The reverse side of the form served for recording survey and topographic details. The list of species had been revised prior to the second intensive survey by eliminating less useful species and incorporating some others (see Appendix IV). It is restricted to indicator species whose form and foliage make them recognizable at any time of the year; floral characters are not necessary for recognition. The species

TABLE 3

Co-occurrence of soil types and vegetation types

Soil type	Vegetation types*	% of sites	Comments
1	<u>G</u>, GC, GD	88	Conforms to expectation
	AG, CG	12	
2	AG, <u>CG</u>, DG, FG	85	Not regarded as non-conforming
	GS, GC, GD	15	
3	C	10	Apparently non-conforming
	<u>CG</u>, DG, FG	80	Conforming
	GC, GD, G	10	Extremely non-conforming
4	<u>A</u>, C, D	68	Conforms moderately well
	CG, DG	28	
	GC, GD	4	
5	F, FD, FG	44	Less than half conforming
	D, CG, DG	40	
	GF, GC, GD, G	16	
7	E, EG	45	High incidence of G not surprising - due soil type definition
	FD, FG	55	

* Where possible to specify, 'ideal' vegetation type for the soil is underlined

are frequently recognizable after controlled burning, so that rough estimates of abundance can be made even under these conditions.

Some soil characteristics subjectively quantified using the numerical rating scale in Appendix IV were included as site attributes in the second principal components analysis. The output from this analysis was used as the basis of the form's design.

The layout was devised so that types having species most likely to occur together in the field were placed in proximity, and so that within each type species were ranked in an order of likelihood of joint occurrence (Fig. 4). Because it had been accepted that description at most sites required a combination of vegetation types, the number of species needed to define each type was reduced.

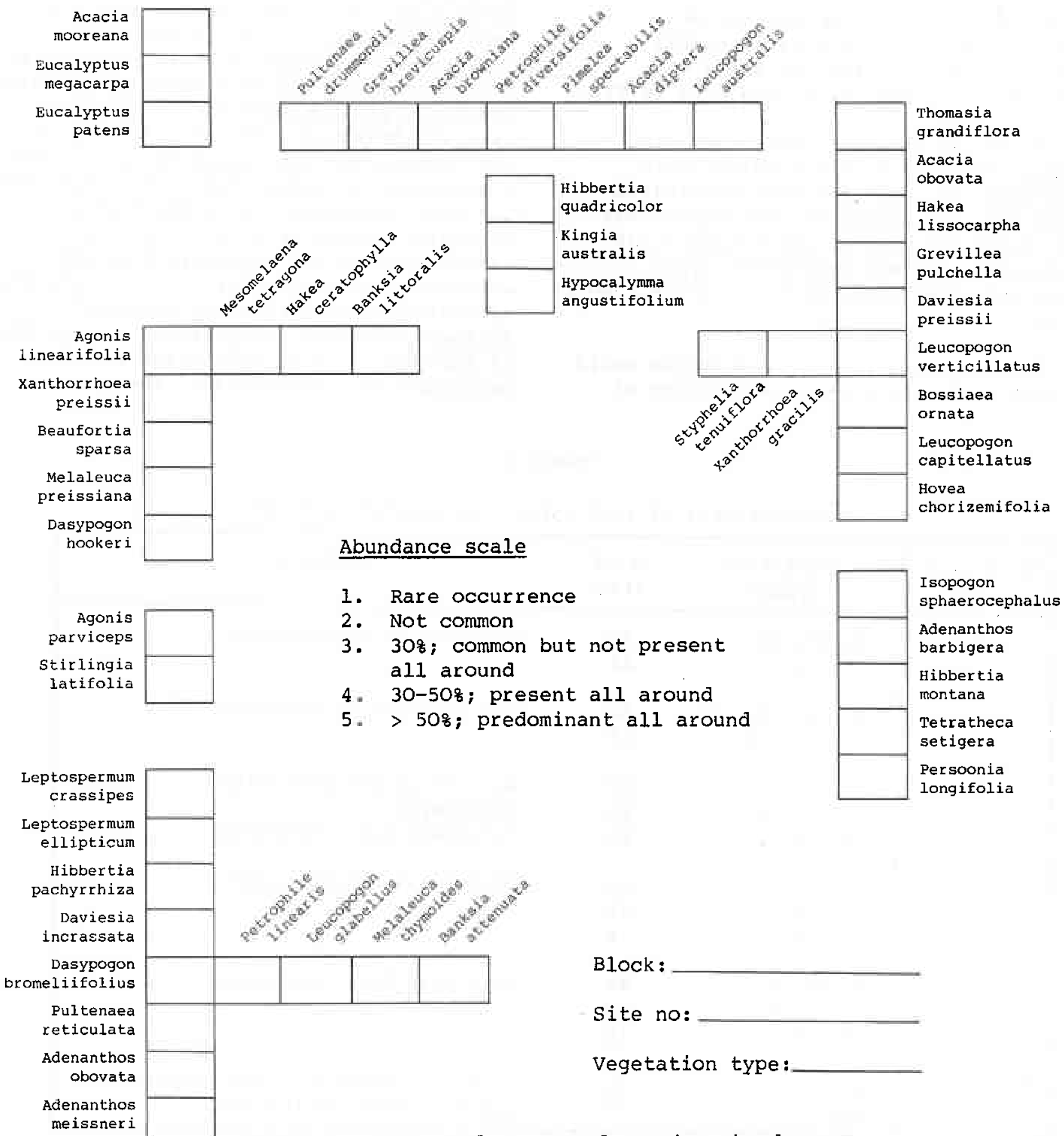


FIGURE 4: Form used to record species abundances

The sequence in the form runs from type A on the very dry, highly leached sandy soils, through type C on the moister sandy soils to type D on the wet, sandy sites. The leached characteristic is less important for species of the moist half of type C but is again prominent on sites classified as type D. Type E occurs on the silty, moist soils, but one of its indicators, *Eucalyptus patens*, can also occur with type D. Type F includes species dominant on heavier-textured soils, and because of the influence that this edaphic feature can have on moisture relationships some of its species can also occur with types D and E. Type G contains at the upper end species occurring on loamy, gravelly soils, and at the lower end species occurring on sandy, gravelly soils. The latter species often occur on sites dominated by species of types A, C and D.

Within each type a rational ranking of species was achieved by considering the species factor loadings and by applying subjective judgement.

The most prominent component of the analysis, identified as corresponding to the range from deep, well drained, highly leached soils to soils of lesser depth over an increasingly effective limiting horizon, was used to rank the species of sandy soils.

For type A, a trend in the magnitude of the species loadings on component 2 of the analysis was attributed mainly to a decrease in the coating of colloidal iron oxide on sand grains and to increased depth of this leached sand free of lateritic concretionary material. The sequence was modified by shifting *Banksia attenuata* to the end, since that species is the most noticeable indicator of the type.

The component 1 scores of type A species correspond closely to the score for *Dasypogon bromeliifolius* (type C), and they have therefore been placed opposite that species.

Type D, although recognizable in the field, is variable in terms of components 1, 2 and 3, and shows some degree of uniformity in scores only on component 4. Scores on component 1 were used to arrange the species sequence in this type. Its range overlaps partially that of type C.

The end group within type D, comprising *Mesomelaena tetragona*, *Hakea ceratophylla* and *Banksia littoralis*, was placed to reflect its ecological affinity with the species of type F.

Agonis parviceps and *Stirlingia latifolia* were subjectively placed between types C and D. The former species was very common and showed an alignment with various groups depending on the component studied, whilst the second was of infrequent occurrence and for that reason was not reliably assigned by the computer analysis. The main effect of the presence of these two species is an extra bias towards type C and away from types G and F.

Type E displayed loadings on components 2 and 4 that were related to lower position in the landscape (occurrence on or near drainage lines), with slight trends apparent. *Acacia mooreana* occupies somewhat higher sites than *E. megacarpa* or *E. patens*.

Type F species, which were fairly uniform with respect to components 2 and 4, were ranked on component 3. This corresponded to slightly decreasing depth of the (A_1 + A_2) horizons, heavier texture of the lower A_2 horizon and an increase in the small amount of lateritic gravel present.

The species in the upper group of type G were recognized as having affinity with type F, and were ranked on component 2, which was probably a reflection of the trend of decreasing depth to, and greater amount of, laterite gravel in the soil profile. *Xanthorrhoea gracilis* and *Styphelia tenuiflora* were placed at the position corresponding to their scores on component 2 and in the relative positions indicated by the trend of their scores on components 1, 3 and 4. Species in the lower group of type G were ranked subjectively on the basis of observed affinities with other species within the type, since no component indicated trends continuous with those of the previous group.

The group comprising *Hibbertia quadricolor*, *Kingia australis* and

Hypocalymma angustifolium was not named, but its position reflects the fact that these species can occur with species of all the surrounding types. They were fairly unresponsive to component analysis, except on component 3, which allied them with F and G.

Use of the form

When all indicator species present at a site had been recorded the vegetation type could quickly be decided upon from the number of species present and the species abundances. The following prescription, based on the affinities of the vegetation and soils, was then consulted to determine the degree of soil profile examination needed to complement the vegetation data.

Types A, E, F, FD - collect no further information.
Types AG, EG, FG, G, GA, GC, GD, GF - probe depth only (record the maximum of 3 depth tests using a 9.5 mm diameter hand-pushed probe).
Types C, D, AC, CD, DF - sample at 610 mm (remove a small sample using a core-tube and record colour and texture).
Gravel content in the profile could be estimated, after some experience had been gained, by gauging the resistance to penetration of the probe.

CONCLUSION

Using this prescription, 56 of the sites sampled on the intensive surveys would have required no soil testing and 610 would have required probing to ascertain depth. The remaining 111 would have required sampling for soil colour and texture.

Table 4 gives the estimated time taken to carry out the soil surveys by digging small pits, and shows in comparison with this the time that would have been needed if the survey method based on vegetation assessment had been used. Estimates were based on timed test assessments.

It can be seen that the vegetation assessment method would have resulted in a reduction by 33% of the time spent on site description. This would have been equivalent to a reduction of about 7% of the total survey time. Furthermore, the reduction in physical effort involved would have allowed an increased output, further reducing the total survey time.

If a quicker method of traversing were used, such as the vehicular traversing along tracks described by McCutcheon (1978), the time saved would be even greater.

ACKNOWLEDGEMENTS

The author wishes to thank Mr J.J. Havel for his guidance in the analysis of vegetation data and his constructive criticism during the preparation. Thanks are also given to Mr B.W. Hartley for assistance in the collection of data and for collation and drafting services during the study.

TABLE 4

Comparison of time (minutes) spent on site description at 777 sites using vegetation assessment and traditional survey methods

Survey method	Number of sites	Site description method and average time: Vegetation 1.81	Probing 0.27	Sampling 0.19	Digging* 2.53	Description 0.46	Sub-totals	Totals
Vegetation assessment	56	101					101	
	610	1104	165				1269	
	111	201	30	21		51	303	1673
Traditional method	777				1966	536**	2502	2502

* Includes time for estimation of gravel % on two samples.
** Descriptions at 150 mm and at 500 mm would have been required on half of the sites.

The scientific names given in this Research Paper are in accordance with usage at the Western Australian Herbarium.

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APPENDIX I

Brief description of the soil types* of the Donnybrook Sunkland

Type 1: boulder or gravel laterite

Type 2: sandy soils less than 500 mm deep over laterite

Type 3: yellowish-brown loamy sands more than 500 mm deep over laterite

Type 4: greyish-brown loamy sands more than 500 mm deep over laterite

Type 5: soils with texture heavier than loamy sand at 600 mm depth

Type 6: soils with sandy clay-loam to sandy clay texture at the surface, becoming heavier with depth, and with moderate to heavy gravel between 600 and 900 mm depth

Type 7: soils with brownish-yellow to strong brown colour in association with drainage lines; texture is commonly silty clay-loam near the surface

* Colours: MUNSELL COLOUR COMPANY (1954). Munsell Soil Colour Charts. Baltimore, Maryland, USA.

APPENDIX II

First key to vegetation types of the Donnybrook Sunkland
(An early seventh type, B, was incorporated into type C)

This was used in the office as a transparent overlay
to abundance records on a standard computer card.

Species	A	C	D	E	F	G
Acacia browniana	×	×	×	\	\	\
Acacia extensa	o	×	×	o	×	\
Acacia mooreana	o	o	o	o	×	×
Acacia preissiana	×	×	×	×	×	\
Adenanthos barbigera	×	×	×	×	o	\
Adenanthos meissneri	\	o	×	×	×	×
Adenanthos obovata	o	•	\	o	×	×
Agonis linearifolia	×	×	o	•	o	×
Agonis parviceps	o	o	o	o	o	×
Banksia attenuata	•	×	×	×	×	×
Banksia ilicifolia	o	o	×	×	×	×
Banksia littoralis	×	o	•	×	×	×
Bossiaea ornata	×	×	×	×	×	•
Casuarina fraserana	×	×	×	o	o	o
Dasypogon bromeliifolius	\	\	×	×	×	×
Dasypogon hookeri	×	o	\	o	o	×
Daviesia incrassata	×	•	o	×	×	×
Daviesia pectinata	×	×	×	×	o	\
Daviesia preissii	×	×	×	×	o	\
Eucalyptus megacarpa	×	×	×	•	\	×
Eucalyptus patens	×	×	×	•	×	×
Hakea ceratophylla	×	o	•	×	×	×
Hakea lasiantha	×	×	×	\	o	×
Hakea lissocarpha	×	×	×	o	•	o
Hibbertia montana	×	×	×	o	×	\
Hibbertia pachyrrhiza	\	o	×	×	×	×
Hibbertia vaginata	\	\	×	×	×	×
Hibbertia quadricolor	×	×	o	×	\	\
Hovea chorizemifolia	×	×	×	×	×	•
Hypocalymma angustifolium	×	×	•	×	\	×
Isopogon sphaerocephalus	×	o	×	×	o	•
Kingia australis	×	o	o	×	\	×
Leptocarpus scariosus	\	\	\	\	×	×
Leptospermum crassipes	×	o	\	×	o	×
Leptospermum ellipticum	×	o	\	o	o	×
Leucopogon capitellatus	×	×	×	×	×	\
Leucopogon glabellus	\	o	×	×	×	×
Leucopogon australis	×	×	o	\	•	\
Leucopogon verticillatus	×	×	×	×	o	\
Lyginia barbata	o	o	o	o	×	×
Melaleuca preissii	×	o	•	×	×	×
Melaleuca thymoides	\	\	o	×	×	×
Mesomelaena tetragona	×	•	\	×	o	×
Petrophile linearis	•	×	×	×	×	×
Persoonia longifolia	×	×	×	×	×	\
Pimelea spectabilis	×	×	o	\	•	o
Pultenaea drummondii	×	×	o	\	o	o
Pultenaea reticulata	×	\	o	×	×	×
Stirlingia latifolia	o	•	o	×	×	×
Styphelia tenuiflora	×	×	×	×	×	\
Tetratheca viminea	×	×	×	o	×	\
Xanthorrhoea gracilis	×	×	o	o	•	\
Xanthorrhoea preissii	o	o	\	\	\	o

KEY: • Obligatory species: \ Probable species:
o Permissible species: × Prohibited species.

APPENDIX III

Non-parametric ranking system for qualitative attributes of soils

Rank	1	2	3	4	5	6	7	8	9	10	11	12
Texture	S	LS	SL	SiL	L	SCL	SiCL	CL	SC	SiC	C	-
Colour	lG	lyB	lgB	yB	gB dG	dyB	dgB	bY	sB	rY	yR	dR
Limiting horizon	none	compact sand	heavy gravel	sheet laterite	clay	iron-cemented clay	winter water table					

Textural components abbreviated are: sand (S), silt (Si), clay (C) and loam (L)

Colours abbreviated are: brown (B), grey (G), yellow (Y) and red (R)

Colour adjectives abbreviated are: light (l), dark (d), strong (s), brownish (b), greyish (g), yellowish (y) and reddish (r)

APPENDIX IV

Indicator species currently in use for the Donnybrook Sunkland (numbers are key to Figures 1 and 2)

1. *Acacia browniana*
2. *Acacia diptera*
3. *Acacia mooreana*
4. *Acacia obovata*
5. *Adenanthos barbigera*
6. *Adenanthos meissneri*
7. *Adenanthos obovata*
8. *Agonis linearifolia*
9. *Agonis parviceps*
10. *Banksia attenuata*
11. *Banksia littoralis*
12. *Beaufortia sparsa*
13. *Bossiaea ornata*
14. *Dasypogon bromeliifolius*
15. *Dasypogon hookeri*
16. *Daviesia incrassata*
17. *Daviesia preissii*
18. *Eucalyptus megacarpa*
19. *Eucalyptus patens*
20. *Grevillea brevicuspis*
21. *Grevillea pulchella*
22. *Hakea ceratophylla*
23. *Hakea lissocarpha*
24. *Hibbertia montana*
25. *Hibbertia pachyrrhiza*
26. *Hibbertia quadricolor*
27. *Hovea chorizemifolia*
28. *Hypocalymma angustifolium*
29. *Isopogon sphaerocephalus*
30. *Kingia australis*
31. *Leptospermum crassipes*
32. *Leptospermum ellipticum*
33. *Leucopogon australis*
34. *Leucopogon capitellatus*
35. *Leucopogon glabellus*
36. *Leucopogon verticillatus*
37. *Melaleuca preissiana*
38. *Melaleuca thymoides*
39. *Mesomelaena tetragona*
40. *Persoonia longifolia*
41. *Petrophile diversifolia*
42. *Petrophile linearis*
43. *Pimelea spectabilis*
44. *Pultenaea drummondii*
45. *Pultenaea reticulata*
46. *Stirlingia latifolia*
47. *Styphelia tenuiflora*
48. *Tetratheca setigera*
49. *Thomasia grandiflora*
50. *Xanthorrhoea gracilis*
51. *Xanthorrhoea preissii*