VERSION 1 – 2008

FIELD SURVEY FOR VEGETATION CLASSIFICATION

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INTRODUCTION

Standard methods to sample, describe, classify and map vegetation in Australia are described in this publication. The methods have been extensively tested in the field and have a wide range of applications in Australia and elsewhere. They also accord as much as possible with the national standards of the National Vegetation Information System (NVIS) and the views of the Executive Steering Committee for Australian Vegetation Information (ESCAVI 2003).

Who Should Use This Manual?

This manual is useful to anyone who needs to collect site-based data about vegetation. This includes those with interests in vegetation mapping and monitoring; flora, fauna and biodiversity surveys; faunal habitats; biomass and carbon sequestration; fire fuel-loads; environmental impact assessment; land cover change; native and introduced vegetation; ground-truthing of remotely sensed images of the earth; preparation of land management plans and systems; and foliage and structure profiling amongst others. The present publication significantly updates Walker and Hopkins (1990) to meet current demands of a range of users operating at scales from small sites, to local government areas, bio-regions, states and national coverage. The methods have been extended to accommodate vegetation dynamics by allowing a range of successional stages to be recorded for both native and non-native vegetation and to record some characteristics of the physical environment from those sites.

How to Use This Manual

Users of this manual can read it from beginning to end. The introductory sections briefly cover what vegetation is, a short history of vegetation classification and mapping in Australia, as well as how to prepare for site-based field work on vegetation. This will be useful to those who do not have much experience in vegetation survey work in Australia.

Those with more experience in vegetation data collection will find it satisfactory to go directly to either the individual attribute they are interested in, or to the Appendices for details on rainforests, wetlands, condition, or proformas. This chapter should be read in conjunction with Thackway *et al*. in prep.

A table of contents is provided to facilitate quick location of major elements of the manual.

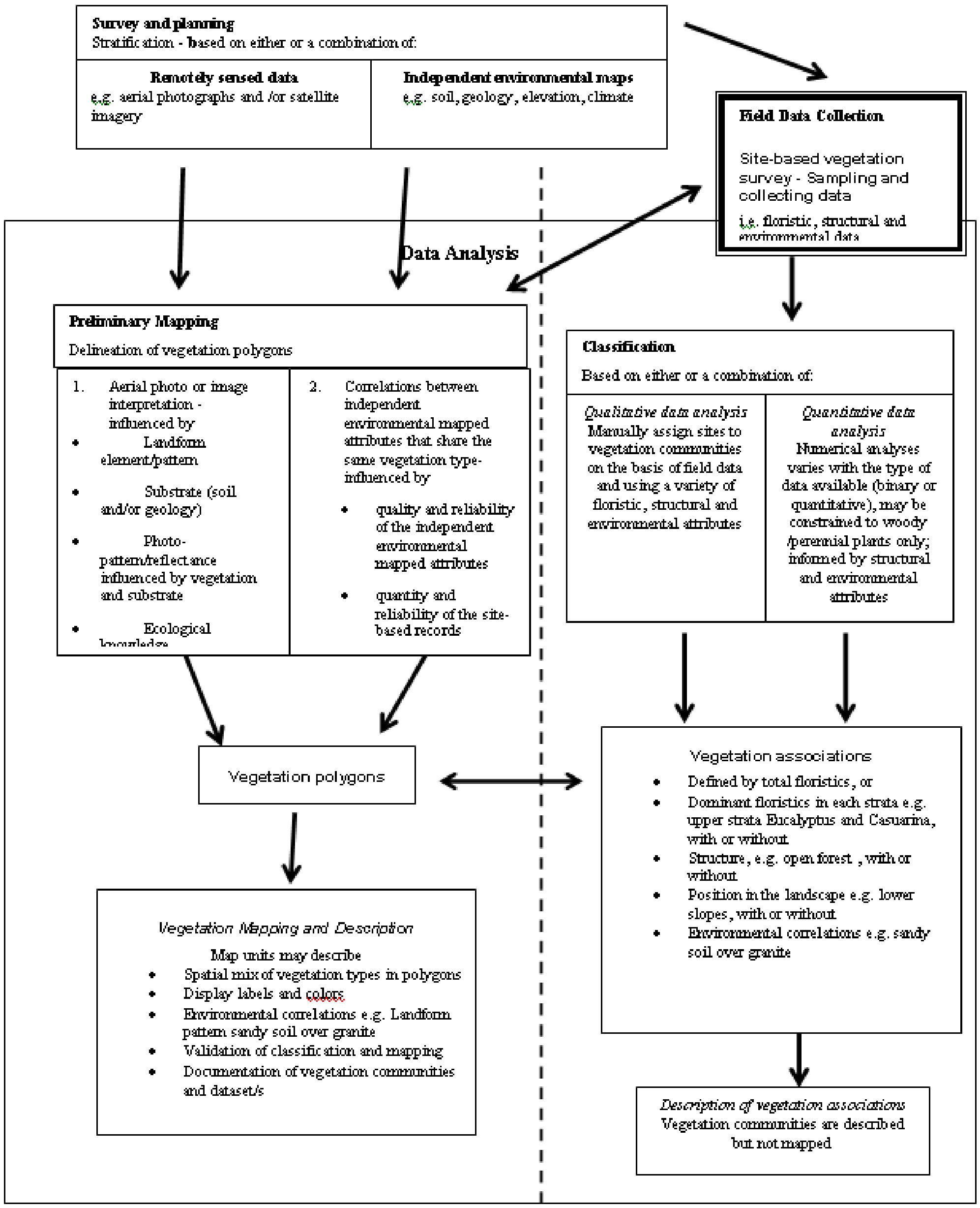
Background

Since the publication of the *Australian Soil and Land Survey Field Handbook* (McDonald *et al*. (1990)), considerable progress has been made in the use of new technologies for remote sensing, geo-location, and floristic understanding, as well as national coordination of vegetation mapping under the auspices of NVIS and the National Land and Water Resources Audit (NLWRA). That vegetation chapter in the *Field Handbook*, by J.

Walker and M. S. Hopkins, has been used extensively in research that includes collecting site-based observations of vegetation.

The relationship of field sampling for vegetation attributes to the broader work of mapping and classifying vegetation has been documented in the *Australian Soil and Land Survey Handbook Guidelines for Conducting Surveys* (Thackway *et al*., in prep) (Figure 1). The methods described in the present publication relate primarily to the structural (physiognomic) and floristic characteristics of the vegetation (as per Walker and Hopkins, 1990), as well as some ancillary site information. Structural characteristics are those that describe the vertical and horizontal distribution of vegetation in space: its growth form, height, density and layering (if present); while floristic characteristics range from the names of dominant and characteristic plant species through to comprehensive species lists at the site. Structural characteristics are the most easily recognised features on air photos or on other remotely sensed images.

Figure 1. The relationships between processes used in vegetation sampling, mapping and classification in Australia (Thackway *et al*. (in prep), adapted from Neldner *et al.* 1999). The vegetation and floristic elements of the 'Field Data Collection' component (highlighted box) is the subject matter of the present document.



A good sample-site record also contains a range of non-vegetation information (metadata) that is essential to the subsequent processing and use of that information (for example, see ESCAVI 2003). The metadata covered here constitute a subset of the full set documented in the Australian Spatial Data Directory (ASDD) (http://asdd.ga.gov.au/asdd/).

The description and classification of vegetation

Vegetation, in its most general, biological meaning, refers to the plant cover of the earth. It includes every form of plant from the tallest trees to the smallest uni-cellular plant, from the driest deserts to rainforests to aquatic habitats (Mueller-Dombois & Ellenberg, 1974). Vegetation displays patterns that reflect a wide variety of environmental characteristics and it is often a major factor defining the habitat for a wide range of plant and animal species. These patterns are formed by changes in species, changes in life form or growth form, or changes in spatial attributes such as cover, height or density. These changes are reflected in plant communities and these are classified in a hierarchical way from the broadest units (Formations) to the most detailed (Associations and sub-Associations).

Different levels of vegetation detail are appropriate for different purposes, but the important aspect is to be able to build explicit relationships between classes and by preference in a hierarchical manner. The NVIS program has suggested such a hierarchy, as shown in Table 1. In Table 1 we show the relationships between the Walker and Hopkins (1990) vegetation classification, the NVIS system (ESCAVI 2003) and the current system, and list the key components to measure at a site in order to satisfy each of the 6 levels in the information hierarchy.

Table 1. Comparison of hierarchical vegetation classification systems

Hnatiuk, Walker & Thackway 2005		**NVIS (2003)**	**Walker & Hopkins (1990)**
Name	**Attributes of the ecologically dominant strata & sub-strata**	**Level / Name**	**Name**

Formation Class	Growth form and cover (see Table 4)	I / Class	Formation Class p64-
Structural Formation	Growth form, cover and height (see Table 4)	II / Structural Formation Class*	Structural Formation p 60-61 `
Broad Floristic Formation	Growth form, cover, height and characteristic or broad floristic categories (see Table 5)	III / Broad Floristic Formation	
		IV / Sub-Formation	Sub-formation-
Floristic Association-	Structural Formation plus dominant species (see Table 3)	V / Association	Floristic Association
-		VI / Sub-association	-

The field data needed to describe and classify vegetation at the various levels here are built upon a long history of vegetation studies in Australia. The first attempt at comprehensive description of the Australian vegetation was in the Intercolonial Exhibition Essays of 1866-67 by Victorian Government botanist, Ferdinand von Mueller (Mueller 1866). The vegetation was classified according to broad structure and then prominent or interesting species. Mueller would have known about Humboldt's ideas of vegetation from early in that century, but his work preceded that of the detailed students of vegetation classification starting later in the 19th century. Diels (1906), a visiting German scientist, produced the next major classification of Australian vegetation, and its first continental vegetation map. His system was also structurally based with floristic dominants defining subunits.

Systems for classifying Australian vegetation began to appear in South Australia and New South Wales in the 1920s and continued in other parts of the country for many decades. While this is not the place to review the history of vegetation studies in Australia, it is worth noting the major points in its development: Mueller (1866) – first vegetation map, Diels (1906) – first national vegetation map, Wood (1930s), Williams (1950s), Specht (1974) – structural classification system, Carnahan (1970s – 80s) – national vegetation maps, Walker and Hopkins (1980's) – site based vegetation methods. There are many others who have contributed to the mapping of vegetation in Australia. Most of the systems proposed were based on units defined by structure at the high levels with subunits being based on floristic composition of either the canopy dominants or those of the understorey.

From the earliest days, vegetation units were related to variation in soils (geology), terrain and climate, and vegetation mosaics were also recognised features. The unusually floristically detailed, yet extensive, studies of vegetation in eastern Victoria by Gullan and others (e.g. Gullan *et al*. 1981) have been an application in Australia of the European school of phytosociology led by Braun-Blanquet and Tuxon. Another, similarly detailed series of studies of forest vegetation in south western Australia by Havel and Mattiske is also based upon detailed floristic analyses and demonstrates a classification based upon understorey strata and characteristic species. Such floristically based studies stand in strong contrast to the structurally based/dominant species systems of most other classifiers. It is worth noting that these major floristic works became possible only after sufficient taxonomic information about the flora of their regions became available. The structural systems gained great support because they gave access to vegetation classification in the face of too limited knowledge about the large and often taxonomically complex Australian flora. These systems also found wide acceptance because they used easily understood terms such as growth form, cover and height.

The balance in the use of floristic information has shifted significantly in the last two decades of the twentieth century, and taxonomic knowledge is now considered standard in most vegetation studies. Every State and Territory has handbooks of their floras for all or most of their regions (see section on Floristics), and there is continental cover for a growing proportion of the flora through the *Flora of Australia*, which increasingly includes families of lower plants (lichens, mosses, algae and fungi). It is also now available inline (http://www.deh.gov.au/biodiversity/abrs/online-resources/flora/index.html) The impact of this is that vegetation scientists are now expected to be able to identify the floras of the vegetation they sample and to include floristics in their vegetation classifications.

Vegetation structure

Vegetation *structure* is the horizontal and vertical distribution of cover and height of the dominant plants. It is recorded for growth forms of major plants, usually repeated for each major layer discernible (Figure 2). A set of schematic illustrations of vegetation structure from a diversity of Australian vegetation types are presented Appendix 8. Those with definable sub-strata are distinguishable from those with continuous canopies. (Carnahan, 1990, republished with permission of Geosciences Australia).

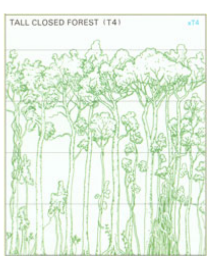


Figure 2. A schematic illustration for tall open forest. (Carnahan, 1990, republished with permission of Geosciences Australia).

For convenience, the vegetation component of landscapes is divided into classes, and these are grouped in a hierarchical system (Table 1). At the highest levels of this system, the classes are defined by the way they look – their structure. At lower levels in the hierarchy, the floristic composition of the dominant plants is used (although in some systems, characteristic species, which are not necessarily the most abundant or dominant) are used to define classes (see Table 1 for the nationally accepted, NVIS 6-level hierarchy in Australia).

The minimum quantitative data set required to classify vegetation

Decide	**NON-RAINFOREST (including plantations)**	**MIXTURE**	**RAINFOREST (wet/moist tropical subtropical)**	**RAINFOREST (Tasmanian cool temperate)**
		Non-rainforest stratum Rainforest stratum	(see Appendix 1)	
Recognise	dominant stratum		dominant stratum only	Dominant stratum
	mid-stratum (if present)			mid-stratum (if present)
	lower stratum (if present			lower stratum (if present
Record	for at least the dominant stratum and lowest stratum		Dominant stratum only	For at least the dominant stratum and understorey strata
	1. Growth form		1. Complexity	1. Dominant species
	2. Crown separation (cover dominant stratum)	Formation Class	2. Leaf size	
58	3. Crown type		3. Crown cover (crown separation)	2. Type of crown
	4. Height	Structural formation	4. Height	3. Height
	5. Foliage cover of the lower stratum		5 Emergents (if any)	
	6. Emergents (if any)		6. Composition	
	7. Species present (at least dominants)	Floristic association	7 Rainforest species present	4. Species present (at least the dominants)
			8. Sclerophyll species present	
			9. Indicator	

			growth forms in subordinate strata	

The basic steps for classification of non-rain forest vegetation

1 Growth form of' dominant stratum	+ Crown separation of dominant stratum =	Formation class(from Table 4)
Example: Tree	*+ Crowns overlapping =*	*Closed forest*
2 Height of dominant stratum =		*Height class* (from Table 2)
Example: 16 metres		*Tall*
3 Height class	+ Formation class =	Structural formation
Example: Tall	*+ Closed forest =*	*Tall closed forest*
4 Dominant species in the dominant stratum =		Floristic association
Example: Eucalyptus grandis	*Vegetation:*	*E. grandis tall closed forest*

Formation Class & Structural Formation

Vegetation classification at the highest level is based on the *growth form* and *cover* of the species forming the dominant stratum. The classes of vegetation at this level are called *Formation Classes*. Growth form is defined as: habit or general appearance of a plant. It is similar in definition to "life form".

Two growth forms are recommended for classifying Australian vegetation at the level of Formation Class: woody plants and herbaceous plants (Table 4). Woody plants include all trees, palms, arborescent cycads, tree ferns, shrubs and woody vines. Used in this context, 'woody' is not based on the anatomical characteristic of the presence of secondary thickening of the xylem, but rather those plants that are anatomically 'woody', plus those that have the same or similar habit, but which is achieved via other anatomical means. Herbaceous plants are those that lack or substantially lack woody tissue, including therophytes, i.e. annuals: those plants that regenerate more or less annually from seeds. In this system, all grasses and grass-like plants are herbs, along with the usual 'forbs'.

When the height of the dominant stratum is added to the Formation Class, the resulting classification units are called *Structural Formations* (Table 4). The structural formations recognised here are based on those previously used by Walker and Hopkins (1990), but differ by removing a number of anomalies, the largest of which is the removal of taxonomically based units from the Formation Classes and Structural Formations, and their inclusion in the next lower level of the vegetation hierarchy, the Broad Generic /Generic Group Formation (Table 5) and sub-Formation. New classes have been added for non-native vegetation and for bare surfaces.

The National Vegetation Information System (NVIS) has a hierarchical system for classifying vegetation. There are six levels as shown in Table 1.

Coding Structural Information

A shorthand nomenclature for structural formations is desirable in several circumstances: data storage and retrieval, air photo marking and mapping. The code system must be computer compatible and applicable at different levels of detail.

The codes used are as follows:

01 Woody: non-rainforest
02 Woody: rainforest
03 Woody: mixture
04 Woody: plantation (food & non-food)
05 Herbaceous: native
06 Herbaceous: non-native
07 Herbaceous: mixed
08 Non-vascular terrestrial plants
09 Aquatic vascular plants
10 Aquatic non-vascular plants
11 No vegetation

In circumstances where the more detailed Broad Generic / Generic Group Formations need coding, for example in maps, then the following system can be used. Each layer in the vegetation is represented by a group of quadrinomials for growth form (2-characters, see Table 5), height class (see Table 2) and crown separation (crown cover percentage) class (see Table 5) in that order: thus 7w1c is a tall open forest. The system is illustrated in greater detail in Figure 3. To ensure compatibility with any existing or future classification, it is strongly recommended that actual height and crown cover percentage (or separation) values be recorded.

Table 2. Height classes and names for various taxonomic-groups/ growth-forms for rainforest and non-rainforest sites

		Plant Type	
Class	**Height (m)**	**Woody plants (trees, palms, mallees, shrubs, cycads, chenopods, xanthorrhoeas, vines)**	**Ground Layer (Tussock and hummock grasses*, forbs*, rushes*, sedges*, ferns, Sod grasses, mosses, lichens, liverworts),**
10	> 50.01	Giant	NA
9	35.01 – 50	Extremely tall	NA
8	20.01-35	Very tall	NA

7	10.01-20	Tall	NA
6	5.01-10	Medium	NA
5	2.01-5.0	Low	Extremely tall
4	1.01-2	Dwarf†	Very tall
3	0.51 – 1	Miniature	Tall
2	0.26-.5	Micro	Medium
1	0.05-0.25	Nano	Low
0	< 0.05	NA	Dwarf

Height should be recorded as precisely as field methods allow. Field records can then be allocated to classes with subsequent processing. Height class boundaries are in general fairly arbitrary, especially when considering vegetation across major environmental and climatic gradients or when the age of vegetation is diverse.

Example of code for a structural formation using Table 2 and Table 5. The code comprises:

height of dominant stratum; growth form and crown separation (= foliage cover) class.

Thus: 7w1r = tall open woodland.

* Height includes flowering heads (but see section on height for details).

† Where it is important to distinguish trees from other woody plants, for example in the National Forest Inventory, then the woody plant must be taller than 2 m to be called a tree.

NA Not applicable.

Adding floristics to the structural formation

Species or generic names can be added to the structural formation name, and at the highest level the dominant species in the dominant stratum is used. More species names can be added to distinguish vegetation types that have similar structures and species dominants in the dominant stratum. The species used in the field to tentatively distinguish vegetation types can be modified later on the basis of numerical analysis or to conform to an already compiled vegetation type list.

The main problem in using the dominant species to qualify the structural formation is that dominance can vary spatially and, for example, in the case of two or more species occurring in varying amounts in essentially the same vegetation type, a variety of names is possible. This problem is best resolved after the field survey is completed and various data manipulations have been tried. One solution is to recognise co-dominants in a stratum and list each of them.

Ideally, all species present in the sample site at the time of sampling should be recorded. However, the completeness of a species list will depend partly on the purpose of the survey, the season of sampling, the degree of disturbance and the botanical expertise of the sampler. Those responsible for the survey must ensure that field workers have adequate botanical training and are familiar with the floristics of an area. As a minimum, the dominant species of the dominant stratum (and mid-stratum and lower-stratum if present) should be recorded or the alternatives noted (Table 3). Where sub-strata are not present, then the ecologically most important species are recorded. Selecting these species requires skill, and the criteria used to select them should be recorded in the field records.

Table 3. Naming floristic associations using species dominance and indicator species in the dominant, mid- and lower strata

First species	Initially the most abundant or physically predominant species in the dominant stratum is selected.
Second species	If another dominant stratum species is always present and conspicuous (a co-dominant species), it is selected. In the absence of a second dominant stratum species, the most abundant or physically predominant species of the next most conspicuous stratum is selected.
Third species	A third species is selected from any stratum, usually a lower stratum, as an indicator species (that is, a species, with known environmental preferences or of such abundance that it cannot be ignored), or to distinguish between associations.
Subsequent species	In some cases more species are required to separate associations; the selection is as for the third species.

Example: *Eucalyptus populnea* (EUPOP) dominant species in dominant stratum
Eremophila mitchellii (ERMIT) mid-stratum dominant
Bothriochloa decipiens (BODEC) lower stratum dominant

ASSOCIATION + STRUCTURAL FORMATION = VEGETATION NAME
e.g. *Eucalyptus populnea* tall woodland (coded EUPOP 7w1i)

Floristic codes

For some field workers, it is helpful if species names do not need to be written out in full, for example, where space is limited on a field record form, then a standard, short code for each species name is valuable. A simple code using the first two letters of the genus and the first three letters of the species is convenient. Few species have the same code, but should this happen; the last alphabetic character is replaced by number. Some workers have found it necessary to use a 4 + 4 code (4 letters for genus and 4 letters for species) to avoid confusing duplicated sequences. There are no national floristic codes and what is suggested here is for the convenience of an individual project, and not for national standardisation.

Examples:

EUPOP Eucalyptus populnea
ERMIT Eremophila mitchellii
ERGLA Eremophila glabra
ERGL2 Eremocitrus glauca

Before Field Data Collection Begins

Purpose of the Vegetation Survey

It is important to both understand and document the purpose of collecting vegetation data. Both the *kind* and the *detail* of data differ for different purposes. While it is not practical to list here all the various special needs of different users of vegetation information, what follows covers the core needs of the kinds of users noted under the earlier heading “Who Should Use This Manual”.

In vegetation mapping, the historically sound guidance is to locate sites within examples of intact vegetation (i.e. not overly disturbed). These are selected to represent what is thought to be mature, i.e. not early regeneration stages of the type. Selecting mature or intact sites is explicitly done because in most circumstances field work cannot be repeated often enough to usefully show the short term changes in vegetation brought about by any of many environmental forces (eg fire, drought, storm, grazing by domestic livestock, human activities). A map of what is often called ‘potential vegetation’ (e.g. Carnahan 1977) represents what is believed to be the kind of vegetation that a particular set of sites, with similar environments and disturbances, will support at maturity. Even though some intact, mature vegetation sites may themselves be succeeded by a different vegetation type if left undisturbed for long enough, they can qualify for site sampling. Clearly it is an issue of relative time scales (e.g. years, decades, centuries, millennia) that are important to define and record.

In contrast to the historical guidance just noted, an increasing range of users now have interests in successional (seral) stages of vegetation ranging from the time of disturbance, through recovery, maturing, senescence and to disturbance again. In some cases there will be progressive replacement of the dominant and other species with new species. Samples from these studies help elucidate vegetation dynamics. Similarly, vegetation samples that are collected in conjunction with a variety of faunal studies may also span different stages in the life cycle of vegetation. These stages are likely to provide different faunal habitats and need recording in their own right. Studies that involve repeated sampling (i.e. monitoring), may also require site-based samples to include successional stages of vegetation, and may use old aerial photos or local knowledge to document past vegetation.

Vegetation data also form one of the basic inputs to a variety of environmental modelling programs: habitats, climate change, soil water balances, disturbance impacts, carbon sequestration, fire fuel-loads etc. The core data recommended here will provide the basic data for these activities, although they will need to be supplemented with project specific data as well.

Vegetation samples are also used as input to numerical vegetation classifications. Classifications are used for a great diversity of purposes. Be sure that the kinds of data needed for the classification are collected at the field sampling sites.

Timing of Field Survey

The impacts of seasons or longer-period weather factors such as drought on the vegetation of Australia are readily observed. For a long time, vegetation field sampling has largely ignored this factor, while surveys for other biological components of ecosystems such as the fauna, now frequently include planned re-sampling to ensure all relevant information is obtained. Similar standards should be adopted for vegetation surveys where these temporal impacts are known to occur (Neldner *et al*. 2004). For example, choose sampling times:

- when most species expected at sites are likely to be visible (e.g. mid to late growing season; after a drought breaks);
- repeat sampling at the same site to ensure that most species are recorded (this may involve sampling in several seasons – winter, spring, summer and autumn or after drought ends).

Sample Detail

It is not possible to specify for all vegetation types and uses, what the level of detail that should be used when collecting information from a vegetation sample plot. However, the following are major factors that influence the level of detail:

- The purpose of the study (e.g. a large-area general survey may need only the dominant species, cover and height for each stratum present *versus* a detailed study of large or small-areas that records a complete list of all species with height, cover, phenology, dispersion, biomass, etc.)
- Whether the data will be used for quantitative floristic analysis (e.g. production of a floristically based classification of vegetation types, based on presence-absence or cover-abundance estimates)
- The resources available (e.g. people, equipment, time, money)
- Whether the sample site is to be revisited or not (e.g. a monitoring site or a reference site).
- Whether the sample site is to be fitted into a pre-existing list of vegetation types (e.g. NVIS or State/Territory lists of vegetation types).

Visual estimation of mean crown separation, ground stratum foliage cover, height of plants to decide classes, the dominant species and the special rainforest attributes takes only a few minutes to collect in the field and is sufficient to broadly classify vegetation.

The minimum quantitative data set is used for more detailed studies and provides significantly more information and flexibility in data analysis. The minimum quantitative data set usually takes less than 30 minutes to collect in the field for forest, woodland, shrubland and grassland. Some types of rainforest and species-rich shrublands may take longer.

Proformas for recording vegetation site-attribute data

Two field proformas are provided here (Appendix 6 and Appendix 7). The minimum data set will work in situations where quick surveys are all that is required. If more detailed records of the field site are needed, then the core data set proforma is more appropriate. Individual projects may need to modify the core proforma to incorporate project- or institution-specific data fields. It is strongly recommended that actual growth forms, heights, crown separation ratios and floristic data be recorded, as these data greatly increase the use of the data.

Recording the minimum quantitative data set to classify non-rainforest vegetation

The minimum data set necessary to classify vegetation involves recording four types of data from each site:

(a) dominant growth form (per stratum, if more than one present),
(b) cover (per stratum, if more than one present),
(c) height (per stratum, if more than one present), and
(d) dominant species (per stratum, if more than one present).

Whilst most field workers prefer to design their own field proformas, the proforma shown in Appendix 6 is convenient to use in the field. Space is provided in the proforma to record 12 measurements of crown variables for the upper and two mid-strata. The ground layer measurements are taken along a tape measure (see Figure 8), and additional plant species other than the dominants may be recorded. Space is available to enter median structural data.

Data collected in this form can be used to classify vegetation in the field, and in the office opens up a number of possible methods of data analysis. The form of data shown in Appendix 6 have been used to generate foliage profiles (Walker and Penridge 1987) using the computer program described by Penridge (1987).

Recording the core data set for vegetation samples

The core data set for a vegetation field site is outlined in Appendix 7. It includes fields for reporting site location and methods used to determine this, recorders names, date(s), environmental or landscape factors affecting the site, contextual information about disturbance and condition, and floristic and vegetation attributes. Some of the fields may not be relevant to all types of surveys, but have been included to indicate some of the types of information that may be needed for surveys in different regions of the continent. For example, distance to nearest water is relevant in many vegetation surveys in the drier regions of the continent, but not so in the wetter ones, because of the potential influence of grazing animals on the vegetation and their relationship with access to water. Similarly, evidence of fire and climatic conditions at time of survey may be relevant for many surveys, but not necessarily all.

Checklist Prior to Going into Field

A generic checklist of steps to help ensure field workers are ready to embark on a field trip is included in Appendix 3.

ATTRIBUTES

In the context of site-vegetation recording, *attributes* are the things that are recorded. They include environmental characteristics of the site and its surroundings, the methods used in the survey, the people doing the survey and the date(s), and the characteristics of the vegetation and plants at and near the sample site.

Attributes are presented here in a standard format: name, definition or description, what to record, how to record issues, special cases and references. The attributes have been grouped according to site location, sampling method, vegetation and plant attributes. A short section on new technology since Walker and Hopkins (1990) is included. Those attributes that deal with the wet tropical and sub-tropical rainforests of north-eastern and central eastern Australia, and the wet, cool temperate rainforests of Tasmania are reported in Appendix 1 and Appendix 2 respectively.

SITE LOCATION

Precise location of the place where sample records will be taken is not a haphazard affair.

An outline of the preparation for site-survey and the tasks to do at a site is presented in Appendix 3 (e.g. locate plot, mark boundaries, take photos, make drawings, collect data on plants, collect specimens, record/collect soils information, permanently mark site).

Locating the Sample Site

Definition/description:

Locating a sample site is a multi-stage process. It starts in the office and is progressively refined until the actual place where sample records will be made is determined.

Once the approximate location of a sample site has been determined from air photos and maps (Thackway *et al.* in prep), the actual placement of the sample plot uses a combination of rigorous techniques and a limited amount of good judgement. The factors being balanced are:

- The location of the plot should be as free from observer bias as possible. In other words, plots should not be chosen to include or exclude particular elements of the vegetation units being sampled (for example moving the edge of the plot to include a particularly desirable or exclude undesirable species or individual, particular size-classes of trees, understorey species etc) which have been previously selected as being homogeneous with respect to specified criteria (eg landscape position, geological/soil substrate, vegetation structure and age).

- The sample site should be characteristic of the vegetation unit it is meant to represent. Conditions on the ground may have changed since the maps or photographs used in stratifying samples were made, resulting in the precise location needing to be changed or abandoned all together.
- The location of the plot should not include elements that are not part of the homogeneous unit, but which are only discovered when initially examining the site. For example, plot boundaries should not cross into other vegetation units, include age or disturbance areas not meant to be part of the homogeneous unit, or include transition zones often called ecotones. These transition zones are usually different from the core areas of vegetation types and may be considered ‘types’ in their own right for certain kinds of studies. Under such circumstances the plot can be relocated using the random method detailed below.

The unbiased location of the sample plot can be achieved by walking from a defined starting point into the sample site to ensure you are well within the homogeneous unit and away from edge effects. Use a set of random numbers to select the number of paces to walk in a predetermined compass direction. Record these numbers and directions so the site can be relocated when necessary. On arriving at the location, use that point as one corner of the plot, or one end of the transect being used as the sampling framework. Examine the area that the plot will cover to ensure that it does not include any elements that are not part of the vegetation unit. If it does, the plot can be shifted slightly to avoid the foreign element but not to include or exclude elements of the unit being studied; otherwise a new location must be found using the random numbers technique just outlined.

What to record:

Once the sample site has been determined, it should be permanently marked so that it can be relocated at a later date. The method used needs to be compatible with the needs and uses of the landowners and managers. Methods that can be used include any or all of:

- Marking location on an aerial photo (pin prick or measure and record distances from eastern and southern margins). Record the identification of the aerial photo used. Ensure the photo is adequately archived for future reference.
- GPS location
- Surveyors tape attached to a tree or stake may last several years
- Burying iron or steel pegs (e.g. 5-10 mm diameter by 200 – 300 mm long) so they are not visible and can not cause damage to others using the site but which can be relocated using metal detectors.

Issues:

The major issues are the use of stratified random techniques, avoidance of observer bias, ensuring a homogeneous sample and adequate recording of the location

References:

Thackway, R., Neldner, J., & Bolton, M. (In Prep). Chapter 7, Vegetation . N. J. McKenzie, Ringrose-Voase A.J, & Grundy M.J (Editors), Australian Soil and Land Survey Handbook Guidelines for Conducting Surveys. 2nd Edition, CSIRO Publishing, Melb.

Walker J. and Penridge LK. (1987). FOL-Prof: a fortran-77 package for the generation of foliage profiles Part 1. User manual. Technical Memorandum. Division of Water Resources Research. CSIRO Australia. (87/9): 1-27 10 refs 8 figs.

SAMPLING METHOD

Plot Shape

Definition/description:

Plot shape is the geometrical shape; usually square, rectangular, circular or point or transect (plotless).

Square plots are preferred, unless conditions specifically require otherwise (e.g. narrow plots for riparian strips, or soft herbaceous vegetation that is easily damaged by trampling).

What to record:

Record the name of the plot shape. If plotless sampling, record the name of the method.

Issues:

Factors to consider are

- whether trampling is an issue (use narrow rectangular rather than square or circular);
- ease of setting up (e.g. circular plots are difficult to establish in tall vegetation);
- cost effectiveness (ease of recording, number of plots relative to the degree of precision needed).

Characteristics of different plot shapes:

- Square plots are the most commonly used and are relatively easy to set up. They have low edge-effects relative to area of the plot when compared with rectangular plots. However, they can also sustain significant trampling of plants, which may affect some attributes being measured such as cover, compared with narrow rectangular plots.
- Circular plots have similar characteristics to square ones. They have advantages with certain kinds of measurements such as basal area, which are determined by sitings from a fixed point (these BA samples are actually from irregular circular plots, not from plots for which the

perimeter of the circle is marked out on the ground). It can be difficult to mark the boundaries where the vegetation is tall.

- Rectangular plots, including 'transect' plots, allow greater access to the plot with relatively less trampling effects compared with square or circular plots. However, they have relatively greater perimeter to area, which increases the risk of edge effects such as the decision of whether a plant is in or out of the plot. Rectangular plots have advantages in sampling vegetation features that are by nature long and narrow in shape, for example riparian habitats.
- Plotless samples come in a variety of types. The 'zigzag' method, outlined in Figure 7, is one example. The 'line intercept' method (see Figure 8) is another.

When using rectangular or transect plots, the orientation of the plot relative to the surrounding environment may become a factor. There are several considerations. Which you choose depends on the purpose of the study or the kinds of analyses intended for the data.

- Orient the long axis of the plot *across* any environmental gradient (for example slope) that is part of the homogeneous unit being sampled. This will assist by increasing the within-sample variation, and making later comparisons with other samples of the type easier. If the number of samples is determined by statistical or other quantitative analysis, then this approach will tend to reduce the number of samples needed compared to the next alternative. It tends to produce a conservative result with respect to recognising vegetation types, i.e. it tends to aggregate results rather than sub-divide them.
- Orient the long axis parallel to within-type environmental gradients (such as slope), thus minimising the within-sample variation. This process narrows the variation included in the sample, but tends to increase the apparent distinctness of samples from what are thought to be a single type thus tending to increase the number of types recognised in subsequent analyses.
- Orient the long axis at random relative to within-type environmental gradients. By taking several samples within the type, the variance due to the included gradient will be incorporated in the aggregated sample of several transects for the location. This approach is similar to the first one.

References

Mueller-Dombois, D. and H. Ellenberg (1974). *Aims and Methods of Vegetation Ecology*. New York, John Wiley & Sons.

Plot Size

Definition/description:

Plot size refers to the area (m^2) covered by the sample plot.

What to record:

Record the dimensions of the plot and the type of plot. If circular, give the radius in metres. If rectangular (including square) give the length and width. If point-centred or 'plotless', indicate by naming method, and if a transect, give the length.

Plot size should vary with the physical dimensions of the things being sampled. As a guide, for plants:

>20 m high, use 900 m^2 (30 m x 30 m) plots;
<20 m high, use 400 m^2 (20 m x 20 m) plots;
< 1 m high, use plots from 25 m^2 (5 m x 5 m) to 4 cm^2 (2 cm x 2 cm; or 0.001256 m^2 (0.02 m x 0.02 m)).

Issues:

Plot size should remain as constant as possible for each vegetation type being sampled. Changing the area of a plot may affect some of the statistics for the survey, for example, within or between sample variances of certain statistics. However, it is appropriate to change the shape (as long as size (area) is not changed) of a plot so that its boundaries do not cross into adjoining vegetation types. For example, use narrow rectangular plots when sampling vegetation that grows in long narrow strips such as riparian vegetation.

Different sizes of plants are usually sampled better by different sizes of plot. That is, large plants like trees require large plots, while shrubs require smaller plots, and herbs and mosses require smaller ones again, i.e. nested plots may need to be part of your sampling design (e.g. when sampling stratified vegetation, the overstorey may require a larger plot size than the mid-stratum, than the ground stratum). When doing detailed studies in previously un-studied vegetation types, it may be necessary to determine optimal plot size based on sampling sets of plots for the attribute(s) in question and plotting the cumulative means of these sets against the cumulative area. The process is repeated until the fluctuation in the mean value sampled ceases or is reduced to negligible.

If quantitative floristic analyses are planned, then species – accumulation curves should be determined and optimal plot size deduced from them. To determine the mean sizes of crowns and crown gaps, several transects 50 m or more long are recommended, rather than the use of extra large plots. In sites dominated by the ground layer (grasslands, low shrubland, mosslands etc) several 1 m^2- 0.01m^2 to total area of perhaps 50 m^2 – 0.5 m^2 or transects 1-20 m long should be used to collect foliage cover and plant height data.

References:

Kent M., and Coker P. (1992). *Vegetation Description and Analysis: A Practical Approach*. CRC Press, Boca Raton.
Kershaw, K. A. (1966). *Quantitative and Dynamic Ecology*, Edward Arnold London
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VEGETATION

Formation Class

Definition/description:

Formation Class is usually the highest level of vegetation classification. Vegetation types at this level are distinguished by their growth form (which at this level has two classes: woody and non-woody) and cover.

What to record:

Record the dominant species. Where it is ecologically meaningful, distinguish trees from shrubs. The full set of Formation Classes is presented in Table 4

How to collect:

See growth form and cover sections under Plant Attributes

Issues:

At this very high level, this attribute is unlikely to be specifically recorded in the field, but is included for completeness. It can be derived from other data such imagery or species names.

A major departure from the previous system of structural formations is the treatment of woody plants. The system proposed here is not so much radical as it is historically sound, practical and descriptive of what one sees in the field. The tree – shrub dichotomy is not a universally applicable concept, whereas the cover and height of woody plants are. In the extensive and relatively dry environments of significant parts of Australia and other continents, there is little ecological gain in trying to distinguish trees from shrubs at a fundamental level in vegetation classification, whereas in the moister regions, the distinction of trees and shrubs is often clear-cut. The system presented here caters for this full range of variation in woody plant form. While the new classification does not depend upon the distinction of tree *versus* shrub, these should be noted on record sheets and databases as an attribute of a species when it is ecologically useful and unambiguous to indicate these growth forms.

References:

Walker, J. and M. S. Hopkins (1990). Vegetation, pp: 58 - 86. In: *Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys*. R.

H. Gunn, J. A. Beattie, R. E. Reid and v. d. Graaff, R.H.M (eds), Inkata Press**.** Melbourne.

Structural Formation

Definition/description:

Structural formations are the second level of vegetation classification in the hierarchical system. They are distinguished by the addition of height to that of growth form and cover.

What to record:

Record growth form, cover class and height for the dominant species in each stratum present. The full set of Structural Formations is presented in Table 4.

How to collect:

See growth form, cover and height sections under Plant Attributes

Issues:

At this level, greater discrimination of vegetation types is possible, compared with Formation Classes, even though it is still at a coarse level. It is not the level at which most natural resource management interest lies.

References:

Walker, J. and M. S. Hopkins (1990). Vegetation, pp: 58 - 86. In: *Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys*. R. H. Gunn, J. A. Beattie, R. E. Reid and v. d. Graaff, R.H.M (eds), Inkata Press**.** Melbourne.

Table 4. Formation classes and structural formations for woody and herbaceous plant.

			Field criteria	Touching-overlapping	Touching-slight separation	Clearly separated	Well separated	Isolated	Isolated	Emergent
			Crown separation ratio	<0	0 – 0.25	0.25 – 1	1 – 20	>20	>20	
			Foliage cover *%	100 - 70	70 - 30	30 - 10	<10	≈<0.20		0-5
			Crown cover *%*	>80	80 - 50	50 - 20	20 – 0.25	<0.25		<5% / <0.2
			% Cover ***	>80	80 - 50	50 - 20	20 – 0.25	<0.25		<5% / <0.2
			Cover code	D	O	S	V	I	L	E
			Name	**Closed**	**Open**	**Sparse**	**Very sparse**	**Isolated plants**	**Isolated clumps**	**Emergent**
Level I (Formation class) Code	**Level II (Structural formation) Code**	**Height class (m)**	**Structural formation name (common name)**							
w	10w	>50.01	Giant woody plants (trees)	Closed giant woody plants	Open giant woody plants	Giant woody plants	Sparse giant woody plants	Isolated giant woody plants	Isolated clumps of giant woody plants	Emergent giant woody plants
w	9w	35.01 - 50	Extremely tall woody plants (trees, vines)	Closed extremely tall woody plants	Open extremely tall woody plants	Extremely tall woody plants	Sparse extremely tall woody plants	Isolated extremely tall woody plants	Isolated clumps of extremely tall woody plants	Emergent extremely tall woody plants
w	8w	20.01 - 35	Very tall woody plants (trees, vines)	Closed very tall woody plants	Open very tall woody plants	Very tall woody plants	Sparse very tall woody plants	Isolated very tall woody plants	Isolated clumps of very tall woody plants	Emergent very tall woody plants
w	7w	10.01 - 20	Tall woody plants (trees, shrubs and vines)	Closed tall woody plants	Open tall woody plants	Tall woody plants	Sparse tall woody plants	Isolated tall woody plants	Isolated clumps of tall woody plants	Emergent tall woody plants
w	6w	5.01 – 10	Medium woody plants (trees, shrubs and vines)	Closed medium woody plants	Open medium woody plants	Medium woody plants	Sparse medium woody plants	Isolated medium woody plants	Isolated clumps of medium woody plants	Emergent medium woody plants

w	5w	2.01 – 5	Low woody plants (trees, shrubs and vines)	Closed Low woody plants	Open low woody plants	Low woody plants	Sparse low woody plants	Isolated low woody plants	Isolated clumps of low woody plants	Emergent low woody plants
w	4w	1.01 – 2	Dwarf woody plants (shrubs and vines)	Closed dwarf woody plants	Open dwarf woody plants	Dwarf woody plants	Sparse dwarf woody plants	Isolate dwarf woody plants	Isolated clumps of dwarf woody plants	Emergent dwarf woody plants
	3w	0.51 – 1	Miniature woody plants (shrubs and sub-shrubs)	Closed miniature woody plants	Open miniature woody plants	Miniatur e woody plants	Sparse miniature woody plants	Isolated miniature woody plants	Isolated clumps of miniature woody plants	Emergent miniature woody plants
w	2w	0.26 – 0.5	Micro woody plants (shrubs and sub-shrubs)	Closed micro woody plants	Open micro woody plants	Micro woody plants	Sparse micro woody plants	Isolated micro woody plants	Isolated clumps of micro woody plants	Emergent micro woody plants
w	1w	0.05 – 0.25	Nano woody plants (shrubs and sub-shrubs)	Closed nano woody plants	Open nano woody plants	Nano woody plants	Sparse nano woody plants	Isolated nano woody plants	Isolated clumps of nano woody plants	Emergent nano woody plants
h	5h	2.01 – 5	Extremely tall ground-layer plants (herbs, hummock and tussock grasses and grass-like plants)	Closed extremely tall ground-layer plants	Extremely tall ground-layer plants	Open extremely tall ground-layer plants	Sparse extremely tall ground-layer plants	Isolated extremely tall ground-layer plants	Isolated clumps of extremely tall ground-layer plants	Emergent extremely tall ground-layer plants
h	4h	1.01 – 2.0	Very tall ground-layer plants (herbs, hummock and tussock grasses and grass-like plants)	Closed very tall ground-layer plants	Very tall ground-layer plants	Open very tall ground-layer plants	Sparse very tall ground-layer plants	Isolated very tall ground-layer plants	Isolated clumps of very tall ground-layer plants	Emergent very tall ground-layer plants
h	3h	0.51 - 1.0	Tall ground-layer plants (herbs; hummock, sod and tussock grasses and grass-like plants, cryptogams, aquatic plants)	Closed tall ground-layer plants	Tall ground-layer plants	Open tall ground-layer plants	Sparse tall ground-layer plants	Isolated tall ground-layer plants	Isolated clumps of tall ground-layer plants	Emergent tall ground-layer plants

h	2h	0.26 – 0.5	Medium ground-layer plants (herbs; hummock, sod and tussock grasses and grass-like plants, cryptogams, aquatic plants)	Closed medium ground-layer plants	Medium ground-layer plants	Open medium ground-layer plants	Sparse medium ground-layer plants	Isolated medium ground-layer plants	Isolated clumps of medium ground-layer plants	Emergent medium ground-layer plants
h	1h	0.05 – 0.25	Low surface crusts (bryophytes and algae on and in soil surface, algae/lichens embedded in rock)	Closed low surface crust	Low surface crust	Open low surface crust	Sparse low surface crust	Isolated low surface crust	Isolated clumps of low surface crust	Emergent low surface crust
H	0h	<0.05	Dwarf surface crusts (bryophytes and algae on and in soil surface, algae/lichens embedded in rock)	Closed dwarf surface crust	Dwarf surface crust	Open dwarf surface crust	Sparse dwarf surface crust	Isolated dwarf surface crust	Isolated clumps of dwarf surface crust	Emergent dwarf surface crust
b	0b	0	Barren surface or vegetative cover less than 1%							

* Foliage Cover is defined for each stratum as 'the proportion of the ground, which would be shaded if sunshine came from directly overhead'. It includes branches and leaves and is similar to the Crown type of Walker & Hopkins (1990) but is applied to a stratum or plot rather than an individual crown. It is generally not directly measured in the field for the upper stratum, although it can be measured by various line interception methods for ground layer vegetation. For the attribute COVER CODE in the Stratum table, the ground cover category refers to ground foliage cover not percentage cover.
** Crown Cover (canopy cover) as per Walker & Hopkins (1990). Although relationships between the two are dependent on season, species, species age etc (Walker & Hopkins (1990), the crown cover category classes have been adopted as the defining measure.
*** The percentage cover is defined as the percentage of a strictly defined plot area, covered by vegetation. This can be an estimate and is a less precise measure than using, for example, a point intercept transect methods on ground layer, or overstorey vegetative cover. That is for precisely measured values (e.g. crown densitometer or point intercept transects) the value measured would be 'foliage' cover. Where less precise or qualitative measures are used these will most probably be recorded as 'percentage' cover.

Broad Generic / Generic Group Formation

Definition/description:

Broad Generic / Generic Group formations are defined as Structural Formations that have been subdivided according to the genus or genus group of the dominant stratum. They reflect major groupings of value to both environmental and economic users of vegetation information.

Wetlands are treated as a special case, see below.

Structural classes are usually used as a guide in determining associations. Extensive vegetation units should not be subdivided only on the basis of small (ecologically insignificant) changes in floristics, height or cover across arbitrary class boundaries, if no other suite of characters supports the distinction.

What to record:

Record the genus or genus group of the dominant stratum, according to the classes provided. The system allows flexibility in selection of genus/genus-group. The classes provided in Table 5 have an 'X' in each cell that is to be replaced with the particular genus/genus-group at the recording site. For example, cell w1.2i is 'X woodland', which for a specific site might be '*Eucalyptus* woodland' or '*Acacia aneura* woodland'. Record the name of the class on the record sheet as this provides a useful basis for remembering the site and communicating about it. The name can be refined/corrected, if need be, after subsequent office work.

Codes have been provided for those who find them useful. They can be distinguished from previous ones in Walker and Hopkins (1990) by their 2-character form: a lower-case letter followed by a number.

How to collect:

See growth form, cover, height and floristics sections under Plant Attributes

Issues:

The groupings presented in Table 5 do not represent all possible classes at this level of vegetation classification. Particular projects may require finer resolution or other categories.

The Broad Generic / Generic Group Formation has categories not previously included (Walker & Hopkins, 1990, ESCAVI, 2003), specifically, classes for vegetation dominated by non-native plants and non-vegetation surfaces. Increasingly, managers of land are required to integrate their management across all of the land for which they are responsible, irrespective of whether it is vegetated with native, non-native or mixed growth of the two, as well as bare (non-vegetated) land (Thackway 2005). The classification provided here is flexible and comprehensive enough to allow vegetation of any of these types to be sampled, classified and mapped within a single framework.

Special cases:

Flushes of Annuals

Vegetation that is periodically dominated by massive flushes of annual plants following rains, e.g. in semi-arid areas of the continent, are classified by using the perennial plants.

Wetland

Wetland vegetation is treated as a special case because on the one hand some types overlap with dryland vegetation types, but on the other hand, some types are unique. There are also situations where the presence or degree of inundation may not be discernable at the time of sampling. The following procedure is recommended.

Wetland sites

Definition/description:

The definition of a wetland adopted by the Ramsar Convention under Article 1.1 (Anon, 1994), and used in *A Directory of Important Wetlands in Australia* (Environment Australia, 2001) is:

> *"wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent of temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres."*

Within this broad definition, the wetland classification system identifies 40 different wetland types in three categories:

- Marine and Coastal Zone wetlands,
- Inland wetlands and
- Human-made wetlands.

What to record:

Record the type of wetland as per those listed in Appendix 2.1.
Record the dominant life forms as per Appendix 2.2.
Wetland specific sampling methods may be found in Anderson (1999) and Brock and Casanova (2000).

How to collect:

Use site observations, especially at planned times of year or relative to drought – non-drought cycles, aerial photos, maps. Brock and Casanova (2000) provide detailed methods of equipment and procedures specific to sampling in wetland environments.

Issues:

Ephemeral and periodic wetlands pose recording issues similar to those of ephemeral annual plants in some inland dryland situations. The speed of temporal changes that affect vegetation structure, cover, height and floristic composition are so great compared with most dryland sites that special sampling programs are required if the essential aspects of wetlands are to be recorded.

Field workers, inexperienced with wetland species, may not know at the time of sampling to which growth form the plants they observe belong, if the wetland is ephemeral, intermittent or fluctuates. In such cases, record the plants as they are seen at the time of sampling, but indicate whether the site appears to be a wetland and whether there is evidence concerning changes in water levels or not.

The method presented here allows aquatic sites to be sufficiently recorded that the major types of wetlands will be identified. Many of the attributes needed for detailed analysis of wetlands are not included.

References:

Anderson, J. R. (1999). Basic Decision Support System for Management of Urban Streams. Report No. 1. Development of the Classification System for Urban Streams. LWRRDC Occasional Paper 8/99 [accessed 12 April 2005: http://au.riversinfo.org/library/nrhp/decn_supp_syst/]

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Thackway, R. (2005). *Assessing Vegetation Assets, States and Transitions (VAST)*. http://www.affa.gov.au/content/output.cfm?ObjectID=A3D50188-7FC0-48E4-BBB4278D49B81C1B. (accessed 10/03/05).

Table 5: Broad Floristic Formations.

		Cover Characteristics							
		Foliage cover	100 - 70	70 - 30	30 - 10	<10	≈0	0-5	
		Crown Cover (%)	>80	80 - 50	50 - 20	20 – 0.25	<0.25	0-5	
		Cover code	D	O	S	V	I	L	
Level III, Broad Floristic, Code	**Broad Floristic Group of dominant stratum**	**Height Ranges (m)**	**Broad Floristic Formation Classes (in each class name, replace the 'X' with the particular taxonomic name from either the dominant genus or genus groups making up the dominant stratum; not all classes require a separate taxonomic name, e.g. *mallee woodland*); in other cases the 'X' name is optional, e.g. *chenopod shrubland* versus *Atriplex chenopod shrubland* or *Atriplex shrubland)***						
w1.0	Trees: Dominant genus e.g. eucalypt	2->50	Closed X forest	Open X forest	X woodland	Open X woodland	Isolated X trees	Isolated clumps of X trees	X trees
w1.1	Trees: Rainforest	2->50	Closed X forest	Open X forest	X woodland	Open X woodland	Isolated X trees	Isolated clumps of X trees	X trees
w1.2	Trees: Planted/cultivated non-food (plantation, timber, cellulose, oil, Christmas trees, urban etc.)	2->50	Closed X forest	Open X forest	X woodland	Open X woodland	Isolated X trees	Isolated clumps of X trees	X trees
w1.3	Trees: Planted/cultivated food (fruits, nuts, horticulture)	2->50	Closed X forest	Open X forest	X woodland	Open X woodland	Isolated X trees	Isolated clumps of X trees	X trees
w1.4	Trees: Planted/cultivated (landscaped/urban/sub-urban/rural, suburban gardens, nurseries)	2->50	Closed X forest	Open X forest	X woodland	Open X woodland	Isolated X trees	Isolated clumps of X trees	X trees
w2.0	Woody plant (indeterminate tree or shrub)	0.1-10	Closed X woody plants	Open X woody plants	X woody plants	Open X woody plants	Isolated X woody plants	Isolated clumps of X woody plants	X woody plants
w2.1	Mallee (tree or shrub)	0.1-30	Closed X-mallee	Open X-mallee	X-mallee	Open X-mallee	Isolated X-mallee	Isolated clumps of X-mallee	X-mallee
w3.0	Shrub: (conifer, dicot, cycad, grass-tree, tree-fern etc)	<20	Closed X shrubland	X shrubland	Open X shrubland	Sparse X shrubland	Isolated X shrubs	Isolated clumps of X shrubs	X shrubs
w3.1	Heath shrub	<3	Closed X-heathland	X-heathland	Open X-heathland	Sparse X-heathland	Isolated X-heath shrubs	Isolated clumps of X-heath shrubs	X-heath shrubs
w3.2	Chenopod shrub	<3	Closed X chenopod shrubland	X chenopod shrubland	Open X chenopod shrubland	Sparse X chenopod shrubland	Isolated X chenopod shrubs	Isolated clumps of X chenopod shrubs	X chenopod shrubs
w3.3	Samphire shrub	<3	Closed X samphire shrubland	X samphire shrubland	Open X samphire shrubland	Sparse X samphire shrubland	Isolated X samphire shrubs	Isolated clumps of X samphire shrubs	X samphire shrubs
w3.4	Planted/cultivated food shrubs (grapes, nuts, vines, soft fruit etc)	< 3	Closed X-food-shrubland	X-food-shrubland	Open X-food-shrubland	Sparse X-food-shrubland	Isolated X-food-shrubs	Isolated clumps of X-food-shrubs	X food-shrubs

w3.5	Planted/ Landscaped Urban/Suburban/ Rural cultivated non-food shrubs (cut flowers, oils, residential yards, nurseries etc)	< 3 m	Closed X industrial shrubland	X industrial shrubland	Open X industrial shrubland	Sparse X industrial shrubland	Isolated X industrial shrubs	Isolated X industrial shrubs	X industrial shrubs
g1.0	Hummock grass	<2	Closed X hummock grassland	X hummock grassland	Open X hummock grassland	Sparse X hummock grassland	Isolated X hummock grasses	Isolated clumps of X hummock grasses	X hummock grasses
g2.0	Tussock grass	<3	Closed X tussock grassland	X tussock grassland	Open X tussock grassland	Sparse X tussock grassland	Isolated X tussock grasses	Isolated clumps of X tussock grasses	X tussock grasses
g3.0	Other grass	<3	Closed X grassland	X grassland	Open X grassland	Sparse X grassland	Isolated X grasses	Isolated clumps of X grasses	other X grasses
g4.0	Sedge	<3	Closed X sedgeland	X sedgeland	Open X sedgeland	Sparse X sedgeland	Isolated X sedges	Isolated clumps of X sedges	X sedges
g5.0	Rush	<3	Closed X rushland	X rushland	Open X rushland	Sparse X rushland	Isolated X rushes	Isolated clumps of X rushes	X rushes
g6.0	Planted/cultivated perennial grass crops (cereal grain)	<3	Closed planted/cultivated X cereal-land	Planted/cultivated X cereal-land	Open planted/cultivated X cereal-land	Sparse planted/cultivated X cereal-land	Isolated X cereal-land	Isolated clumps of X cereal-land	Other X cereal-land
g6.1	Planted/cultivated perennial grass crops (pasture grass)	<3	Closed X pasture	X pasture	Open X pasture	Sparse X pasture	Isolated planted/cultivated X pasture	Isolated clumps of planted/cultivated X pasture	Other planted/cultivated X pasture
g6.2	Planted/cultivated perennial grass crops (Other industrial grass)	<3	closed planted/cultivated X grassland	Planted/cultivated X grassland	Open planted/cultivated X grassland	Sparse planted/cultivated X grassland	Isolated planted/cultivated X grasses	Isolated clumps of planted/ cultivated X grasses	Other planted/ cultivated X grasses
h1.0	forb	<2	closed X forbland	X forbland	Open X forbland	Sparse X forbland	Isolated X forbs	Isolated clumps of X forbs	X forbs
h2.0	Planted/cultivated perennial herbaceous crops (food)	<2	Closed X herbaceous foodland	X herbaceous foodland	Open X foodland	Sparse X foodland	Isolated X food plants	Isolated clumps of food plants	X food plants
h2.1	Planted/cultivated perennial herbaceous crops (industrial non-food)	<2	Closed X industrial herbland	X industrial herbland	Open X industrial herbland	Sparse X industrial herbland	Isolated X industrial herbland plants	Isolated clumps of X industrial herbland plants	X industrial herbland plants
h2.2	Planted/cultivated annual herbaceous crops (industrial non-food)	<2	Closed X industrial non-food herbland	X industrial non-food herbland	Open X industrial non-food herbland	Sparse X industrial non-food herbland	Isolated X industrial non-food herbland	Isolated clumps of X industrial non-food herbland	X industrial non-food herbland
h2.3	Planted/cultivated annual herbaceous crops (food)	<2	Closed X industrial food herbland	X industrial food herbland	Open X industrial food herbland	Sparse X industrial food herbland	Isolated X industrial food herbland	Isolated clumps of X industrial food herbland	X industrial food herbland
f1.0	Fern (excluding tree ferns)	<2	Closed X fernland	X fernland	Open X fernland	Sparse X fernland	Isolated X ferns	Isolated clumps of X ferns	X ferns
m1.0	Bryophyte	<2	Closed X bryophyteland	X bryophyteland	Open X bryophyteland	Sparse X bryophyteland	Isolated X bryophytes	Isolated clumps of X bryophytes	X bryophytes
l1.0	Lichen	<5	Closed X lichenland	X lichenland	Open X lichenland	Sparse X lichenland	Isolated X lichens	Isolated clumps of X lichens	X lichens
c1.0	Surface crusts (dwarf mosses, lichens, liverworts, algae)	< 0.05	Closed X crusts	X crusts	Open X crust	Sparse X crusts	Isolated X crusts	Isolated clumps of X crusts	X crusts

v1.0	Vine	0.5->30	Closed X vineland	X vineland	Open X vineland	Sparse X vineland	Isolated X vines	Isolated clumps of X vines	X vines
a1.0	Aquatic non-woody, (fresh or brackish, submerged, floating or emergent)	<2	Closed X aquatic bed	X aquatic bed	Open X aquatic bed	Sparse X aquatics	Isolated X aquatics	Isolated clumps of X aquatics	X aquatics
a2.0	Seagrass (marine)	<2	Closed X seagrass bed	X seagrass bed	Open X seagrass bed	Sparse X seagrass bed	Isolated X seagrass bed	Isolated clumps of X seagrass bed	X seagrass bed
a3.0	Algae (fresh or brackish)	Record thickness of layer	Closed X algae	X algae	Open X algae	Sparse X algae	Isolated X algae	Isolated X clumps of algae	X algae
a4.0	Algae (marine)	< 30m	Closed X marine algae	Marine X algae	Open marine X algae	Sparse X marine algae	Isolated X marine algae	Isolated X marine algae	X marine algae
b1.0	Bare surface (rock, salt pan, beach, dune, eroded soil, un-vegetated water surface)	0	Closed bare X	Bare X	Open bare X	Sparse bare X	Isolated bare X	Isolated bare X patches	Bare X

Strata (Layers)

Definition/description:

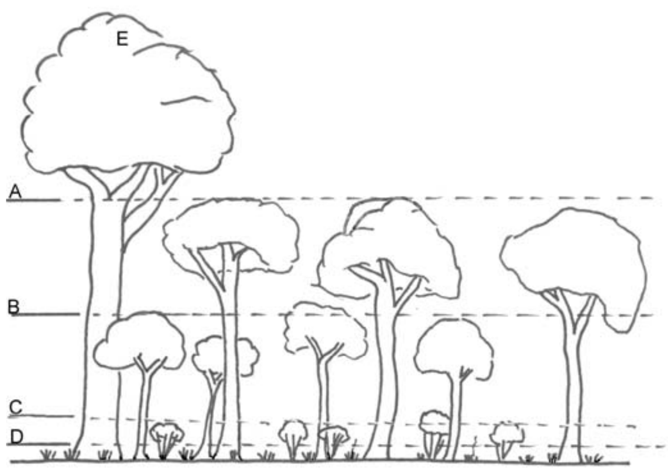
A stratum is defined as a visually conspicuous layer, of a measurable depth, in a plant community, produced by the occurrence of an aggregation of branches and photosynthetic tissue (when present) (see Figure 3). There is always at least one stratum if vegetation is present on a site. There may be more than one stratum, or a single stratum may extend from the top of the canopy to near ground level.

What to record:

Record, in metres, the height of the top of each stratum. It is the *median* height, i.e. the middle height of the ranked height records. It is not the height of the tallest plants, nor is it the arithmetic mean, especially when there are a few very tall or very short plants making up the top of a stratum or canopy (see Figure 3).

Where a study requires it, also record the depth of the stratum. Like the top of the stratum, the height of the bottom of the stratum is the *median* height.

Figure 3. An example of the coding of a sample site where four strata are clearly evident.



For height and cover in example see:
Table 2 – Height class code
Table 9 and Table 4 – Crown separation conversion to crown cover class
Table 4 – Structural formation code

Example:

Dominant stratum (A = top): height 21 m; crown separation 0.1; Tree =
21m = 8; 0.1 = O (67% cover);Tree. w1.0;
8Ow1.0 (very tall, open, tree canopy)

Mid stratum 1 (B = top): height 11 m; crown separation 0.9(22% cover) /S; Tree =
7Sw1.0 (tall, sparse, tree stratum)

Mid stratum 2 (C = top): height 2m; crown separation 1.5 (13% cover); Shrub
4Vw3.0 (very tall, very sparse, shrub stratum)
Ground stratum (D = top): height 0.7; 25% cover; Tussock grass
3Sg2.0 (Tall, sparse, tussock stratum)
Emergent (E): height 29 m; crown separation 4 (3% crown cover); Tree
29 m = 8; crown separation 4 = 3% = e (emergent); tree =w1.0
E8w1.0 (emergent very tall trees)

Level of detail

1 Formation class: **w** (woody vegetation)
2 Structural formation: **w7** (tall woody vegetation)
3 Broad Structural Formation (add genus/genus group of dominant stratum)
7Ow1.0 eucalypt (tall open eucalypt forest)
4 Floristic Association (add major understorey species)
8Ow1.0 eucalypt/7Sw1.0 eucalypt/4Vw3.0 *Eremophila*/3Sg2.0 *Bothriochloa*

The total structural code is: **8Ow1.0/7Sw1.0/4Vw3.0/3Sg2.0**
(Eucalypt very tall open woodland with sparse eucalypt understorey over very tall, very sparse *Eremophila*, with tall sparse *Bothriochloa* ground stratum.

With an emergent, as in Figure 3, an E is placed at the beginning of the tallest stratum code; E8ew1.0 *Angophora* (emergent very tall *Angophora*).
If a continuum of foliage height occurs, C is placed at the beginning of the mid or lower stratum code(s) (not illustrated, but see Appendix 4).

How to collect:

Measure a sample of plants that comprise the canopy, and sub-strata separately if they exist. Note, this 'sample' is not a sample of all plants in and near the canopy; rather it is of those that comprise the top of the canopy or layer, i.e. emergents and sub-canopy plants would not be included in the sample measuring the canopy but would require a separate set of samples. Calculate and record the *median* for each of these data sets. Where LIDAR data are available (Appendix 4), they may suffice, or be field tested.

Issues:

The recording of layers should not involve the use of predetermined classes, i.e. it should not be based on arbitrary or fixed height classes. The recognition of sub-strata is not a necessary prerequisite for defining plant communities (see below, *Special Cases*: regrowth).

Naming strata is as follows:

Dominant, or upper, stratum (U)

The dominant stratum is the one which contains the plants with the greatest ecological influence on the vegetation.. In most cases, the tallest stratum will also be the dominant stratum. The exception is in the case of emergents (*cf.* 'emergents' under 'special cases' below). All vegetation types have a dominant stratum, or there is no vegetation at the site. There is no mandatory height limit (upper or lower) for the dominant stratum.

Ground-stratum (G)
The ground stratum occurs beneath a taller stratum and is the stratum close to the ground. If the ground stratum is also the dominant stratum, then it is recorded as the dominant stratum. (For example, in closed grassland, the dominant stratum is the grass layer. There is no mandatory height limit on the ground layer, but it is usually less than 2.0 m tall.

Mid-stratum (M)
The mid-stratum is the one, if it occurs at the sample site, that occurs below the dominant stratum and above the lowest or ground stratum. It is so named because it occurs between a higher and a lower stratum. It is not mandatory to recognise such a stratum. When present, there are no preconceived height limits for this stratum. The important action is to record actual heights and fit into classes later.

Sub-Strata
At times it will be useful to record subdivisions of the three main strata. Such situations occur when a major stratum is seen to be composed of two or more different elements. For example, the dominant stratum may consist of one species that makes up most of the canopy, but its lower limit is made up of mostly a different species, a co-dominant. In such cases, separate *strata* do not really exist, but recognition of a sub-stratum may make it possible to elucidate a significant aspect of the vegetation (eg development stage, species mixtures etc).

Special cases:

Emergents
Situations occur in vegetation where the tallest plants are relatively scarce to the point where they no longer form the dominant or most significant layer, even though they are the tallest. For example, a few tall *Araucaria* or *Eucalyptus* trees towering above a closed rainforest canopy, or widely scattered eucalypts or acacias over a lower shrubland or grassland in semiarid regions. In these situations, the tallest stratum is classified as an 'emergent layer' (see *emergents* below for definition and discussion) and the dominant layer on which the vegetation will be classified is usually the next tallest layer.

Forestry
In forestry, the common practice is to record the heights of the tallest trees, as these are good indicators of site quality or potential, not the stratal height as defined here.

Regrowth – Complex Canopies

Vegetation that has been disturbed or is still recovering from certain kinds of disturbance can produce complex 'canopies'. For example, where a canopy has been reduced, but not totally removed by clearing, ringbarking or poisoning, two or more cohorts of canopy species may occur. When of clearly different ages, the cohorts are also likely to differ in height, making the description of the 'canopy' difficult. For example, this situation occurs over extensive areas of grazing land in Queensland.

The methods already described for defining 'dominant stratum' and 'emergents' should be applied to these situations. This type of vegetation can be further characterised by recording 'mixed age' from Table 6 (see below). The different cohorts should not be amalgamated unless they are too similar in structure to consistently be distinguished. Arbitrary height boundaries should not be used to separate them.

References:

Australian Land Information Group and J. A. Carnahan (1990). *Atlas of Australian Resources, Vegetation*. Canberra, Australian Government Publishing Service, Canberra.

Walker, J. and M. S. Hopkins (1990). Vegetation, pp: 58 - 86. In: *Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys*. R. H. Gunn, J. A. Beattie, R. E. Reid and v. d. Graaff, R.H.M (eds), Inkata Press**.** Melbourne.

Growth Stage

Definition/description:

Growth stage of a vegetation sample is the phase in the life cycle of that vegetation that the sample represents. It generally applies to time periods that fall within the life cycle of the dominant species at the site. Where clear signs of growth stage are visible, then such information should be recorded as it is an important aspect of any vegetation sample.

What to record:

When information is available at the site, record one of the five categories: early regeneration, advanced regeneration, uneven age, mature phase, senescent phase (see Table 6). Codes for the growth stages classes are provided in the Table for those who need them.

Record the features that the assessed stage is based on in the notes section of the field record sheets.

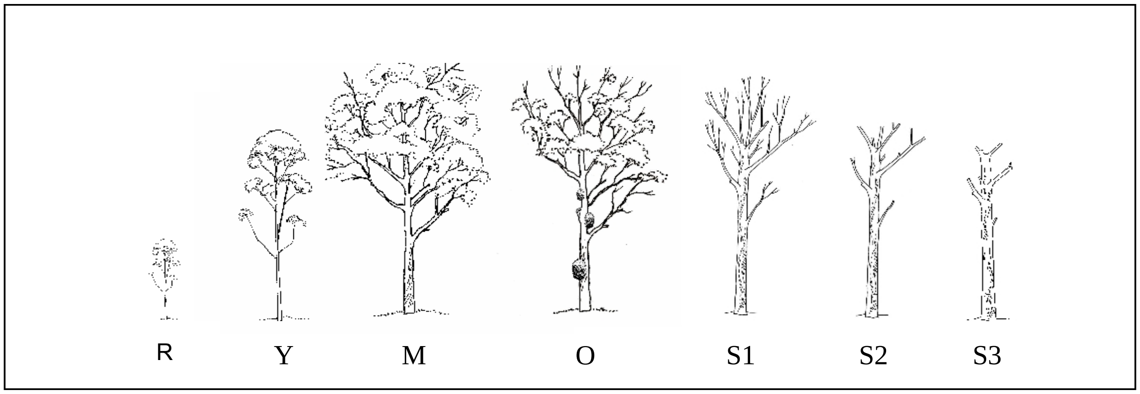
Table 6. Indicators of vegetation Growth Stage

Code	Growth Stage	Trees dominant	Shrubs dominant	Grasses & herbs dominant	Cryptogams dominant
1	Early regeneration	Dominated by small, juvenile-stages, often dense to open regenerating plants, with or without a few older, widely spaced; emergent plants may be present	Dominated by small, juvenile-stages, often dense to open regenerating plants, with or without a few older, widely spaced; emergent plants present	Plants small, juvenile stages predominate; exposed soil or old litter common.	Thin growth of young plants or widely spaced clumps of young plants.
2	Advanced regeneration	Dominated by dense to open, well developed, but not mature-form plants. If large, emergent plants are present, then they occupy less than 5% canopy cover of the site, but if more, classify as 'uneven age' (see next category below). Trees have well developed stems (poles) with a crown of small branches but below maximum height for the stand type, and apical dominance still apparent in vigorous trees.	Dominated by dense to open, well developed, but not mature-form plants. If large, emergent plants are present, then they occupy less than 5% canopy cover of the site, but if more, classify as 'uneven age' (see next category below).	Vegetative growth abundant; plants approaching full mature size but reproductive material absent or in early stages only; soil surface largely obscured in average sites.	Cover of plants high for the site; some reproduction evident.
3	Uneven age	A clear mixture of different size and age classes present, usually identified by two or more strata dominated by the same species, but can also be sites with different species regenerating in the understorey of an older canopy.	A clear mixture of different size and age classes present, usually identified by two or more strata dominated by the same species, but can also be sites with different species regenerating in the understorey of an older canopy.	A mixture of mature, perennial and immature annual species present on site.	A mixture of mature reproductive plants with immature regeneration
4	Mature phase	May have well-spaced mature-sized plants, or have very densely packed plants with crowns touching, with or without emergent senescent plants. Trees will have reached maximum height for the type and conditions and the crown will have	May have well-spaced mature-sized plants, or have very densely packed plants with crowns touching, with or without emergent senescent plants.	Marked by predominance of plants of reproductive age; depending on vegetation type, reproduction commonly evident now, or would be if environmental conditions were	Swards of plants common; plants of mature physiognomy (clump sizes and forms); sexual and asexual reproduction common at appropriate times of year; overall health and vigour high.

Code	Growth Stage	Trees dominant	Shrubs dominant	Grasses & herbs dominant	Cryptogams dominant
		reached full lateral development in un-locked stands. Although branch thickening may be evident, apical dominance has been lost.		appropriate (eg adequate water available in hummock grassland)	
5	Senescent phase	Dominated by 'over-mature' plants particularly in the dominant stratum; evidence of senescence in many plants, some without obvious links to disturbance. Tree crowns show signs of contracting in extent, and dead wood (stag heads) present; crown diameter and leaf area decrease. Distorted branches and burls may be common. Dead trees may be present.	Dominated by old plants (thick stems and primary branches, crowns may be either extremely dense with much dead wood, or thin and open if species sheds dead branches) particularly in the dominant stratum; evidence of senescence in many plants, some without obvious links to disturbance.	In largely annual vegetation, reproduction is complete and plants are dieing or mostly dead; in perennial vegetation, plants have lost vigour, are breaking down; large areas of soil are being exposed. Litter accumulation may be high.	Clear evidence of the degeneration of plants or clumps; dead older parts of plants may be conspicuous.

Where the vegetation is dominated by trees, especially eucalypts in south eastern and south western parts of the continent, the signs of ageing are well documented (Jacobs 1955, Eyre *et al*. 2000). The form of the tree in profile can tell you much about the relative age of the tree (Figure 4). Where the vegetation is dominated by woodland, growth stages of the trees are similar to those of open forest, but the overall tree-form is shorter and wider. Figure 5 provides indicative forms of trees at different growth stages. Where the vegetation is dominated by shrubs, there is little documentation of growth stages, however, that of Lange and Purdie (1976) is indicative of the general cycle of ageing of shrubs in inland Australia (Figure 6)

Figure 4 – Growth Stages forest (Eyre et al. 2002)

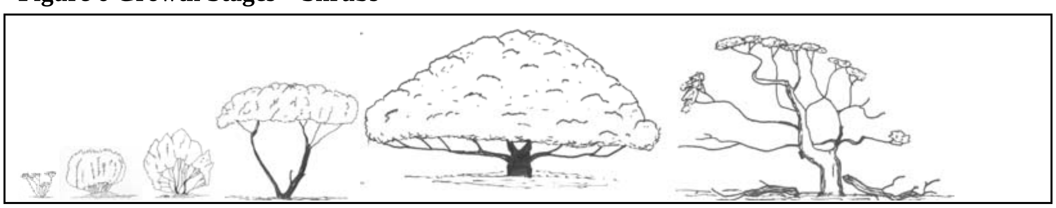


Numbers refer to growth stage categories in Table 6

Figure 5 Growth Stages – Woodland

Numbers refer to growth stage categories in Table 6.

Figure 6 Growth Stages – Shrubs



Development stages of western myall, *Acacia papyrocarpa*, redrawn from Lange & Sparrow, 1992 (ex Lange & Purdie 1976). Numbers refer to growth stage codes from Table 6.

How to collect:

Walk throughout site and immediately surrounding area, looking for signs that indicate the history of the development of the vegetation on the site. Table 6 and Figure 4, Figure 5, and Figure 6 summarise some of these, but all possibilities for all vegetation types cannot be covered here. The more knowledgeable the field worker is with the vegetation type, and vegetation dynamics in general, the easier and more reliable the assessment will be.

Issues:

Accurately assessing the growth stage of a vegetation type can be difficult in vegetation that is not well known, so care needs to be taken when recording this attribute. The knowledge-base is generally best for forests and woodlands, and much poorer for shrublands, grasslands and herblands.

Growth stage is also an attribute of interest when assessing the *condition* of a vegetation sample. It may not always be possible to separate the effects of increasing age from responses due to stress caused by environmental factors such as pest, diseases, or major changes due land use change.

References:

Eyre, T.J., Kelly, A.L., Sutcliffe, T., Ward, D., Denham, R., Jermyn, D., and Venz, M., (2002). *Forest Condition Assessment and Implications for Biodiversity - Final Report*. Queensland Department of Natural Resources. [Accessed 24 May 2005: http://pandora.nla.gov.au/pan/26050/20020805/www.ea.gov.au/land/nlwra/condition/brigalow/index.html].

Jacobs, M. R. (1955). *Growth Habits of the Eucalypts*. Canberra, Forestry and Timber Bureau, Department of the Interior, Commonwealth Government Printer, Canberra.

Lange, R.T. & Purdie R, 1976. Western myall (*Acacia sowdenii*), its survival prospects and management needs. *Australian Rangelands Journal* 1: 64-69.

Ex Lange, R.T. & Sparrow, A.D. 1992. Growth rates of western myall (*Acacia papyrocarpa* Benth.) during its main phase of canopy spreading. *Australian Journal of Ecology* 17: 315-320.

PLANT ATTRIBUTES

Floristics

Definition/description:

Floristics is the list of plant species found at a sample site.

What to record:

Record the name of each species. Preferably use the full scientific name. If using *ad hoc* species names, ensure that appropriate voucher specimens are collected and records are updated with correct scientific names.

Record all species, native and non-native alike, unless your project has specifically defined a shortlist of what to include/exclude. The use of standardised plant names improves the capacity of data sets to be combined. At the time of publishing this document, each State and Territory maintains their own comprehensive list of plants species for their jurisdictions. However, in 2004-05, the heads of the major State, Territory and national herbaria established a program, known as the *Consensus Census*, to produce a national list of scientific names, with major synonyms. The List of Agreed Australian Vascular Plant Names will be the names used in Australia's Virtual Herbarium (http://www.anbg.gov.au/avh/index.html). Progress with the *Consensus Census* can be found on http://www.chah.gov.au.

The total range of vegetation types for parts of Australia is sufficiently known that persons carrying out field surveys can in many instances acquire comprehensive lists of the species that can be expected in a region or in specific vegetation types. State and Territory environment departments or herbaria may be the source of this information. There may be local or regional lists of quality names that could be used. Such lists should be used as part of the field recording proforma to speed the recording of site floristics and to direct attention to unusual species records requiring detailed notes and possibly voucher specimens or photographs. Prepare this list as an initial check list (see sample proforma in Appendix 7).

How to collect:

For large parts of the Australian continent, it is now possible to satisfactorily identity the species of plants that form the vegetation. Both nationally and in many States, there is increasing access to web-based identification tools. Published volumes of the *Flora of Australia* are available on line, (http://www.deh.gov.au/biodiversity/abrs/online-resources/flora/index.html) as are a range of State-level identification tools. Interactive multi-entry digital keys to major plants groups are available and more can be expected in the future. This means that in most cases, field workers should be competent to either identify the species they encounter, or to collect adequate vouchers for later identification of those they are unsure of. Voucher specimens should be collected as part of most surveys to provide reference material to verify or confirm species identifications, or as tools to help ensure consistent identifications between workers and over long periods of time.

Procedures to help with the floristic component of site-based sampling can be found on the websites of most of the major herbaria in the country (see web links in *References* below). Good field-based floristic work is based on the following practices:

- Ensure that appropriate collecting permits and/or permissions are obtained before collecting. Each State/Territory/Commonwealth has its own regulations and procedures that must be followed. In many instances these can be accessed from web pages of the relevant authority (e.g. environment departments, national parks agencies)

- Know what constitutes an adequate specimen for the various types of plants you will encounter. Contact your local or State/Territory Herbarium, or an experienced field collector for advice if need be. Guidelines are also available from various web-sites.
- Know what rare flora may be encountered in your area. Know how to identify it and what to do if any are discovered during field work. There may be limits on collecting such material. Photographic records may suffice with rare flora.
- Record in a field note book, especially maintained for plant collections, the basic information for voucher specimens: plant name, location where collected (geo-coordinates, distance/direction from known/named geographic feature), date, collector and collector's number, habitat (soil, vegetation type, other notes that are important), plant height, phenological state (flowering, fruiting, leafing, dormant, colours of plant parts etc).
- Attach a string tag to each specimen, recording the collector's name/initials and field number that should be unique to the collector or the project, and which will also be recorded on the field data sheets.
- Preserve the plants by drying in a plant press especially designed for this purpose. Some types of plants may need special treatment (e.g. mosses, lichens, fungi, algae, aquatic plants, succulents, very large plants/leaves).
- If using field names and ID numbers, ensure subsequent updating of records when formal identification is complete.
- Determine the rules and conditions under which voucher specimens can be deposited in an appropriate herbarium and then where possible arrange to deposit a voucher specimen set there. Voucher collections can be of two types: one as a reference set for the field workers (may be taken into the field and consists of only snippets of relevant plant parts, or scanned and printed images of such plants, to aid in field identification), and one for depositing in a herbarium, in which case higher collecting and recording standards may apply.

Issues:

Most vegetation studies in Australia and elsewhere have concentrated on the 'native' plant species in their natural habitats. While the methods presented here are particularly suited to such studies, they are also equally suitable for use in agricultural and horticultural vegetation situations (e.g. Payne *et al*., 1998, Boyland 1974, Walker *et al*. 1973). The height and cover (vegetation structure) of a wheat field, a cotton crop, a vineyard, or grazing paddock can all be sampled and reported within the system presented here. The advantage of using a single comprehensive system for recording all vegetation lies in the power of integrating all vegetation of a landscape, region or continent into a single system, which can then be used for holistic planning, assessment or modelling.

Special cases:

Some field workers prefer to use species codes for their field records, while others prefer to record full scientific names (genus/species/infra-species) where ever possible. There is no preferred guideline; rather it is a matter of either personal preference or institutional practice. If in doubt, opt for recording the fullest scientific name possible. The major value of species codes is that they take less space to record. Their disadvantage is that they add an extra layer of risk of errors in recording.

References:

Boyland, D.E. (1974) - "Vegetation" in Western Arid Region Land Use Study Part 1. Div. of Ld Util. Tech. Bull. No. 12 Qd Dep. Prim. Ind. 47-70.

Payne, A.L, Van Vreeswyk, A.M.E., Pringle, H.J.R., Leighton, K.A. and Hennig, P. (1998). An Inventory and Condition Survey of the Sandstone-Yalgoo-Paynes Find area, Western Australia. *Technical Bulletin* no. 90. Agriculture Western Australia, South Perth.

Walker J., Ross D.R., and Beeston G.R. (1973). The Collection and Retrieval of. Plant Ecological Data. C.S.I.R.O. Woodland Ecology Unit Publication No.1. 31 pp.

Web-based links to major State and Territory Herbaria:

ACT: www.anbg.gov.au/
www.anbg.gov.au/cpbr/herbarium/index.html
NSW: http://www.rbgsyd.gov.au/conservation_research/herbarium_&_services
NT: http://www.nt.gov.au/ipe/pwcnt/index.cfm?attributes.fuseaction=open_page&page_id=6277
Qld: www.epa.qld.gov.au/nature_conservation/plants/queensland_herbarium
SA: www.flora.sa.gov.au
Tas: www.tmag.tas.gov.au/Herbarium/Herbarium2.htm
Vic: http://www.rbg.vic.gov.au/biodiversity/
WA: http://science.calm.wa.gov.au/herbarium/
Australia's Virtual Herbarium: http://www.anbg.gov.au/avh/index.html

Growth Form

Definition/description:

Growth forms are terms describing what a plant looks like (Table 7).
Two levels of growth form are used here. At the highest (most general, i.e. *Formation Class*) level, there are two growth forms: woody plants (w) and herbs (h) (see Table 4). At a lower level (*Structural Formation*, Table 4), there are 15 growth form classes, often based on the predominant growth form of a genus or group of genera. At this level for completeness, bare surfaces are also recognised, although they technically are not a Formation Class.

What to record:

For each species recorded, indicate its growth form at either the Formation Class level (i.e. woody or non-woody), or its Structural Formation level. Where useful and feasible, record shrubs separately from trees.

Table 7. Definitions of Growth Forms for Formation Classes and Structural Formations (modified from ESCAVI (2003)).

TERM	Broad Floristic Code	DEFINITION
Algae – marine	a4	A member of the Chlorophyta, Cyanophyta, Phaeophyta or Rhodophyta living in marine environments. May range from thin surface hugging layers to tall algal forests.
Algae – fresh or brackish	a4	A member of the Chlorophyta, Cyanophyta, Phaeophyta or Rhodophyta, living in fresh or brackish aquatic environments.
Aquatic higher plants	a1 (or 'w')	Dicotyledonous or monocotyledonous plants growing for a significant portion of their lifecycle in fresh or brackish water. (For convenience, may include various woody vegetation such as mangroves, eucalypt, melaleuca or other woody, periodically submerged vegetation, which span saline aquatic environments from brackish to hyper saline. Which of these is used will depend on the particular emphases of the survey.)
Bare surface	b1	Soil, rock or water surfaces with less than 0.5% plant cover.
Bryophyte	m1	A member of the Division Bryophyta, i.e. mosses and liverworts. Mosses are small plants usually with a slender leaf-bearing stem with no true vascular tissue. Liverworts are often moss-like in appearance or consist of a flat, ribbon-like, green thallus.
Chenopod shrub	w5	Single or multi-stemmed, semi-succulent shrub of the family Chenopodiaceae exhibiting drought and salt tolerance.
Fern	f1	A member of the Division Pterophyta, i.e. ferns and fern allies. Characterised by large and usually branched leaves (fronds); herbaceous and terrestrial to aquatic; spores in sporangia on the undersides leaves. Tree ferns are classified with woody plants as they have the same vegetational structure.

Food – shrubs	w7	Shrubs planted in rows for the production of food crops
Food – trees	w1.3	Trees, planted in rows, for the production of food crops
Forb	h1	Non-graminoid herbarceous plant
Grass other	g3	Member of the family Poaceae, but having neither a distinctive tussock nor hummock appearance, e.g. could be climbing or mat-forming.
Grass: planted & cultivated grasses:	g6	See 'Herb: perennial or annual grass'
Heath	w4	Shrub usually less than 2m tall, commonly with ericoid leaves (nanophyll, less than 225 sq. m.). Often a member of one the following families: Epacridaceae, Myrtaceae, Fabaceae and Proteaceae. Commonly occur on nutrient-poor substrates.
Herb	h1	Herbaceous or slightly woody, annual or sometimes perennial plant. (Dicotyledonous or monocotyledonous.).
Herb: food	h2	Herbaceous plants (monocotyledons or dicotyledons) cultivated as food for human consumption
Herb: industrial non-food	h2.1	Herbaceous plants (monocotyledons or dicotyledons) cultivated or maintained as food for animals, whether harvested or grazed directly.
Herb: perennial or annual grass crops – human food	h2.0	Member of the Poaceae cultivated as food for human consumption.
Herb: perennial or annual grass crops – pasture	g6.2	Member of the Poaceae cultivated or maintained for the production of food for animals, whether harvested or grazed directly.
Hummock grass	g1	Coarse xeromorphic grass with a mound-like form often dead in the middle; genera are *Triodia, Plectrachne* and *Zygochloa*.
Lichen	l1	Composite plant consisting of a fungus living symbiotically with algae: without true roots, stems or leaves.
Mallee	w2	Any of the eucalypt trees or shrubs with multiple stems

		arising from a lignotuber; usually a eucalypt.
Rainforest	w1.1	No widely accepted or universal definition for Australian rainforests. Usually distinguished by their dark green colour and species composition from the surrounding, grey or reddish-green and often eucalypt dominated vegetation.
Rush	g5	Herbaceous, usually perennial erect monocot that is neither a grass nor a sedge. For the purposes of NVIS, rushes include the monocotyledon families Juncaceae, Typhaceae, Liliaceae, Iridaceae, Xyridaceae and the genus *Lomandra;* i.e. "graminoid" or grass-like genera.
Samphire shrub	w6	A subdivision of 'Chenopod Shrubs'. Genera (of Tribe Salicornioideae, viz: *Halosarcia*, *Pachycornia*, *Sarcocornia*, *Sclerostegia*, *Tecticornia* and *Tegicornia*) with articulate branches, fleshy stems and reduced flowers within the Chenopodiaceae family, succulent chenopods (Wilson 1984). Also the genus *Suaeda*.
Seagrass	a2	Genera and species of flowering angiosperms of the families Hydrocharitaceae and Potamogetonaceae, forming sparse to dense mats of material at the sub tidal and down to 30m below MSL. Occasionally exposed.
Sedge	g4	Herbaceous, usually perennial erect plant generally with a tufted habit and of the families Cyperaceae (true sedges) or Restionaceae (node sedges).
Shrub	w3	Woody plant multi-stemmed at the base (or within about 200mm from ground level) or, if single-stemmed, less than about 5m tall; not always readily distinguishable from small trees.
Shrubs: Landscaping/ industrial	w8	Shrubs planted in mostly urban/suburban settings such as gardens, street trees, and nurseries.
Surface crusts	c1	Assemblages of one or more species of minute plants at or within the surface of soil or rock. May consist of bryophytes, lichens, cyanobacteria, green algae and fungi (adapted from Eldridge 1997); may in some cases include very small vascular plants.
Tree	w1.0	Woody plant more than 2m tall usually with a single stem, or branches well above the base; not always

		distinguishable from large shrubs.
Trees: Landscaping/ urban & suburban	w1.4	Trees planted in mostly urban/suburban settings such as gardens, street trees, nurseries
Trees: plantation	w1.2	Trees planted in rows for the intense production of food and non-food crops
Tussock grass	g2	Grasses, forming discrete but open tufts usually with distinct individual shoots, or if not, then forming a hummock. These include the common agricultural grasses.
Vine	v1	Climbing, twining, winding or sprawling plants usually with a woody stem.
Woody plant	-	Plants with woody tissues, but, for the purposes of vegetation classification here, also those plants that achieve a growth form similar to that of woody plants (e.g. cycads, palms, tree ferns); includes both trees and shrubs.

Issues:

In most instances, recording growth form will not be difficult. The distinguishing of trees from shrubs is the major area where problems arise in widespread, dry areas of the country. With the system presented here, this problem is avoided.

Special cases:

Wetland plants have a separate set of growth form categories. The recommended ones are in Appendix 2.2.

References:

Eldridge, E and Merrin E. Tozer (1997). *A Practical Guide to Soil Lichens and Bryophytes of Autralia's Dry Country*. New South Department of Land and Water Conservation, Sydney.

ESCAVI, (2003). *Australian Vegetation Attribute Manual: National Vegetation Information System, Version 6.0*, Department of the Environment and Heritage, Canberra. [Accessed 19 April 2005: http://www.deh.gov.au/erin/nvis/avam/]

Wilson, P.G. (1984). Chenopodiaceae. *Flora of Australia* 4: 81-317. Australian Government Publishing Service, Canberra.

Cover

This manual deals with three aspects of *cover*: estimates of canopy cover; estimates of ground cover; and combined cover-abundance estimates.

Canopy Cover

Definition/description:

Crown cover is the percentage of the total area of a sample site that is covered by a vertical projection of the crown. This is also the generic definition of *plant cover*.

Crown cover percent is recommended here as the method for reporting cover for plants over about 1.5 m high. The recommended method of measuring it is the crown separation ratio.

Foliage cover is used to estimate the cover of the ground layer. Percentage foliage cover is the percentage of a measured distance covered by the vertical projection of the leaves (and branches if woody, *sensu* Carnahan, 1977) onto a tape measure.

There are several methods of estimating plant cover and each measures a slightly different aspect of vegetation and is thus subject to different environmental conditions, but each results in a quantitative estimate that allows plant species or vegetation structural components to be ranked for relative importance, which is the goal of recording ‘cover’. It is important, depending on the objectives of a survey, to measure plant cover as accurately as survey resources allow.

What to record:

To measure cover for plants taller than about 1.5 - 2 m, start by measuring the *crown separation ratio* (CSR), then convert it to either percent foliage cover or percent crown cover. CSR is recorded on field sheets, and may be converted to *crown cover* by the use of tables (see Table 9).

For plants less than about 1.5 m high, estimate plant cover using the vertical projection method.

How to collect:

In rapid field surveys it is usually possible to decide which cover class a particular stratum fits into, that is, are the crowns touching, well separated etc. However, because primary data, for example actual crown cover percent, are usually more valuable than pre-classified data, a method to accurately estimate the crown separation ratio is needed. In addition the method to convert the ratio into either crown cover percent or foliage cover percent is also given. The zigzag method described here is an effective method for sampling a relatively large number of trees in the minimum horizontal distance, while at the same time incorporating the natural variability in crown widths and gaps. A proforma for field recording CSR and other structural attributes is shown in Appendix 6.

Field estimation of the crown separation ratio (C) for discrete crowns

The crown separation ratio is calculated as the ratio of the mean distance between crowns relative to the mean crown size.

$$\text{Crown Separation Ration (C)} = \frac{\text{Mean gap}}{\text{Mean width}}$$

The crown separation ratio (C) is discussed in detail by Walker *et al.* (1988) and Penridge and Walker (1988) and its limitations outlined. There are three key elements in the field estimation of C:

1 Sample along a zigzag transect as shown in Figure 7. Establish a transect PQ, start at a crown near P (in this case A), and select the next crown encountered going *towards* or *across* the transect line, and in the direction P $\longrightarrow$ Q.
2 Measure crown widths and crown gaps for each stratum separately irrespective of species (in the field a mean of 12 measurements is usually sufficient (see Appendix 6).
3 Where crown overlap occurs, the crown gap has a negative value; the greater the overlap, the larger the negative value.

Penridge and Walker (1988) show that:

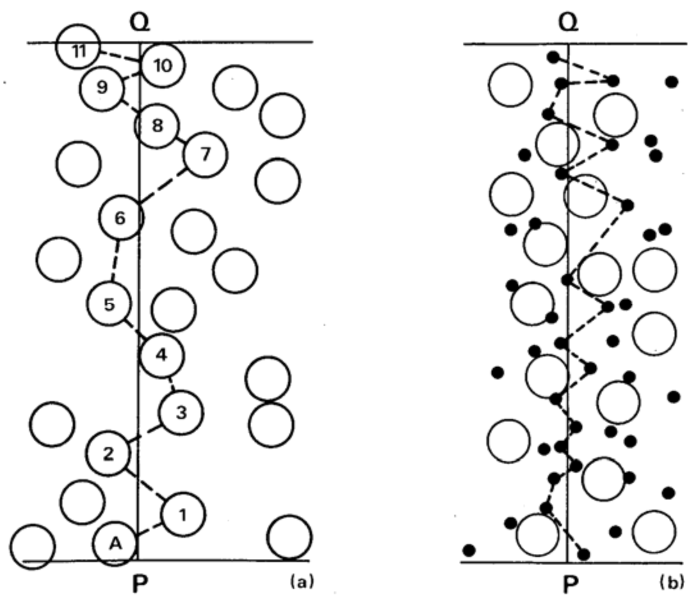
$$\text{Crown cover (\%)} = \frac{\text{k}}{(1+\text{C})^2}$$

where the constant k = 80.6 for samples taken along a zigzag transect as shown in Figure 7. A conversion table for a range of cover values is given in Table 9.

There are some limitations to the use of the crown separation ratio that will apply in some field situations (Penridge and Walker (1988)). These situations are:

- CSR should be measured for each stratum separately to avoid situations where crowns overlap;
- Crown shapes should approximate circles or non-extreme ellipses. In cases where crown shapes are so non-circular as to prevent a near-circular equivalent being determined, an alternative method to determine cover should be used (for example, use a line-intercept method). For ovoid crowns, the shortest and longest diameters are averaged.
- The zigzag method of measurement should be used to avoid long distances between trees, which could invalidate the underlying geometric assumptions of the method.

Figure 7. The zigzag sampling procedure is used for each stratum or layer, for example (a) for the dominant stratum (b) for a mid-stratum.



Conversion of crown cover percentage to Percentage foliage cover

The estimation of crown cover percentage assumes an opaque crown and to convert crown to foliage cover requires that the crown type (degree of openness) be considered. Crown type or crown openness is derived by matching the photographs in Figure 9 with actual tree crowns.

Percentage foliage cover = percent crown cover x crown type

Example: Crown separation ratio is 1.0, therefore percentage crown cover = 20% (Table 9)

Crown type (Figure 9) is say 60%, therefore percentage foliage cover = 20% x 60% = 12%

Field estimation of foliage cover in the ground layer

The ground layer normally comprises low shrubs, grasses, forbs, rushes, sedges etc., and it is necessary, in this classification, to estimate the foliage cover as a vertical projection. For many purposes a visual estimate will suffice to place the ground cover into a cover class (Table 8). Foliage cover of the ground layer may be accurately estimated using point quadrats or foliar intercepts along transects (Mueller-Dombois & Ellenberg, 1974). A rapid field method uses a 30 m tape laid out within the sample site (Figure 8).

The method is intended for use in grassy (leaves and inflorescences) or low shrub (leaves and branches) situations. Looking vertically down onto the tape and foliage (and or branches), the amount of foliage and branches intercepted along the tape is estimated, and expressed as a percentage of the transect length. It is easiest to estimate and record the amount of foliage and branches intercepted per metre of tape and add these amounts at the completion of the transect.

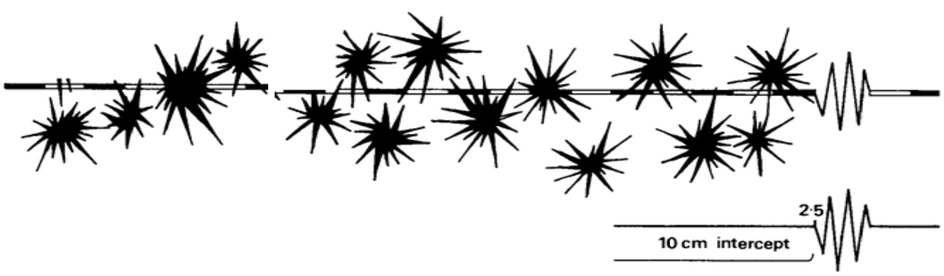


Figure 8 . An example of the field measurement of percent foliage cover using a line transect. The length of intercepted foliage is measured along a tape and foliage cover calculated as a percentage of the total length of the transect.

Usually two to four transects are needed per site depending on the spatial variability of the ground cover around the soil observation point. In most grassy situations 10m of transect is usually enough, and in small shrubs 20m. The more patchy the ground layer, the greater the total length of transect that will be needed.

In some situations, for example in rangeland environments where the formation class may require subdivision, it is often useful to collect information about basal area and/or plant density and recognise a number of cover classes in the <10% foliage cover class. Locating the transects should be done independently of the ground layer so that the sample is not biased by what the recorder might want in or out of the sample. The starting point and direction can be fixed in relation to some aspect of the dimensions of the sampling plot, or they can be determined by reference to random numbers for the starting point and bearing of the transect.

Issues:

There are three commonly used field definitions of percentage plant cover: They are crown cover, foliage cover and projective foliage cover. These give different values for percentage cover and none are correlated in a simple way with leaf area or leaf area index. Each of them, if applied consistently, will provide a useful index for ranking sites and vegetation types, even though they measure or estimate slightly different aspects of the vegetation canopy.

Crown Cover percentage (used here) is the percentage of the sample site within the vertical projection of the periphery of crowns. In this case, crowns are treated as opaque. It is the method recommended here for use. Current research indicates that it may be accurately estimated from LIDAR data.

Foliage cover percentage (*sensu* Carnahan 1977) is the percentage of the sample site occupied by the vertical projection of foliage and branches (if woody). It can be estimated from LIDAR data and hemispherical lenses.

Projective foliage cover percentage (pfc) (*sensu* Specht *et al.* 1974) is the percentage of the sample site occupied by the vertical projection of foliage only. It may be estimated from remote imagery where ‘greenness’ is measured, but in these cases, the imagery does not always distinguish between ‘canopy’ and ‘sub-canopy’ photosynthetic layers.

PFC for plants over 1.5 m tall is relatively time-consuming to estimate in the field using point quadrats, optical instruments or photography, and, in common with foliage cover, it is difficult to estimate where lower vegetation blocks the line of sight to upper strata. Both are unsatisfactory in situations that contain either deciduous species or species with vertical or near vertical leaves.

Crown cover percentage (the recommended method) does not suffer from these problems and is easily estimated both in the field and in large-scale aerial photography, and it appears to be measurable using LIDAR (Lee *et al.* 2004). Crown cover percentage is estimated (except with LIDAR) using the mean gap between crowns divided by mean crown width (the crown separation ratio).

Special cases:

There are situations where measuring actual cover values for species or strata is not practical. In these situations, estimates of cover within cover classes can be used. Arbitrary crown cover classes (Table 8) have been selected to coincide as closely as possible with the projective foliage cover classes of Specht *et al.* (1974), and which are easily separated in the field. Table 8 indicates the classes used and how to judge the cover values.

Table 8. **Field criteria used to determine crown and foliage cover classes**

Code	**Cover class**	**Field criteria used for estimation of the cover class for trees or shrubs or plants with distinct crowns**	**Foliage cover percent for ground cover**
		Woody plants	**Grasses, forbs etc.**
D	Closed or dense	Crowns touching to overlapping	>70%
M	Mid-dense	Crowns touching or slightly separated	30-70%
S	Sparse	Crowns clearly separated	10-30%
V	Very sparse	Crowns well separated	5-10%
I	Isolated plants	Trees about or greater than 100 m apart, shrubs about 25 m apart	<5%
L	Isolated clumps	Clump of two to five woody plants 200 m or further apart. A sample site may be in a clump, in which case the clump may be in classes D, M, S or V.	_

References:

Carnahan, J. A. (1977). Natural Vegetation. Atlas of Australian Resources, Second Series. Canberra, Department of Natural Resources.

Lee, A., Lucas, R. M., Brack, C. (2004) Quantifying vertical forest stand structure using small footprint lidar to assess potential stand dynamics. *Proceedings, NATSCAN - Laser scanners for forest and landscape assessment instruments, processing methods and applications* 03-06 October, Freiburg, Germany. International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol 36, part 8/W2, pp 213-217

Mueller-Dombois, D. and H. Ellenberg (1974). Aims and Methods of Vegetation Ecology. New York, John Wiley & Sons.

Penridge and Walker *(1988)*. The crown-gap ratio (C) and crown cover: Derivation and simulation study. *Australian Journal of Ecology* 13: 1090-120.

Specht, R.L., Roe, E.M. & Boughton, V.H. (eds) 1974. Conservation of major plant communities in Australia and Papua New Guinea. *Australian Journal of Botany Supplement* No. 7.

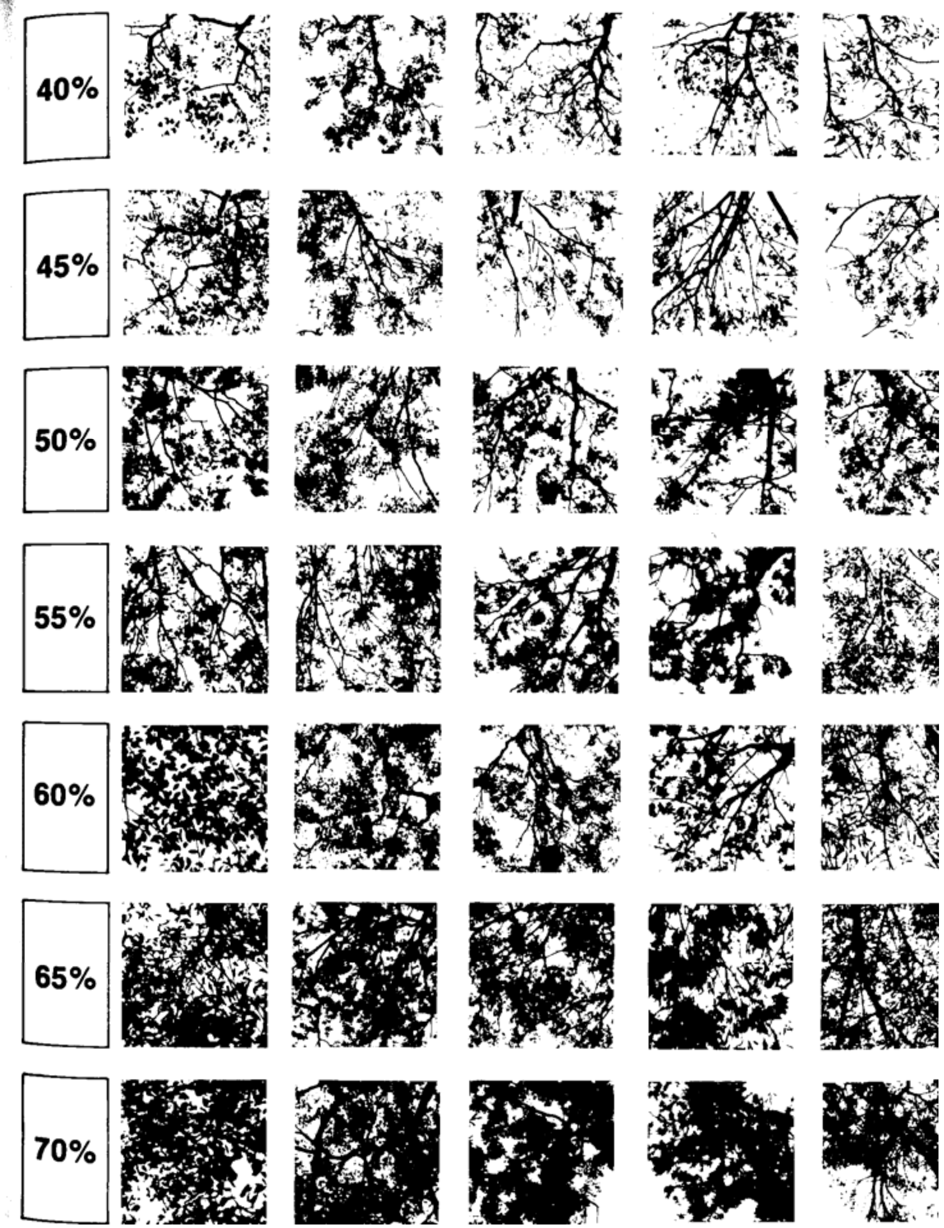
Walker, J., Crapper, P.F. and Penridge L.K. (1988). The crown-gap ratio (C) and crown cover: The field study. *Australian Journal of Ecology* 13: 101-108.

Table 9. Conversion of crown separation rations (crown gap:crown size) to percentage crown cover

	Overlap		Touching											Crowns separate											
Crown separation ratio	--.01	-.05	-.02	0	.05	.1	.15	.2	.25	.3	.4	.5	.6	.75	1.0	1.25	1.5	2.0	3.0	4.0	8.0	10	15	20	30
Percentage crown cover (%)	100	89	84	81	73	67	60	56	52	48	41	34	31	26	20	16	13	9	5	3	1	.6	.3	.2	.1

Figure 9. Crown types

Estimate the openness of individual tree or shrub crowns by matching the crown with a photograph. The rows show similar crown types for different leaf size (large to small, left to right). Acacia phyllodes are in the right hand column. Most Australian woody plants are in the range 40% - 70%.



Cover – Abundance

Definition/description:

Cover-abundance is a method for estimating the quantity of each species in a vegetation sample. It is called 'cover-abundance' because it combines, in one scale, both cover and abundance estimates. For cover values greater than 5%, the scale is a measure of 'cover' (see 'cover' attribute above). For cover values less than 5%, the scale is a measure of abundance (i.e. the number of individuals in a defined area).

The Braun-Blanquet cover-abundance scale presented here is the one, of many that have been proposed, that has survived to be most widely used. It is simple to use, but produces estimates of cover-abundance that are robust for most vegetation classification processes. The system is predicated on the view that it is most useful in vegetation classification to have many samples of each type, with good estimates of species quantities than to have only one or a few samples with high precision of measurement of these quantities. The basis for this view is that vegetation is often highly variable and that it is better to have many samples of this variation than to have only a few but precise and time consuming measures that don't represent the diversity of the field situation.

What to record:

The Braun-Blanquet cover abundance system is shown in Table 10. Record the code values for the class that represents each species at the sample site.

Table 10. The Braun-Blanquet cover-abundance scale for estimating species quantities.

Code	Description	Cover class
5	Any number of plants covering more than ¾ of the sample site	> 75%
4	Any number of plants covering between ½ and ¾ of the sample site	50% - 75%
3	Any number of plants covering ¼ to ½ of the sample site	25% - 50%
2	Any number of plants covering between 1/5 and ¼ of the sample site	5% - 25%
1	Numerous individuals, but cover < 1/5 of the sample site, or scattered with cover up to 1/5 of the sample site	<5%
+	('+' pronounced 'cross') few individuals with small cover	Insignificant cover
r	Single individual with small cover	Insignificant cover

(Modified from Mueller-Dombois & Ellenberg, p59-60, 1974)

How to collect:

Having thoroughly acquainted oneself with the sample site by walking through and around it several times, choose a location where the site can be best seen in its entirety or as close to it as possible. For each species, estimate and record the cover-abundance. Start by asking whether a species cover is > or < 50%? If >50%, is it > or < 75%? If it is <50%, is it > or < 25%? If it is < 25%, is it > or < 5%? If it is < 5%, is there more than 1 individual?

For the lower cover classes, it can be useful to mentally imagine moving all individuals into one area and comparing that with a reference for the sample site. For example, if the sample site is 400 m^2, 5% is the area is 20 m^2 (4m x 5m), and 1% is 4 m^2 (2m x 2m).

It is useful to have the cover-abundance scale attached to the cover of ones field notebook so that it can always be referred to when making the estimates. This helps reduce the errors inherent in the method.

Issues:

Although the method provides an absolute value for classes 2 – 5 (i.e. it is a percent of a defined sample area), the class boundaries are wide and cover is being estimated, not measured. Many studies have shown that there are often large variations between observers, as well as in one person's estimates at different times. Because of these inherent errors, it is important to regularly calibrate observers between themselves, if more than one person is making records for a survey, and for a single person to calibrate their own method to ensure consistency.

In broad-ranging surveys, it is usually better to have large numbers of samples with good cover-abundance estimates, rather than a few samples of high quantitative precision, but not covering the inherent variability of the vegetation. If the objectives of the survey are narrowly focussed and looking for fine levels of discrimination between samples or sampling times, then actual quantitative measurements may be more appropriate.

References:

Greig-Smith, P. (1983). *Quantitative Plant Ecology*. Studies in Ecology Vol. 9. Blackwell Scientific, Oxford

Mueller-Dombois, D. and Ellenberg, H. (1974). *Aims and methods of Vegetation Ecology*. Wiley International, New York, 547 pp.

Height

Definition/description:

Height measurements record the distance from ground level to the apex of a plant. In the field, actual height measurements should be made, not estimates of height classes. The exception to this is recording plants taller than 10 m can be within 5m class intervals as finer distinctions are probably not ecologically useful and visually-based methods become increasingly inaccurate as height increases.

What to record:

The height recorded here is the height from the ground to the highest part of the plant above ground. Where the height of flower stalks (e.g. grasses, grasstrees) or leaves (e.g. palms, cycads, grass trees, tree ferns) add significantly to plant height and contributes significantly to a 'stratum', then two measurements of height are recorded: total height from ground level to the top of the highest part of the plant, and also the height from ground level to the top of the leaves (e.g. *Xanthorrhoea johnsonii* 2.5m / 1.3 m; *Sorghum intrans* 1.9m / 1.3m). This provides an accurate record of the field situation and allows various uses in analysis.

How to collect:

Height can be measured using measuring tapes or poles for low vegetation. For tall vegetation, laser or sonic ranging instruments, visual siting instruments or LIDAR can be used (see Brack, 1998).

Issues:

Ensuring that the tops of tall trees are adequately seen is a major short coming of visual siting methods. Differences between visually based measurements of tall trees (>20 m) and LIDAR based measurements have shown that the visual methods produce errors caused by the difficulty in determining the highest part of a tree with a rounded and spreading canopy (Alex Lee, 2005 pers. comm.).

The UNESCO (1973) cautions that 'height limits are only a generalised guide, not an absolute limit' in vegetation studies. Within extensive vegetation units, height of the canopy often varies across environmental gradients, for example, from temperate towards tropical regions, from moist to dry areas and from low to high altitudes. It also varies with the age of the vegetation. Such units should not be subdivided only on the basis of small changes in height across arbitrary class boundaries, if no other suite of characters supports the distinction (see note under coding structural information). Consensus between workers in different areas will allow agreement on what height boundaries should be used where anomalies occur along artificial boundaries such as State or Territory borders.

References:

Brack, C. (1998). (Accessed 24/02/2005). http://sres.anu.edu.au/associated/mensuration/BrackandWood1998/TOOLS.HTM#height. Includes internal links to individual instruments, methods of use and comparisons of performance.

UNESCO (1973). International Classification and Mapping of Vegetation. Geneva, United Nations Educational, Scientific and Cultural Organisation. [Accessed 19 April 2005: http://unesdoc.unesco.org/images/0000/000050/005032mb.pdf]

Basal Area

Definition/description:

The area of ground surface covered by a plant, measured at or near ground level. In forest without buttresses or multiple stems, it may be measured at 'breast height' (DBH) (ca. 1.2-1.4 m above ground). For low plants such as tufted/tussocky grasses, it is the area of ground covered by the stems/shoots where they emerge from the ground. BA is not crown cover.

Basal area per species gives a measure of species dominance at a site; the species with the largest BA is usually taken to be the dominant.

The basal areas by species per site also have uses in other applications, for example determining relationships with soil erosion potential, NDVI (normalised difference vegetation index) when using satellite data, biomass estimates if equations exist relating BA to biomass, proportions of trees in different growth stages or having defined defects. BA also can provide an indicator of potential of a site to grow trees (e.g. a ranking of fertile to infertile sites).

What to record:

What to record depends on the method used. There are two major types of methods: (i) measurements of diameters (at breast height or at ground level), and (ii) basal area sweeps using a siting device.

i. Measure either the diameter or circumference of the plant at either ground level or DBH. If the diameter is measured, then the basal area is calculated according to:

$$BA = \left(\frac{D}{200}\right)^2 \pi$$

Where: BA = basal area in m^2, D = diameter in cm, π = 3.142.

If the circumference is measured, then basal area is calculated:

$$BA = \left(\frac{C^2}{40{,}000\pi}\right)$$

Where: BA = basal area in m^2, C = circumference in cm, π = 3.142

Basal area per species = sum of each species measures of BA for a defined sample.

To calculate basal area for a site (stand), add all the individual basal areas for the site or sample.

ii. Basal area sweep: record the number of trees that are ‘in’ (counts 1) or marginal (counts half). Record the sum of whole and half counts. Record the basal area factor for the instrument being used.

Stand basal area (m^2/ha) = BAF x count

Where: BAF = basal area factor, which is specific to the instrument being used, and ‘count’ is the sum of the number of trees that exceed the siting image (each counted as ‘1’) plus the number of those that exactly match the siting image (counted as half each).

How to collect:

If measuring BA for low plants by measuring diameters, then mark out a defined area such a $1m^2$ and measure all the individual by species in the plot. Measurements will be of the area of the bases of the plants as they come out of the ground, not the extent of their canopies.

The BA sweep involves a 360^O sweep, using a basal wedge or siting device. Care needs to be taken that the recorder keeps the device over a defined point rather than rotating their body over a point with the device tracing a circle around the recorder.

Several non-overlapping samples should be taken at the site to increase reliability. The final value for the site is the median value of the samples.

Basal area prisms can be purchased from commercial suppliers, or siting devices can be constructed from a variety of materials (Abed & Stephens, 2003, Mueller-Dombois & Ellenberg, 1974).

Issues:

The siting device should have a basal area factor that allows about 5-10 trees to be counted. More or less than this can result in errors in estimates. This means that the recorder should have access to more than one siting device when in the field and more than one sweep with different basal area factor siting devices may be necessary to find the best one for the site.

References:

Mueller-Dombois, D. and H. Ellenberg (1974). Aims and Methods of Vegetation Ecology. New York, John Wiley & Sons.

Abed, T. and Stephens, N.C. 2003. *Tree measurement manual for farm foresters*. Second edition, edited M. Parsons. National Forest Inventory, Bureau of Rural Sciences, Canberra. [http://www.affa.gov.au/corporate_docs/publications/pdf/rural_science/forest_vegetation/t_mmtwo.pdf (accessed 22 March 2005)].

Emergents

Definition/description:

An emergent is a plant that rises above the level of a more significant stratum, but because its total cover is small, is not considered to be a stratum, rather an *emergent* of the next lower stratum. Depending on the type of vegetation, the total cover of emergents will be either less than 5%, or less than 0.2% (see below for details).

What to record:

Record the total percent cover, median height and/or maximum height and the genus (and species if possible) of the emergent layer.

How to collect:

Measure height and cover as for other plant attributes described earlier.

Issues:

When the tallest stratum is not the most significant stratum, the guidelines differ for different kinds of vegetation as follows.

(a) Where the vegetation is dominated by forest, woodland or shrubland, and the tallest layer emerges above a dominant canopy (i.e. cover > 5%) and has generally less than 5 percent total cover, then the tallest trees or shrubs are called emergents. If emergents are present in the stand, they should be registered by genus or species, if possible, followed by the word 'emergents': for example 'with hoop pine emergents'; 'with *Araucaria* emergents'; 'with *Eucalyptus* emergents'. If no emergents are present, no qualifying character is nominated.

(b) Where the vegetation is dominated by perennial grasses, e.g. *Triodia*, and there is a taller layer of woody plants that emerges above it and has generally less than 0.2% cover (crown separation ratio of <20), then the tallest plants are called emergents and should be named as in the example above.

(c) Where the vegetation is seasonally or sporadically dominated by annual plants amongst a mix of perennial plants that form a taller layer, then, in most cases the dominant layer is the taller perennial layer. For example, open eucalypt woodland with seasonally dominant *Sorghum* in the understorey; open acacia woodland with periodically dominant annuals of Asteraceae and other families.

(d) In the case of ephemeral wetlands, where the dominant layer is only present periodically when sufficient water is present and there is no taller woody layer present, then the dominant layer is the ephemeral layer. It is recorded as ephemeral, for example: ephemeral mixed herbaceous herbland.

References:

Walker, J. and M. S. Hopkins (1990). Vegetation. Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys. R. H. Gunn, J. A. Beattie, R. E. Reid and v. d. Graaff, R.H.M. Melbourne, Inkata Press**:** 58 **-** 86.

CONDITION of the SITE AND VEGETATION

Definition/description:

Condition, in the context of this document, is the state of a patch of vegetation at the time of sampling *relative* to some specified standard or benchmark. A benchmark is a set of specified attributes with values determined from either a single reference site, or an average (or range) of values determined from a set of reference sites that represent the range of variability deemed acceptable for the vegetation type. The reference sites should be clearly and precisely located and documented for their benchmark values at known times.

A single site may be assessed from more than one perspective, depending on the focus of the 'condition assessment'. For example:

- a 'native vegetation integrity' perspective would be of interest to a biodiversity manager and should be based on a 'fully natural' benchmarks;
- a 'fodder production' perspective would be of interest to a grazing property manager and should be based on a 'best practice sustainable production' benchmarks; and,
- a 'carbon sequestration' perspective would be of interest to a climate-change mitigation manager and should be based on a 'optimum sustainable carbon capture / storage' benchmarks.

Each perspective has different benchmarks. At any one site, management objectives for condition assessment will determine which perspectives and benchmarks are relevant.

A single site may be assessed from more than one perspective, depending on the focus of the 'condition assessment'. Native vegetation, non-native or different growth stages of vegetation should each have their own set of benchmarks. For native vegetation, the benchmarks should be based on the best examples representing pre-European conditions (sometimes called 'fully natural'). For vegetation managed for economic production, reference sites should represent best-practice, fully ecologically sustainable conditions.

Condition assessment is still an area of active research and development. The concept of vegetation that is in 'good' condition or in 'poor' condition is generally well understood. However, taken across the whole of the Australian continent, no single set of attributes will measure condition for all land uses (*cf.* undisturbed native vegetation *vs* non-native cropland), nor will a single set of attributes apply to all vegetation types (e.g. ash and karri forests *vs* inland woodlands *vs* shrublands *vs* grasslands *vs* wetlands *vs* soil crusts).

For the vegetation you are sampling, determine whether a benchmark exists, or whether published descriptions of the attributes of such sites exist, or whether there is expert knowledge available. These may be available from Commonwealth, State and Territory conservation, Environment Protection Agencies (EPAs), agriculture or forestry departments and agencies. If such benchmarks exist, standard methods for recording a field site condition for those vegetation types may also be available from the same sources. Record what the benchmark for your site is.

Most work to date has been on developing condition assessment methods for native biodiversity (Parkes *et al*. 2003), particularly in forested (*e.g.* Eyre *et al.* 2002), wetland (e.g. Parsons *et al*. 2002a, b) and rangeland (Smyth *et al.* 2003) areas, and for production in rangelands (Pickup *et al*. 2001). An interim standard for the assessment of native vegetation condition (Commonwealth of Australia 2004b) has been developed as part of an active program by ESCAVI (as of the time of writing - May 2005) to develop a national approach to this issue.

Wetland condition may be defined by reference to the Ramsar (1999) definition of ecological character for wetlands (see Holmes and Papas, 2004a):

> *Ecological character is the sum of the biological, physical, and chemical components of the wetland ecosystem, and their interactions, which maintain the wetland and its products, functions, and attributes. Change in ecological character is the impairment or imbalance in any biological, physical or chemical components of the wetland ecosystem, or in their interactions, which maintain the wetland and its products, functions and attributes.*

This definition of ecological character of wetlands provides a conceptual underpinning for indexes of wetland condition (Holmes & Papas 2004b).

What to record:

The attributes used ought to provide some assessment of aspects of long-term sustainability of the site under the current or proposed management regime. They should cover the long term viability of the current vegetation (structure and floristics) or the preferred vegetation if the objective is to change to a new set of conditions. Environmental attributes relating to soil condition, water resource condition, as well as social conditions, including economic condition, should form part of a holistic assessment of vegetation condition. This broad assessment, while essential, is beyond the scope of this chapter.

For vegetation sites that represent native vegetation (modified or not), commercial production, urban amenity, or wastelands, Appendix 5.3 may be useful to assess condition (Thackway & Lesslie, 2005). At the national scale, recommendations for condition assessment have been compiled by Commonwealth of Australia (2004b).

For woody vegetation, particularly for biodiversity condition in native forest in south-eastern Australia (Parkes *et al.* 2003), the attributes in Appendix 5.1 or Appendix 5.3 may be suitable. The biodiversity condition of rangelands has received considerable research attention, but final recommendations for condition assessment are not yet available (Smyth *et al.* 2003).

Rangeland condition with respect to pastoral production has been assessed for many decades with on-ground surveys (Holm *et al*. 1984, Pickup *et al*. 2001). However, methods using combinations of satellite imagery (Landsat TM and multi-spectral scanner resolution) and ground survey to monitor range condition are the current focus of research. Rangeland condition with respect to biodiversity conservation is actively being researched (Smyth *et al.*2003) and national standards should be available in due course.

For vegetation that either does not match the above, or where attributes of the physical site are required, attributes from Appendix 5.2 may be suitable.

There are methods available for assessing wetland condition, (Anderson 1999, Ladson *et al*. 1999, MDB, 2005, NRM 2004, Parsons *et al*. 2002 a & b). The core of these methods is outlined in Appendix 5.4 (adapted from Anderson 1999, NRM 2004, and Commonwealth of Australia 2004a).

Parkes *et al.* (2003) extend their indicator method by proposing a method of converting individual, site-based condition values into synthetic whole-site condition indexes. These are not included here as they relate to office based processing of site-based data.

How to collect:

If a benchmark is available, compare the sample site to the standard for each of the attributes identified for that type of condition (e.g. biodiversity, commercial production, water resource) and rank it accordingly. Parkes *et al*. 2003 & 2004 provide descriptions of some ways to deal with variability of sites and reference sites, as well as suggested methods for evaluating and scoring sites. McCarthy *et al*. (2003) provide suggestions for improvements.

If no benchmark is available, and the sample is native vegetation, provide a qualitative assessment using the attributes provided in Appendix 5.2 and Appendix 5.3.

Issues:

Vegetation condition is a complex phenomenon. It only has meaning relative to some agreed or specified standard or benchmark, which itself is meaningful only in a context of specified management intent.

For biodiversity condition, these standards are generally taken to be the typical characteristics of sites that represent undisturbed, little disturbed or highest quality representative examples of a native vegetation type. The attributes assessed refer to status of vegetation structure and floristics, and presence of adequate habitat for a diversity of species (Parkes *et al.* 2003).

How vegetation dynamics are factored into the assessment (e.g. time scales of change to floristics, structure, or physical environment) need special attention and standard methods have not yet been agreed nationally. Examples of natural variability include: mature tree size varying within a vegetation type due to variability of site productivity; variation related to growth phases and species behaviours following major disturbances; and, not all benchmarked attributes will necessarily be present even in a mature stand of a vegetation type (e.g. scattered trees) (McCarthy *et al.* 2003). Some current approaches are:

- use a different benchmark for each readily definable variant, or
- use a 'mature' reference point but annotate early and senescent stages of the growth cycle to explain condition scores that are less than the that of the mature site, or
- use benchmark values that are derived averages for the values taken from a range of reference sites that reflect the variability in the values.

Some attributes, which indicate good condition and which in general are considered better if the scores are high, may have optimal values at less then maximal expression of the attribute. For example, an over-abundance of tree stems/cover (sometimes called 'locked stands'), in a stand recovering from clearing, may be detrimental to the rate at which a site returns to its ideal reference condition, but the overall role of such stands in the functioning of ecological systems would need to be explored.

In addition to vegetation, other site condition factors such as soil stability and water resources need to be assessed to be at long term, sustainable levels. Short-term excessively high values for any of the factors (for example, very high bumper cropping from unsustainable procedures, or very high native herbivores) at the expense of the long-term stability of the whole may represent unsustainable exploitation and actually a decline in condition.

Integrated assessments of biodiversity and production systems over regional scale landscapes is a goal being addressed, but which is still some way from being able to be widely implemented, but basic research is underway (e.g. Lindenmeyer *et* al. 1999).

Native vegetation, mixtures of native and non-native vegetation, and substantially non-native vegetation need to be considered separately. Variation in each of these broad classes requires different benchmarks.

Individual sites supporting native vegetation, mixtures of native and non-native vegetation, and substantially non-native vegetation may be considered from one or more perspectives. Each perspective requires a different benchmark. Maximum scores relative to one benchmark will typically not align with maximum scores relative to a different benchmark (Table 11).

Table 11. An example of benchmark scoring three vegetation types based on two different benchmarks. The score in each cell has a potential maximum of 100.

Type/use	**Score relative to** Pre European Benchmark	**Score relative to** Sustainable Production Benchmark Grazing Cattle
Remnant Native forest	90	20
Grazed woodland	55	85
Wheat field	5	25

For all vegetation, the primary issue is that the development and standardisation of methods are still actively evolving. People who need methods for sampling sites for vegetation condition should search the web, relevant research sites and agencies to determine the current status of methods.

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NEW TECHNOLOGY

New ways of collecting site and vegetation attributes continue to develop. Those that provide rapid, cost efficient ways of collecting core data will progressively be incorporated into the field methods of vegetation scientists. Each innovation not only provides a new, efficient way to gather data in a different way, it also provides new ways of seeing vegetation. New methods can also make accessible, information about vegetation that was previously inaccessible, for example the three-dimensional distribution of biomass. While it is realised that by the time these guidelines are in use, even newer methods may have become available, it is useful to update the previous handbook.

Remotely sensed vegetation attributes, whether from sensors on aircraft, satellites or on the ground, continue to provide the major innovations in vegetation site-records. Aerial photographs, satellite imagery in visible and near-infra-red wave bands continue to provide the most commonly used remotely sensed data. To these is now added LIDAR (Light Detection And Ranging) data. Synthetic Aperture Radar (SAR) data have also been demonstrated as useful for crop production forecasting and forest cover mapping (e.g. http://www.asf.alaska.edu/user_serv/sar_faq.html) and should also be watched, along with other forms of remote sensing, for utility as they arrive and mature in vegetation studies.

Geographic location records

GPS

Definition/description:

The global positioning system (GPS) is a method for locating points, in 3 dimensions (latitude, longitude,(or UTM), and altitude) on the earth's surface using a system of earth-orbiting satellites.

What to record:

Datum

The datum used in calculating latitude and longitude must be recorded. The Geocentric Datum of Australia 1994 (GDA94) is the preferred standard method to use when recording latitude and longitude from GPS. Older instruments may use the World Geodetic System 1984 (WGS84). Which ever system is used must be recorded on the site-record. Each system uses a slightly different set of corrections that allow for the variation of the earth's shape from a simple geometric shape. If the system is not specified, errors can occur when the data are combined with other data sets, for example in GIS mapping projects.

The following are some useful web links if your work requires better than a few metres accuracy:

- Web:
  - http://www.anzlic.org.au/icsm/gda/index.htm
  - http://www.icsm.gov.au/
  - http://www.icsm.gov.au/icsm/gda/index.html
- GDA Technical Manual:
  - http://www.icsm.gov.au/icsm/gda/gdatm/index.html
  - http://www.icsm.gov.au/icsm/gda/faq.html

UTM Zone, Eastings and Northings

The Universal Transmercator Projection (UTM) of datum GDA94 gives coordinates (eastings and northings) in metres from a standard reference point. The UTM projection of the earth is divided into *zones*, 6^0 longitude wide, which for the Australian continent and Australian Territories are zones 38 through 58. Record both the zone and the eastings and northings from the GPS unit.

How to collect:

GPS instruments vary greatly in quality, size, precision and cost. They vary from small, low cost recreation-quality instruments to large, high cost, survey-quality ones. The precision of positions varies accordingly from 10-100m to 1-10m to less than 1cm.

To obtain an accurate position, signals from 4 satellites are needed. This may require taking instrument readings several times if the times of satellite positions are not known. Planning-software is available at no cost from major GPS manufacturers, which will allow surveys to take best advantage of satellite positions to optimise the time of taking readings (Johnson & Barton, 2004).

If high degrees of positional precision are required, then use *differential GPS*. Differential GPS receivers use not only the satellite signals, but also a signal from a known fixed broadcasting location. Together, these allow for increased precision of less than 10m error. Very high degrees of positional accuracy can be obtained using *dual frequency* technology available in high quality survey instruments.

Issues:

Apart from ensuring enough satellites are within range, local factors can influence the utility of GPS readings. Rugged terrain or dense forest canopies can reduce accuracy through masking satellite signals. In such circumstances, it may be possible to take readings from nearby locations free of obstruction, or to mount a temporary aerial that can receive the required signals.

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Johnson, C E. and Barton C.C. (2004). Where in the world are my field plots? Using GPS effectively in environmental field studies. *Frontiers in Ecology and the Environment* 2(9): 475-482.

LIDAR & Other Electromagnetic Spectrum Remote Sensing

Definition/description:

LIDAR (Light Detection and Ranging) is a measurement system that uses pulses of laser light to determine distances, amongst other attributes. It can produce data on canopy height, canopy diameter, canopy depth, foliage cover (leaves plus branches) and stratification of vegetation over large areas. Currently data are obtained from sensors flown in aircraft, much as aerial photographic data are obtained.

What to record:

LIDAR instruments emit pulses of laser light and record the return-times and strengths of the reflected signals. These are processed by software packages to provide data on attributes such as altitude of the ground surface, plant canopy height, sub-strata height and depth, crown cover, leaf and stem biomass, and clumping and gaps in crowns. In some systems these can be linked at time of recording to GIS and digital imagery to enhance subsequent analysis.

How to collect:

LIDAR records can be obtained from airborne or satellite platforms carrying appropriate instruments, or from portable ground-based systems. Various commercially available instruments and software packages are available.

Issues:

LIDAR data can be used as a mapping tool, or as a method for gathering data to inform mapped units. Projects to mount LIDAR in satellites to map vegetation commenced with NASA in the 1990s but were halted.

Various instruments and software packages are available. There is a trade-off between relatively expensive aircraft costs covering large areas *versus* quality point data that can be obtained with ground sampling but also with high cost technical staff and travel. The cost of crews to gather the data can be offset by the extensive data from LIDAR survey. It is likely that surveys with different purposes will favour one kind of data over the other.

It is important to have adequate ground controls for the biological components when using any remotely sensed data, including LIDAR. Sample measurements of cover, height, canopy depth and diameter and canopy gaps are needed to calibrate the data coming from the LIDAR analyses. Once calibrated, LIDAR data provide extensive area coverage of measured attributes that cannot be obtained from ground measurement.

Potential uses include large area mapping of basic vegetation structural attributes of cover and height. Three dimensional measurement and reporting of the distribution of biomass (horizontal and vertical) is potentially useful when using vegetation measurements as surrogates for biomass sampling or habitats created by vegetation (Lee *et al*. 2004, Lovell *et al*. 2003, Stoker 2004).

Special cases:

At the time of writing, LIDAR technologies are maturing for some kinds of uses but are still rapidly developing in others. There are commercial packages that can provide crown heights and cover. There are also active programs to develop methods of extracting more information from the LIDAR signals, thus more techniques should become available.

Hyperspectral imagery is being used in a wide range of research projects, either alone or in combination with other remotely sensed data and on ground reference sites. It has been used to map vegetation and environmental attributes in both terrestrial and shallow water benthic situations.

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Soils

Definition/description:

Basic soils information (Great Soil Group, textures, drainage, colour etc) usually form part of a vegetation survey. The methods to be used for these data are not covered here, but can be found in other chapters of this volume or in Gunn *et al*. (1990). There are major advances in techniques for sampling soil attributes, which were not available even at the end of the 20th century, but are being rapidly developed with new technology. These methods open the way to extend techniques for sampling soil micro organisms, carbon contents, root distributions with in many cases little disturbance to the soil. Correlating such greatly improved soils information with vegetation types may go a long way to improve understanding of variations in vegetation attributes such as cover, height, species composition and soil dynamics.

Information on soils in Australia is accessible on the internet via the Australian Soil Resources Information System: http://audit.ea.gov.au/anra/land/land_frame.cfm?region_type=AUS&region_code=AUS&info=soil_asris. A compendium of world soils (Rossiter 2005) can be found at: http://www.itc.nl/~rossiter/research/rsrch_ss_digital.html.

Issues:

Soils are an area where there has been frustratingly little change in the limited methods available until now. Those who sample vegetation should keep abreast of changes in soils methods as they will significantly change the way soils and vegetation are understood in the not too distant future.

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Acknowledgements

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APPENDICES

APPENDIX 1

Rainforest

Rainforests extend as discontinuous patches across the whole of tropical northern Australia and down the eastern seaboard through to Tasmania. They are usually easy to distinguish from adjacent forests, which are often dominated by *Eucalyptus* and related genera. Rainforests tend to have closed canopies that are continuous or irregular when viewed in profile. The colour of the canopy is usually dark green and easily distinguished from the generally greyish and reddish-green of surrounding forests. The 'dry scrubs' of south eastern Queensland are closely related to rainforests, and are treated as such.

Rainforests can be classified using the same attributes and methods as other vegetation types, that is the methods outlined earlier in these guidelines (see examples in Table 14; also Table 5). However, the difficulties in identifying species, together with the high degree of structural complexity of the wet tropical and subtropical rainforests of eastern Australia will in some circumstances provide a barrier to the use of standard vegetation methods. The simpler structure of rainforests in drier parts of the tropics (Northern Territory and Western Australia), and in southern New South Wales and Victoria, are usually sampled using the standard methods. The cool temperate rainforests of Tasmania can be complex in structure. They can be sampled using either the standard vegetation methods, or for some of these forests, extra structural attributes are recorded to fully reflect the accepted patterns in cool temperate rainforest in that region.

The special rainforest attributes that are used for complex, wet-tropics/sub-tropics rainforests are presented in Table 13. Those relevant to Tasmanian rainforests are given in Table 19.

Tropical and Sub-tropical Rainforests

Table 12. Rainforest classification Attributes and options used in the classification of rainforest vegetation. The code for the various attributes is shown.

	Core attributes				Qualifying attributes	
Complexity	**Leaf size of tallest stratum trees(Table 13)**	**Floristic composition of tallest stratum trees**	**Indicator growth form**	**Structural formation**	**Emergents**	**Sclerophyll species in tallest stratum trees**
S Simple	**1** Macrophyll	**M** Mixed	**1** Moss	As per Table 5 and Table 2	With (species description) emergent	With (or, and)… sclerophylls (or species description)
X Simple-complex	**2** Macrophyll-mesophyll	**S** Described by one or two species	**2** Fern			
C **C**omplex			**3** Fan palm			
C **C**omplex	**3** Mesophyll		**4** Feather palm		**E** or **A**	
C **C**omplex	**4** Mesophyll	**X** Mixed + one	**5** Vine		**E**	

	Core attributes				Qualifying attributes	
Complexity	**Leaf size of tallest stratum trees(Table 13)**	**Floristic composition of tallest stratum trees**	**Indicator growth form**	**Structural formation**	**Emergents**	**Sclerophyll species in tallest stratum trees**
	notophyll	species description			Sclerophyllous emergents	
C **C**omplex	**5** Notophyll		**6** No dominant indicator growth form		**A** Non sclerophyllous emergents	
C **C**omplex	**6** Notophyll-microphyll					
C **C**omplex	**7** Microphyll					
C **C**omplex	**8** Microphyll nanophyll					
Complex	**9** Nanophyll					

Examples of classifications based on the growth form, height and cover classes of Table 5 and Table 2 and the above attributes including codes. The non-rainforest code precedes the rainforest code.

Table 13. -Coding_vegetation types.

e.g.	Word description	Code	Rainforest code (Table 11)	notes
(a)	Complex mesophyll mixed tall closed forest.	7w1D	C3M6	
(b)	Simple notophyll very tall closed coachwood forest with *Tristania conferta* emergents.	8Ew1D	S5S6	(note E for emergents coded with structure)
(c)	Simple notophyll tall closed mixed fan palm forest and *Acacia*.	7w1D	S5M3S	
(d)	Simple notophyll tall closed *Schizomeria* forest with *Syncarpia* emergents and eucalypts.	8Ew1D	S5S6S	(note last S for sclerophylls in upper stratum)
(e)	Complex mesophyll mixed extremely tall closed black bean forest.	9w1D	C3M6	
(f)	Simple macrophyll-mesophyll low closed *Macaranga-Trichospermum* forest with *Acacia* emergents (young secondary forest)	9w1D	C3M6	

Mixtures: a giant trees open woodland of *Eucalyptus regnans* above a simple microphyll very tall *Atherosperma moschatum* forest. 10w1 EUREG + 8w1 ATMOS (S5S7).

Complexity

Definition/description:

This attribute defines the overall degree of complexity apparent in the structure of the tropical and sub-tropical rainforests of eastern Australia.

What to record:

Three options are available: simple, simple-complex and complex.

S	*Simple*	Forests showing most or all of the following properties: • tendency for one or a few species to dominate the canopy; for example species such as coachwood *(Ceratopetalum apetalum)* or Antarctic beech *(Nothofagus moorei);* • reduced number of structural features; for example plant buttresses absent, or most stems unbuttressed or with star buttresses; • tendency for one or two growth forms to become more conspicuous than others; for example trunks are not usually obscured by climbing plants and epiphytes but when this occurs one growth form usually dominates, or understorey layers may have a very conspicuous growth form such as a tree fern layer, ground fern layer, shrub or palm layer; • stems of the canopy trees are usually uniform in size; and • discrete strata are usually distinguishable below the tallest stratum; for example a tree fern layer, or an understorey tree layer or shrub layer.
X	*Simple-Complex*	Forests showing properties of both simple and complex forests. Where doubt exists or the vegetation does not possess at least four out of the five properties listed for each of the simple and complex categories this intermediate category should be used.
C	*Complex*	Forests characteristically showing all or most of the following properties: • tallest stratum has a large number of species. • large range of structural features is usually apparent; for example plant buttresses, spur buttresses, unbuttressed stems; compound leaves, simple leaves, lobed and deeply divided leaves, strap-like leaves. • large range of growth forms, none of which tend to dominate to the exclusion of the others, is present; for example, trunk bases are usually obscured by climbing pandans, palms, ferns, and aroids robust and slender lianes are present; the understorey is complex and consists variously of shrubs, seedlings of larger trees, palms, gingers, pandans and ferns. • vegetation between the tallest stratum and the ground is not usually arranged into distinguishable, discrete strata. • stems of tallest stratum trees are usually uneven in size.

How to collect:

Issues:

Special cases:

The structural complexity of the 'dry' rainforests of the Northern Territory, Western Australia, and parts of Queensland, do not require this level of detail to be classified adequately. The methods given in the main part of this document should be used. Similarly, the simple temperate rainforests of the south-eastern mainland of Australia should be recorded as for all other vegetation types.

References:

Webb L.J. 1959. A physiognomic classification of Australian rain forests. Journal of Ecology 47: 551-70.

Webb L.J, Tracey, J.G. and Williams, W.T, 1976. The value of structural features in tropical forest typology. Aust. J. Ecol. 1:3-28.

Leaf size

Definition/description:

In the classification of the wet tropical and sub-tropical rainforests of eastern Australia, leaf size refers to the one-sided leaf-area classes in Table 14. This attribute reflects the sizes of the leaves of the tallest stratum trees. The leaf size categories are those of Walker and Hopkins (1990) based on Raunkiaer (1934) and Webb (1959).

Detailed calculations of precise leaf areas are not required for these purposes.

What to record:

Record the length and width of a representative set of canopy leaves (i.e. 'sun leaves', those that are exposed to the full sun during their early development, as occurs in leaves at the top of the tree canopy) (see below '*How to collect*'. For the purposes of determining leaf size categories for classifying rainforests, precision greater than the classes in Table 14 and Figure 10 is not required.

Table 14. Leaf size categories for rainforest trees after Raunkiaer (1934) and Webb (1959). (see Figure 13)

Leaf size category	*Leaf area Mm^2*	*Approximate length of lanceolate leaf (mm)*	*Approximate length of cordate or peltate leaf (mm)*
Macrophyll	>18225	>250	>160
Mesophyll	4500-18225	125-250	80-160
Notophyll	2025-4500		
Microphyll	225-2025		
Nanophyll	25-225		

Table 15. Descriptive terms for various compositions of leaf size in tallest stratum of rainforest

	Term describing leaf size of forest stand	**Number of individual trees (maximum 10) with specified leaf sizes**	**Percentage of individuals in tallest stratum with specified leaf size**
1	Macrophyll	5 macro	>50% macro
2	Macrophyll-mesophyll	3 - 5 macro and 1 - 4 meso	30 - 50% macro and 10 - 40% meso
3	Mesophyll	>5 meso	>50% meso
4	Mesophyll - notophyll	3-5 meso and 1-4 noto	30-50% meso and 10-40% noto
5	Notophyll	>5 noto	>50% noto
6	Notophyll-Microphyll	3-5 noto and 1-4 micro	30-50% noto and 10-40% micro
7	Microphyll	>5 micro	>50% micro
8	Microphyll-nanophyll	3-5 micro and 1-4 nano	30-50% micro and 10-40% nano
9	Nanophyll	>5 nano	>50% nano

How to collect:

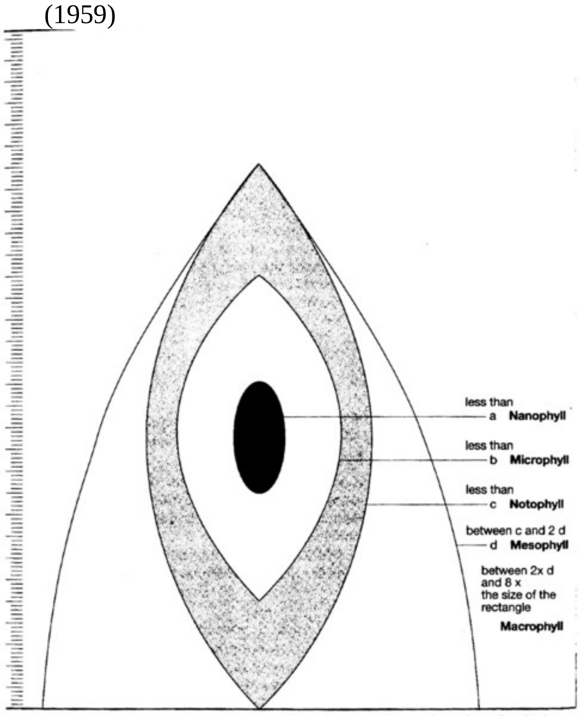
The forest is described in one of nine possible ways (Table 15) depending on the proportion of individual trees in the tallest stratum with leaves in each of the leaf size categories. The procedure for doing this is as follows:

- Ten adjacent canopy trees in the sample plot, near the soil profile should be examined and their leaves size - classed. The following rules should be adhered to:
    - In cases where the average leaf size of a tree appears to be intermediate between size classes (for example, the leaf length of a lanceolate leaf is approximately 75mm), the larger size class (for example notophyll) should be nominated.
    - Only leaves that are exposed to the sun should be considered (that is, sun leaves). Because sun leaves are usually at the top of a tree, a shotgun or catapult may be necessary. An alternative is to locate recently fallen leaves on the forest floor.
    - Leaves of palms, aroids, and vines should not be considered.
    - The leaflet of a compound leaf should be considered as a 'leaf' for the purpose of sizing.

The appropriate term describing the leaf size composition of the forest stand can be assessed from Table 15.
Two possible, but unlikely, combinations of leaf sizes cannot be placed within this scheme. If all leaf sizes are represented equally (20% each), the forest should be described as notophyll. If any three size classes should be represented equally (for example, 30% macrophyll, 30% mesophyll and 30% notophyll), the intermediate forest leaf size term mesophyll should be selected.

Figure 10. Leaf sizes.

Leaf size categories for rainforest trees after Raunkiaer (1934) and Webb (1959)



Leaf size category	*Leaf area (mm^2)*	*Approximate length of lanceolate leaf (mm)*	*Approximate length of cordate or peltate leaf (mm)*
Macrophyll	>18225	>250	>160
Mesophyll	4500–18225	125–250	80–160

Issues:

References:

Raunkiaer, C. (1934). The Life Forms of Plants and Statistical Plant Geography. Oxford, Oxford University Press.

Webb L.J. 1959. A physiognomic classification of Australian rain forests. Journal o0f Ecology 47: 551-70.

Numerical values and a field sheet of actual leaf sizes are given in Table 14.

Floristic Composition of the Dominant Stratum

Definition/description:

The type of rainforest is named by using the most abundant species of the dominant stratum.

What to record:

Use the system given in the following table.

Table 16. Floristic composition of the dominant stratum

M	Mixed	No one or two species combined contribute 50% or more of the crown cover percentage in the tallest stratum of the stand examined.
S	One or two species description	The one or two species described constitute 50% or more of the crown cover of the tallest stratum in the stand examined. Common or generic or specific names can be used (for example Coachwood – crabapple; *Ceratopelalum* **-** *Schizomeria*; *Ceratopetalum apetalum* – *Schizomeria ovata*). For coding purposes abbreviations of species names are used (for example CEAPE.SCOVA) except in the case of fan or feather palms. These two terms should not be used as common names since they are used to denote structural features elsewhere in the nomenclature (see Indicator Growth Forms below). If sclerophyll species constitute 50% or more of the crown cover of the tallest stratum, they should be included.
X	*Mixed plus one species*	Although no species or two species combined make up 50% of the crown cover of the dominant stratum, one species (the *one* species nominated) is conspicuously abundant. Once again, common or generic or specific names can be used except in the case of feather or fan palms (for example Mixed Booyong; Mixed *Argyrodendron;* Mixed *Argyrodendron trifoliolatum* or ARTRI). This floristic term can be used to nominate species of particular indicator value to the user.

How to collect:

Naming is done after the floristics and cover each species of the tall has been recorded.

Many rainforest species can and do form small aggregations of five or six trees. Care should be taken to ensure that tallest stratum domination is evident over a much wider area than a few trees if the species qualifications are used.

Issues:

Species identification and estimates of crown cover may be difficult in tall, dense rainforest.

References:

Walker, J. and M. S. Hopkins (1990). Vegetation. Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys. R. H. Gunn, J. A. Beattie, R. E. Reid and v. d. Graaff, R.H.M. Melbourne, Inkata Press**:** 58 - 86.

Indicator growth forms

Definition/description:

Many of the simple rainforests and some of the complex and simple – complex rainforests develop strata that are visually dominated by particular growth forms (Table 17). Four of these growth forms have particular environmental significance (Webb 1968) and terms for them are included here. The fifth can be an indicator of prior catastrophic disturbance. Illustrations of these growth forms are given in Webb *et al.* (1976).

What to record:

Record either the growth form name or its code on the field sheets.

Table 17. Rainforest_indicator growth forms.

1	*Moss*	Describes forests in which mosses and lichens almost completely replace vascular epiphytes and vines on the trunks and in the crowns.
2	*Fern*	If tree ferns form a dense (75% crown cover) and discrete stratum in the understorey.
3	*Fan palm*	(A palm with branches spreading out in a fan shape, for example *Licuala* or *Livistona).* The term describes forests in which fan palms form a closed stratum (75% crown cover) below the tallest stratum within the forest; if they form a closed stratum within the upper stratum.
4	*Feather palm*	(Palms with relatively narrow long leaves, which from a distance are feather **-** like, for example coconut palm). The attribute is used if feather palms form a closed stratum (75% crown cover) in the understorey of the forest stand.
5	Vine	Describes forests in which vines, twining or scrambling plants, drape the tallest stratum and form 'climber towers' on emergent trees. At least 60% of the exposed canopy surface should be smothered in vines if this term is used.
6	None	If none of the five growth forms above reaches the required level of dominance nominated, the description should record no dominant indicator growth form

How to collect:

These terms are inserted before or within the Broad Generic / Generic Group formation category (Table 5): for example tall *fern* forest; very tall closed *fan palm* forest; low closed *vine* shrubland; tall closed *feather palm* forest.

References:

Walker, J. and M. S. Hopkins (1990). Vegetation. Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys. R. H. Gunn, J. A. Beattie, R. E. Reid and v. d. Graaff, R.H.M. Melbourne, Inkata Press**:** 58 - 86.

Height and crown cover classes

Definitions of height and cover classes have been given previously (see Table 2 and Table 8).

Emergents

Definition/description:

Trees that are clearly above the dominant stratum and whose crown cover is less than 5% are emergents (see earlier section on 'emergents'). Trees that have a greater crown cover and project above a rainforest are coded and named as in the non-rainforest section (see Table 4 or Table 5).

What to record:

If emergents are present in the stand, they should be registered by genus or species, if possible, followed by the word 'emergents': for example 'with hoop pine emergents'; 'with *Araucaria* emergents'; 'with *Eucalyptus* emergents'.
If no emergents are present, no qualifying character is nominated.

- E Common sclerophyllous emergents over rainforest include the following genera: *Eucalyptus, Acacia, Syncarpia,* Casuarinas, *Tristania* and *Melaleuca.*
- A Common non-sclerophyllous rainforest emergents include: *Agathis, Podocarpus, Araucaria, Flindersia,* and *Erythrina*

How to collect:

Emergents are usually identified visually by experienced workers, but are confirmed by actual records of cover.

Issues:

Special cases:

In some instances, the crown cover of 'emergents' may exceed the 5% level, but will still be classified as emergents. For example, this occurs in some forest stands where *Araucaria* trees emerge above a closed rainforest canopy and in some places, the total cover of the *Araucaria* exceeds 5%, but these patches don't warrant being classified as separate vegetation types.

References:

Walker, J. and M. S. Hopkins (1990). Vegetation. Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys. R. H. Gunn, J. A. Beattie, R. E. Reid and v. d. Graaff, R.H.M. Melbourne, Inkata Press**:** 58 - 86.

Sclerophyll species in dominant stratum

Definition/description:

Sclerophyll species are defined as hard-leaved evergreen woody species that are associated with 'non-rainforest' situations. Common sclerophyll genera are *Eucalyptus, Corymbia, Acacia, Syncarpia, Casuarina, Allocasuarina, Tristania, Tristaniopsis and Melaleuca.* Hard-leaved plants can occur in rainforest, and commonly occurring genera are *Agathis, Podocarpus* and *Araucaria*; by definition these are non-sclerophylls.

What to record:

Record the presence of any of the genera listed in the definition of 'sclerophyll'.

S If sclerophyll species (defined above) are present in the dominant stratum, these should be registered by the addition of the qualifying term 'and sclerophylls'. If the sclerophylls can be identified, 'sclerophyll' should be replaced by the specific or generic, or common name (for example 'and wattles'). In cases where sclerophyll species represent 50% of the crown cover of the canopy, this fact will have been recorded previously and need not be repeated.

How to collect:

Issues:

The term 'sclerophyll' was originated by Schimper (1903) to apply to 'hard-leaved' evergreen tree and shrub communities adapted to Mediterranean-type climates of the world. In Australia the term has a different connotation, being associated with a mixture of community type, floristics and low soil nutrient status, especially phosphorous. Although some rainforest canopy species may also have 'hard leaves', these are not included in the definition of 'sclerophyll' as used here.

References:

Schimper, A. F. W. 1903. *Plant-geography upon a physiological basis.* Clarendon Press, Oxford,

Coding of rainforests

Coding examples are given in Table 12. The structural and floristic codes are similar to those used for non-rainforest vegetation; in many cases a continuum in height classes will exist and care should be taken to use the code C. The core attributes are added to the structural attributes and coded as shown in Table 12. Rainforests can also be coded using the system provided for all other vegetation (Table 5)

Tasmanian Rainforests

Rainforests in Tasmania can be sampled in the field using the standard methods in the first part of these guidelines. However, a system of classification is now widely in use in Tasmania that classifies rainforest as follows based on the work of Jarman, Kantvilas and Brown (1991) and Reid (1999). It uses a combination of floristics and structure that can be coded into the NVIS vegetation hierarchy at level IV.

The rainforests of Tasmania are divided into two alliances: myrtle-beech and montane rainforest. Myrtle-beech is the most widespread and although recognised as comprising a continuum it is divided into three sub-alliances termed callidendrous, thamnic and implicate. The characteristics of these four units are presented in Table 18.

Table 18 Tasmanian Rainforests. The distinguishing characteristics of the two alliances and three sub-alliances of Tasmanian rainforests.

Alliance	Code	Sub-alliance	Characteristics
Myrtle-beech	C	Callidrendrous	Medium to tall forest dominated by *Nothofagus cunninghamii and/or Atherosperma moschatum.* Trees well formed and widely spaced, and the understorey is open, shady and park-like. Diversity of woody species is low, and these plants are sparse and inconspicuous in the understorey of most communities.
Myrtle-beech	T	Thamnic	Medium height forest dominated by two – five species, mostly of: *Nothofagus cunninghamii, N. gunnii* (rarely), *Eucryphia lucida, E. milliganii, Atherosperma moschatum, Phyllocladus aspelniifolius, Lagerostrobus franklinii* and *Athrotaxis selaginoides*. Trees are well-formed and a distinct shrub layer is present.
Myrtle-beech	I	Implicate	Low-stature forest, with broken uneven canopies. Dominance is usually shared by several species including *Nothofagus cunninghamii, N. gunnii* (rarely), *Eucryphia lucida, E. milliganii, Phyllocladus aspelniifolius, Athrotaxis selaginoides, Lagerostrobus franklinii, Diselma archeri, Leptospermum nitidum, L. glaucescens, L. scoparium, L. lanigerum, Melaleuca squarrosa* and *Acacia mucronata*. The understorey is tangled and mostly forms a continuous layer from the ground to the canopy and emergents may be present. Species diversity is relatively high for trees and shrubs.
Montane Rainforest	M	Open montane rainforest	Low forests dominated by *Athrotaxis cupressoides* and less commonly by *A. selaginoides*. The canopy is usually open with widely spaced trees, though dense clumps may occur. The understorey is dominated by low shrubs, grasses or mosses (*Sphagnum*). Shrub heights range from half to two-thirds the height of the canopy. Woody species diversity is relatively high.

References

Jarman, S.J., Kantvilas, G. and Brown, M.J. (1991). *Floristic and ecological studies in Tasmanian rainforest.* Tasmanian National Rainforest Conservation Program (NRCP) Australia. Report No. 3. 67 pp

Reid, J.B., Hill, R.S., Brown, M.J., Hovenden, M.J. (eds.) 1999, *Vegetation of Tasmania*, Flora of Australia Supplementary Series Number 8, University of Tasmania, Forestry Tasmania, CRC for Sustainable Production Forestry, Hobart.

Aquatic and Wetland Types

The forty aquatic and wetland types listed here are taken from the *Directory of Important Wetlands in Australia* (Commonwealth of Australia, 2001). The definition of wetland is consistent with that adopted by the Ramsar Convention, Article 1.1.

Marine vegetation below 6m depth is not covered in this document.

A—Marine and Coastal Zone wetlands

1. Marine waters—permanent shallow waters less than six metres deep at low tide; includes sea bays, straits
2. Subtidal aquatic beds; includes kelp beds, seagrasses, tropical marine meadows
3. Coral reefs
4. Rocky marine shores; includes rocky offshore islands, sea cliffs
5. Sand, shingle or pebble beaches; includes sand bars, spits, sandy islets
6. Estuarine waters; permanent waters of estuaries and estuarine systems of deltas
7. Intertidal mud, sand or salt flats
8. Intertidal marshes; includes saltmarshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes
9. Intertidal forested wetlands; includes mangrove swamps, nipa swamps, tidal freshwater swamp forests
10. Brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea
11. Freshwater lagoons and marshes in the coastal zone
12. Non-tidal freshwater forested wetlands

B—Inland wetlands

13. Permanent rivers and streams; includes waterfalls
14. Seasonal and irregular rivers and streams
15. Inland deltas (permanent)
16. Riverine floodplains; includes river flats, flooded river basins, seasonally flooded grassland, savanna and palm savanna
17. Permanent freshwater lakes (> 8 ha); includes large oxbow lakes
18. Seasonal/intermittent freshwater lakes (> 8 ha), floodplain lakes
19. Permanent saline/brackish lakes
20. Seasonal/intermittent saline lakes
21. Permanent freshwater ponds (< 8 ha), marshes and swamps on inorganic soils; with emergent vegetation waterlogged for at least most of the growing season
22. Seasonal/intermittent freshwater ponds and marshes on inorganic soils; includes billagongs, sloughs, potholes; seasonally flooded meadows, sedge marshes
23. Permanent saline/brackish marshes
24. Seasonal saline marshes
25. Shrub swamps; shrub-dominated freshwater marsh, shrub carr, alder thicket on inorganic soils
26. Freshwater swamp forest; seasonally flooded forest, wooded swamps; on inorganic soils

27. Peatlands; forest, shrub or open bogs
28. Alpine and tundra wetlands; includes alpine meadows, tundra pools, temporary waters from snow melt
29. Freshwater springs, oases and rock pools
30. Geothermal wetlands
31. Inland, subterranean karst wetlands

C—Human-made wetlands

32. Water storage areas; reservoirs, barrages, hydro-electric dams, impoundments (generally > 8 ha)
33. Ponds, including farm ponds, stock ponds, small tanks (generally < 8 ha)
34. Aquaculture ponds; fish ponds, shrimp ponds
35. Salt exploitation; salt pans, salines
36. Excavations; gravel pits, borrow pits, mining pools
37. Wastewater treatment; sewage farms, settling ponds, oxidation basins
38. Irrigated land and irrigation channels; rice fields, canals, ditches
39. Seasonally flooded arable land, farm land
40. Canals

References

The Ramsar Convention on Wetlands (1971, amended 1982 & 1987, published 1994, posted on web 1996), accessed 3 March 2005: http://www.ramsar.org/key_conv_e.htm

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Cowardin, L. M., V. Carter, F. C. Golet, E. T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/1998/classwet/classwet.htm (Version 04DEC98) (accessed 03 Mar. 05).

Wetland Growth-forms

code	Type	Notes
1	Emergent, permanent	Woody or herbaceous, not ephemeral
2	Emergent, ephemeral	Herbaceous, ephemeral
3	Floating stems with leaves at the surface but roots in substrate	Herbaceous; leaves at surface
4	Floating mats	Herbaceous (predominantly); e.g. grass matts not attached to substrate
5	Fully submerged with roots attached to substrate	Herbaceous; with whole plant below surface (in some cases flowers may be emergent)
6	Fully submerged, floating	Unattached plant, submerged (e.g. free floating herbs or algae)

Steps in the Field Survey Process

Before Going in the Field

- Clearly define the aims, goals, or purposes of the survey. Include the requirements of the expected users and those funding the survey.
- Consult with those with major interests in the survey or who may be affected by the work or outcomes of the survey: funding agencies, landowners, users, other survey groups with interests in the area, herbaria, media etc. These consultations should aim to gain support, discover details of sites that could affect site selection or interpretation or extant information.
- Obtain necessary permits for access to land for the purposes of the survey, and collecting permits should voucher specimens be needed.
- Office based site-selection processes:
    - Has the area been surveyed before? If so, are results available and satisfactory for current project?
    - Determine sampling method, then if appropriate:
        - Obtain relevant mapping: remotely sensed imagery, geological, environmental, climatic, soil, cadastral, any other that shows attributes relevant to the project.
        - Determine density of sampling depending on total area being surveyed.
        - Stratify sampling area and allocate sites to units
    - Locate potential sample sites on remotely sensed imagery, preferably most detailed available, eg 1:50,000 or 1:25:000 aerial photographs, documenting the closest location a vehicle can reasonably get to the site and potential route to walk to the site if needed. Program these into GPS unit if feasible.
- Prepare field equipment and transport.
- Prepare sampling teams, ensuring relevant skills (biological, sampling methods, health and safety).

Near the Site

- Record the location of the vehicle access from known locations within nearby towns and properties, roads and directions used to get to the closest place for vehicles.
- If relevant, mark the take off point beside the road/track, using plastic tape, but balance the need for relocation against unwelcome attracting of attention or potential defacing of the place.
- Record direction(s), distances and route taken from vehicle to the sampling site.
- Use a random numbers method to locate the actual place where the sample plot will be located, in order to avoid bias in choosing the site.
- Reconnoitre the sampling site to see it meets basic criteria. The field situation may have changed since aerial photos were taken, for example. Try to keep the site is at least 100m away from vegetation edges, major intrusions into the site of 'foreign' elements such as tracks, rock outcrops etc. Where the unit being sampled is small or narrow, allowances for this will influence the siting of the sample plot.

At the Site

- Walk around the outside of the site to acquaint yourself with it. Avoid too much traffic within the area to be sampled so as not to disturb the ground layer before measuring and recording it.
- Mark out plot boundaries, or locate centre or end point if using plotless sampling.
- Make any general notes about the site (quality, condition, exceptional aspects etc.).
- Record site location (GPS, on aerial photo, map as appropriate). Draw sketch map showing general features: vegetation boundaries, tracks, drainage lines, disturbance etc).
- Locate sub-plots for plants of small stature.
- Record and measure the ground layer.
- Record and measure the canopy, and tall understorey if present, using plots of relevant sizes.
- Record soil and other environmental information. Collect and label specimens as needed.
- Make photographic records from standard locations, plus any subsidiary photos, recording relevant data about the photos onto the record sheets.
- Complete record sheets and re-check to ensure all fields are completed.
- Ensure relevant voucher specimens have been collected, labelled and packed.
- Place permanent marker(s). Use a system that will allow accurate relocation, but that won't endanger or limit other users of the site, unless restricted access has been arranged in advance with the land custodian/owner.
- Check all equipment has been packed for return to vehicle

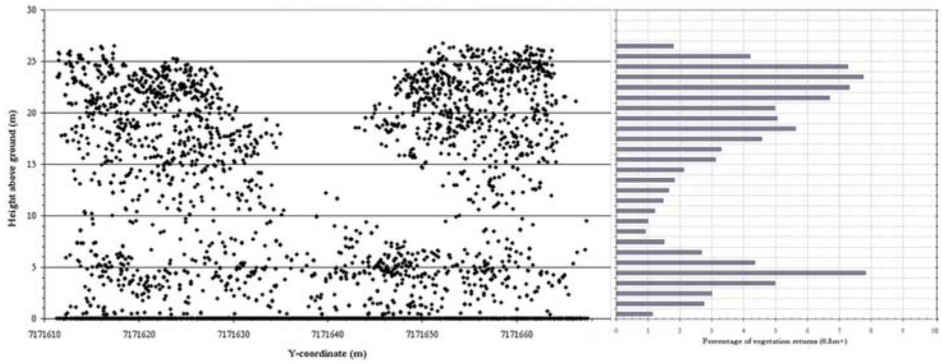
The use of LIDAR in determination of the height of strata in vegetation

Airborne scanning LiDAR can be used to generate vertical profiles of foliage density (Lee 200X). However research is still required to fully understand how these relate to actual ecological strata that can be identified in the field (Lovell, *et al*., 2003). Two representations of foliage structure from processed LiDAR data are shown here.
One representation displays the vertical and horizontal distribution, in two dimensions, of all foliage elements at the resolution of the data acquired (Figure 14). This is a representation of the vegetation, viewed from the side, as if looking into the plot.

From Figure 14 (left), two tree clusters with a canopy at approximately 25 m are clearly seen, as is an understorey at about 4-6 m height. The continuity of the foliage elements is also clear, from the tops of the dominant trees down through the understorey immediately below them. There are also some extensions to the understorey that are not related to the tree canopy. From this Figure, two 'strata' could be distinguished.

The second representation of the vertical distribution of foliage density is seen in Figure 14 (right). In this figure the, the relative amounts of overstorey and understorey for this sample plot was determined by assessing the number of returns per 1m height interval, and depicting this as a percentage of all the non-ground returns for the whole sample. The largest percentage values occur where the foliage is most dense and the crowns widest. Strata are separated by relatively low percentage values (troughs in the curve). Two strata are again visible.

Figure 14: Longitudinal profile view of air-borne LiDAR data (left) for a field plot, and it's associated vertical profile (right). The resolution is 1m spacing between returns, with a footprint size of 0.10m, within a 50x50m field plot from Injune in central Queensland. The vegetation is a *Eucalyptus populnea* (poplar box) woodland with emergent *Angophora*.



Appendix 5

Vegetation Condition

Appendix 5.1

Table 19. Condition of woody vegetation, particularly tree-dominated, native vegetation in southern Australia.

Attribute	**Notes relative to benchmark**
Large trees	‘large’ is relative to benchmark
Tree (canopy) cover	‘cover’ is relative to benchmark
Understorey (non-tree) strata	Quantity and kind of understorey depends on the type of vegetation
Lack of weeds	Include consideration of relative impact & invasiveness depending on the weed species and the vegetation type
Recruitment	Amount of recruitment will vary with the vegetation type and position in the growth-stage cycle
Organic litter (fine and medium and coarse woody debris; and non-woody debris)	Amount of organic litter present depends on: • the geographic location in Australia, which affects the kind and rate of organic decomposition; • the vegetation type; • position in the disturbance regime; and • a defined fire frequency.

Table 20. Condition attributes: the following list of attributes are being used by State and Territory agencies to record aspects of vegetation and site condition.

Attribute	Recorded observation
site disturbance: % cover	
Disturbance-observation type	
none	
limited clearing	
cultivation	
gravel pit	
cleared within 30m quadrat	
coppice regrowth	
drains	
earthworks	
fire breaks	
fence lines	
off-road vehicles	
power lines	
rubbish dumping	
remnant vegetation beside roadside	
slashing	
sprays	
watering points	
access tracks	
mining	
logging	
Bee hives	
exotic weeds	
salinity	
flood	
die-back	
other/fire/wind/water	
Frequency of major disturbances affecting site::	
current disturbance occurring	
single recent 1-10 yrs	
few recent 1-10 yrs	
disturbances all > 10yrs	
type & intensity accelerated erosion	
Extent & type surface:	
crusting	
rocks	
logs	
branches	
litter (% cover, depth)	
bare ground	
Departure from highest quality site of the type:	
pristine	

Attribute	Recorded observation
intact	
disturbed	
very disturbed	
Grazing:	
Nil	
Light	
moderate	
Heavy	
Cattle	
horses	
native herbivore	
Pigs	
Other	
Nearest water km	
Fire:	
Year of last fire or evidence of fire	
Fire frequency	
nil	
< 1yr	
1-2 yrs	
2-5 yrs	
> 5yrs	
Fire intensity	
no damage	
minor some/most trees& shrubs	
some trees/shrubs killed	
most trees/shrubs killed	

Table 21. Assessing vegetation Assets, States and Transitions (VAST).

Increasing vegetation modification from left to right

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		State 0	State I	State II	State III	State IV	State V	State VI
			Native Vegetation Cover Dominant structuring plant species indigenous to the locality and spontaneous in occurrence – i.e. a vegetation community described using definitive vegetation types relative to estimated pre1750 states			**Non-native Vegetation Cover** Dominant structuring plant species indigenous to the locality but cultivated; alien to the locality and cultivated; or alien to the locality and spontaneous		
Vegetation Cover Classes		State 0: NATURALLY BARE Areas where native vegetation does not naturally persist and recently naturally disturbed areas where native vegetation has been entirely removed. (i.e. open to primary succession).	State I: RESIDUAL Native vegetation community structure, composition, and regenerative capacity intact – no significant perturbation from land use/land management practice	State II: MODIFIED Native vegetation community structure, composition and regenerative capacity intact - perturbed by land use/land management practice	State III: TRANSFORMED Native vegetation community structure, composition and regenerative capacity significantly altered by land use/land management practice	State IV: REPLACED - *ADVENTIVE* Native vegetation replacement – species alien to the locality and spontaneous in occurrence	State V: REPLACED - *MANAGED* Native vegetation replacement with cultivated vegetation	State VI: REMOVED Vegetation removed - alienation to non-vegetated land cover
Diagnostic criteria	Current regenerative capacity	Complete absence of in-situ regeneration capacity except for ephemerals and lower plants	Natural regenerative capacity unmodified	Natural regeneration capacity persists under past and /or current land management practices	Natural regenerative capacity limited / at risk under past and /or current land use or land management practices. Rehabilitation and restoration possible through modified land management practice	Regeneration potential of native vegetation community has been suppressed and in-situ resilience at least significantly depleted. Potential for restoration using assisted natural regeneration approaches	Regeneration potential of native vegetation community likely to be highly depleted by intensive land management. Very limited potential for restoration using assisted natural regeneration approaches	Nil or minimal regeneration potential. Restoration potential dependent on reconstruction approaches
	Vegetation structure	Nil or minimal	Structural integrity of native vegetation community is very high	Structure is predominantly altered but intact e.g. a layer / strata and/or growth forms and/or age classes removed	Dominant structuring species of native vegetation community significantly altered e.g. a layer / strata frequently and repeatedly removed	Dominant structuring species of native vegetation community removed or extremely degraded	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
	Vegetation composition	Nil or minimal	Compositional integrity of native vegetation community is very high	Composition of native vegetation community is altered but intact	Dominant structuring species present - species dominance significantly altered	Dominant structuring species of native vegetation community removed	Dominant structuring species of native vegetation community removed	Vegetation absent or ornamental
Examples		Bare mud; rock; river and beach sand, salt freshwater lakes, rock slides and lava flows	Old growth forests; native grasslands that have not been grazed; wildfire in native forests and woodlands of a natural frequency and/or intensity	Native vegetation types managed using sustainable grazing systems; selective timber harvesting practices; severely burnt (wildfire) native forests and woodlands not of a natural frequency and/or intensity	Intensive native forestry practices; heavily grazed native grasslands and grassy woodlands; obvious thinning of trees for pasture production; weedy native remnant patches; degraded roadside reserves; degraded coastal dune systems; heavily grazed riparian vegetation	Severe invasions of introduced weeds; invasive native woody species found outside their normal range; isolated native trees/shrubs/grass species in the above examples	Forest plantations; horticulture; tree cropping; orchards; reclaimed mine sites; environmental and amenity plantings; improved pastures. (includes heavy thinning of trees for pasture); cropping; isolated native trees/ shrubs/ grass species in the above examples	Water impoundments; urban and industrial landscapes; quarries and mines; transport infrastructure; salt scalded areas

Table 22. Attributes used in the assessment of wetland condition.

(Adapted from Anderson 1999, NRM 2004, and Commonwealth of Australia 2004a).

Biological Indicators	Physical Chemical Indicators
vegetation extent: • % cover of 3- 5 dominant woody species in upper and middle layers • % herbaceous ground cover • % cover aquatic vegetation (submerged, floating, emergent) • % cover exotics • Native regeneration • Width of riparian zone (Left and Right banks)	pH
Longitudinal connectivity	conductivity
Expected species lists for regional community monitoring	turbidity
macroinvertebrates	transparency
phytoplankton	colour
chlorophyll *a*	dissolved oxygen
	nutrients

Appendix 6

A field proforma for recording cover and structural characteristics for major species at a field site.

SITE No - ------------- LOCATION --------- ~ ----------- DATE ----------

Dominant stratum CROWN

SPECIES CODE	Height	Width	Depth	Gap	Type
MEDIAN					

2nd Stratum CROWN

SPECIES CODE	Height	Width	Depth	Gap	Type

3rd StratumCROWN

SPECIES CODE	Height	Width	Depth	Gap	Type

ADDITIONAL SPECIES:……..….
……...
…………………………………………………………………………………………………….~SAMPLE AREA …… x …… m
% Grass Height Intercept in cms per……….m transect

Median values per stratum:

Height Width Depth Cover% Type* Stratum Height Width Depth Cover% Type* Stratum Height Width Depth Cover% Type* Stratum

* 'type' refers to crown type from Figure 9.

Appendix 7

SITE-BASED VEGETATION RECORDING FORM

NB: Pages numbers in this Appendix refer to: Gunn, R.H., J.A. Beattie, R.E. Reid and R.H.M. van der Graaff (eds.), 1990, *Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys*. Inkata Press, Melbourne.

1. SITE & RECORDER IDENTIFICATION

Survey Code	Site No	Permanent plot? y/n	Date
Site Type 1.Quadrat; 2.Plotless.	Plotless type	Broad Generic / Generic Group Formation (Table 5) ………………………………………………………..	

Site Dimensions	Approximate area of vegetation being represented by sample site: sq m or ha	Replicate No	Previous Sampling Date
Recorder	Site Photo: Film/media No	Photo No	Location from which photos taken:

Map No	Map Name	Map Scale	Mapped Vegetation Unit? Y / N

AMG Zone	Easting	Northing	Latitude	Longitude	Location in plot to which coordinates apply: ……………

Geocode method	Geocode precision	Tenure Type

Locality: ____

Air Photos:

Air Photo (AP) year	AP No	AP Run	AP Print	AP colour Black & white	AP: Scale 1: ………………….
AP of site location: from west edge of photo: mm to east: …………………….. From south edge of photo: mm to north: ………………….					
Weather conditions When sampled: Current & previous season:					

2. LANDFORM DATA

Altitude: m (above +/below - msl) ………………………………………….. m	Altitude: method	Altitude: Source
Aspect: (^{o}) ………………………………………..	Aspect Method (circle) Compass Map derived Estimate – descriptive Other: …………………………………..	Aspect: Source
Slope: (^{0} or %) ………………………………………..	Slope: Method	Slope: Source
Morphological Type: (p13)	Landform Element: (pp24-34)	Landform Pattern: (pp 48-57)
Site Runnoff (p101-2)	Distance to closest water supply(m)	Type of water supply: Permanent / seasonal / controlled / other

3. LANDSURFACE & SUBSTRATE DATA

Soils:

Observation Type (p103)		Surface Texture		Surface Colour
Great Soil Group		Soil depth		Soil Drainage(pp151-2)
Microrelief Y/N		Vertical Interval		Horizontal Interval
Gilgai Type (p89)		Hummock Type(p90)		Other Type(p91)
Litter %	Dead wood%	Bare ground %	Bare rock % (not lichen covered)…. Lichen-covered….	Biological crust: %

Substrate:

Observation Type (p153 or map)	Rock Type (p160)	Rock class (p165)

Disturbance: **Observation Type:**

Disturbance	Degree of impact	Age (time since disturbance)	Presence/ % area affected	Disturbance	Amount	Age (time since disturbance)	Stratum affected	Degree of impact
Storm damage				**Roadworks**				
Logging / thinning				**Fire**				
Ringbarking				**Salinity**				
Extensive clearing				**Weeds**				
Grazing: Type of evidence:				**Floods**				
Feral digging				**Erosion**		Type: Water Wind		

Comment:____

4. VEGETATION STRUCTURE

GF = Growth Form (L-1: woody/herb.); Height methods: ………. Cover method: ……….. BA = Basal Area (BA method: (DBH sample / BA sweep: Y/N / BA factor …)

GF L-1	GF L-3	Height (m)	Cover %	BA m^2	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6

Vegetation Strata (Stratum 1 is the highest stratum, irrespective of height)

	Stratum	Dominant stratum (√)	Cover %	Height to stratum top: median (m)	Height to stratum top: max (m)	Height of stratum base: median (m)
Crown Cover:	**1**					
	2					
	3					
Method used for crown cover:			Total Plot cover %..........			

NOTES and profile diagram :____

5. WETLAND VEGETATION

	Marine and Coastal Wetland	Inland Wetland	Human-made Wetland
Wetland type (Appendix 2.1)			
Growth-form (Appendix 2.2)			

Wetland Notes: ____

Indicators of vegetation Age Structure

Code	Growth Stage	Trees			Shrubs	Grasses & herbs	Cryptogams
		% crown cover	Commonest crown shape	Mean crown openness	% crown cover	% crown cover	% crown cover
1	Early regeneration						
2	Advanced regeneration						
3	Uneven age						
4	Mature phase						
5	Senescent phase						

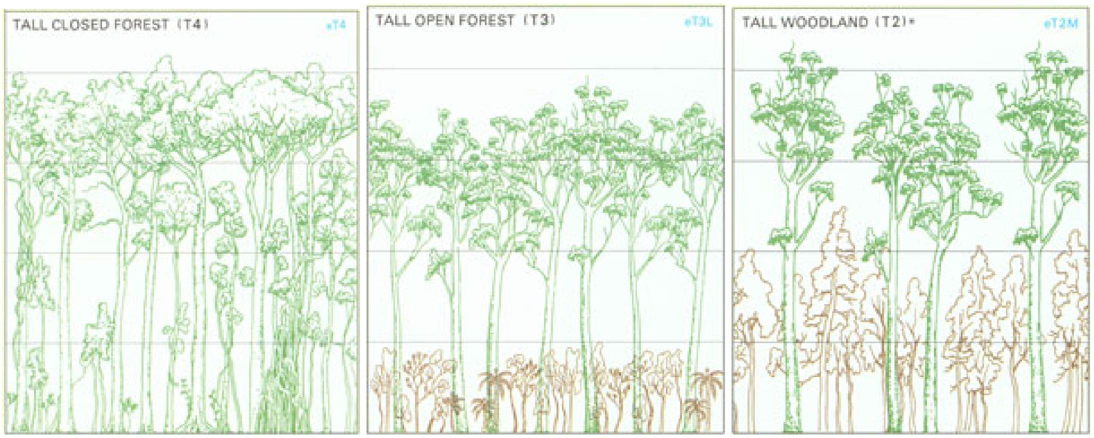
5. FLORISTICS

GF (L-3)=growth form; St=stratum; Ht=height (m); %C=% crown cover; A=abundance; BA=basal area; C=collection no.; ID is ticked (√) when id is completed.

GF	St	Ht	%C	A/BA	Species name	C	ID	Herbarium ref. #

Schematic illustrations of vegetation structure from a diversity of Australian vegetation types.

While each schematic representation of these vegetation types in relates to the structural classification developed by AUSLIG (1990), they nevertheless illustrate the growth forms and height/cover classes recognised at the level of Formation Class and Structural Formation in Table 4. The map codes printed in blue used in each structural diagram are those presented on the 1:5 million scale map of ‘Vegetation - Atlas of Australian Resources’ (AUSLIG 1990).




CLOSED FOREST (M4)
OPEN FOREST (M3)
WOODLAND (M2)
OPEN WOODLAND (M1)
LOW CLOSED FOREST (L4)
LOW OPEN FOREST (L3)
LOW WOODLAND (L2)
LOW OPEN WOODLAND (L1)
CLOSED SCRUB (S4) *
OPEN SCRUB (S3)
TALL SHRUBLAND (S2)
TALL OPEN SHRUBLAND (S1)


CLOSED HEATH (Z4) *
OPEN HEATH (Z3)
LOW SHRUBLAND (Z2)
LOW OPEN SHRUBLAND (Z1)
HUMMOCK GRASSLAND (H2)
CLOSED TUSSOCK GRASSLAND OR CLOSED SEDGELAND (G4)
gyG4
TUSSOCK GRASSLAND OR SEDGELAND (G3)
yG3
OPEN TUSSOCK GRASSLAND (G2)
SPARSE OPEN TUSSOCK GRASSLAND (G1)
yG1
DENSE SOWN PASTURE (F4)
SOWN PASTURE (F3)
OPEN HERBFIELD (F2) *
SPARSE OPEN HERBFIELD (F1)