The Vegetation of the Australian Tropical Savannas

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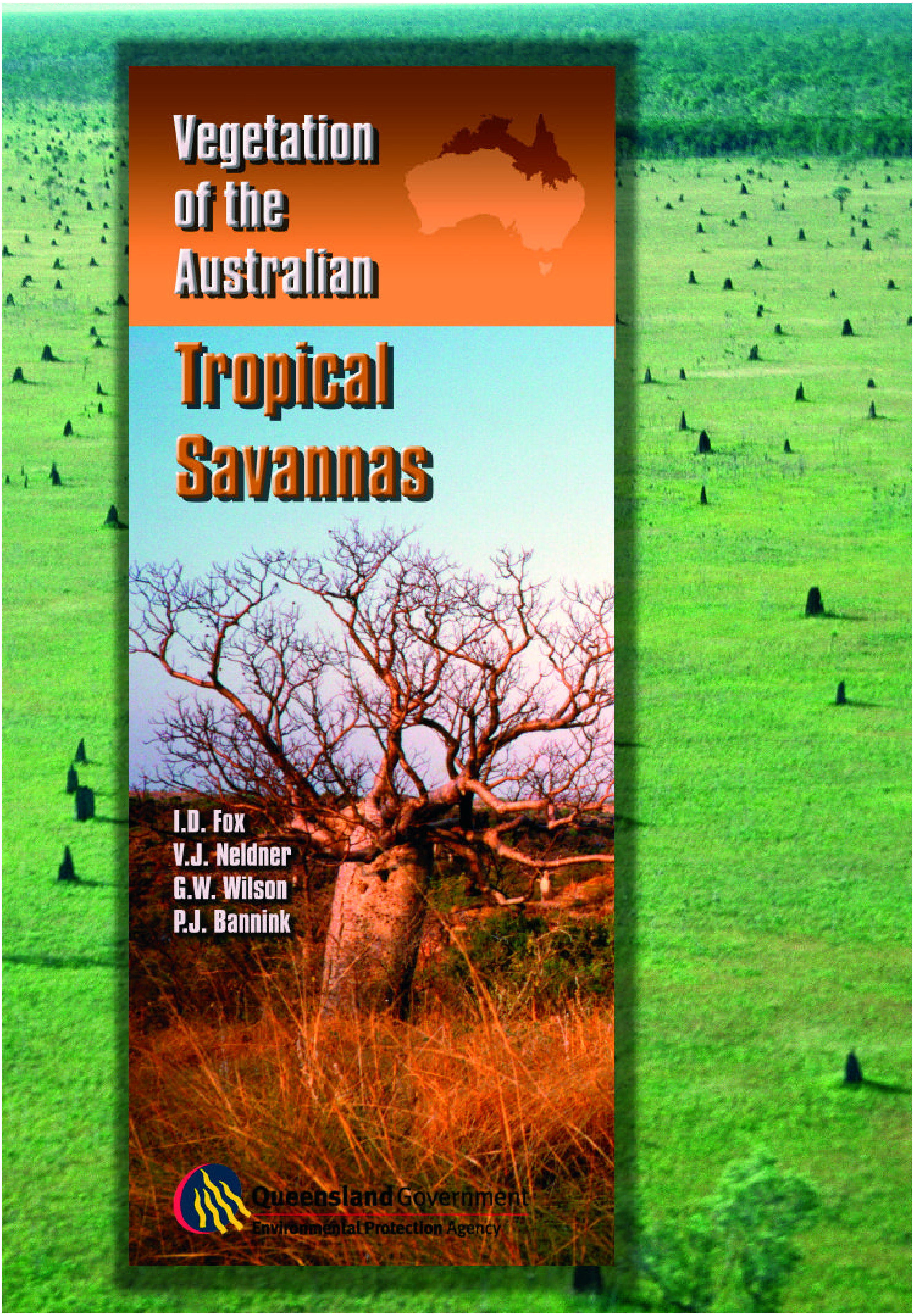

Vegetation of the Australian Tropical Savannas

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Queensland Government
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THE VEGETATION OF THE AUSTRALIAN TROPICAL SAVANNAS

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Technical report to accompany the map of
'The Vegetation of the Australian Tropical Savannas'

by

I.D. Fox, V.J. Neldner, G.W. Wilson and P. J. Bannink

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Summary

This report was written to accompany the 1:2 000 000 scale map of the Vegetation of the Australian Tropical Savannas (Fox *et al.* 2001), a map that represents the undisturbed vegetation of the north of the Australian continent. Disturbance from land clearing is not represented on the map. The map extent was derived from 22 bioregions (Environment Australia 2000) that incorporate the Australian tropical savannas and also a number of other vegetation types, including some *Triodia* spp. hummock grasslands of the central Australian semi-arid zone and some rainforest communities of the humid north and of the northeast.

125 map units are delineated on the map and described in this report, as well as two of the three non-savanna biogeographic regions adjoining the map area on the east coast. A digital 1:1 000 000 scale vegetation coverage delineating 249 map units has also been produced. For small scale and national analyses these vegetation units have been grouped into 26 broad vegetation groups.

Tropical savannas occupy close to a quarter of the Australian continent where they are perhaps better known as the northern grassy landscapes or northern grassy woodlands. In the past there has been little work to integrate the ecological studies that have taken place within the jurisdictional boundaries of Queensland, the Northern Territory and Western Australia. This project, funded by the Environmental Protection Agency (Queensland Herbarium) and the Cooperative Research Centre for Tropical Savannas Management (formerly the Cooperative Research Centre for Sustainable Development of Tropical Savannas), has taken existing vegetation mapping data from across the region and produced a seamless vegetation map. The project is an example of what can be achieved through collaboration of State, Territory and Federal agencies and researchers. In addition to collating existing map data, the project produced a new vegetation map for a large area in northwest Queensland.

The report provides a brief history of vegetation mapping in northern Australia that has evolved from earlier floristic studies to the study of interactions between ecological units. There is also an introduction to the important concept of land zones, which were used as an integral part of the project. An overview of the development over time of the Australian physical environment provides a background to the evolution of the north Australian flora. Plant nomenclature is current to 2001 and was based on the plant collection database HERBRECS (Queensland Herbarium 2001). Where plants were not listed in that database, reference was made to the Plant Name Index (Australian National Botanic Gardens 2001).

Computer mapping techniques made the project possible and the methods used to manipulate the mapping datasets are explained here. However, despite the importance of these technologies, the science of vegetation interpretation and classification underpins the project and its map outputs. The methods used to classify the vegetation and then to aggregate the vegetation units on the basis of land zone, are also explained.

In discussing the vegetation we recognize that there has been some impact from recent development in the region and especially in Queensland, although in parts of the Kimberley and the Northern Territory there have also been some localised but significant impacts. A section on land cover change data is presented. Finally, a substantial section has been devoted to describing the 128 vegetation map units that appear on the map of the vegetation of the Australian tropical savannas. The result is a comprehensive report that, in combination with the map, can be used by people with an interest in Australian vegetation or for conservation planning and research at the national scale.

ACKNOWLEDGEMENTS

A project of this scope could not have been completed without the assistance of a great number of people. The mapping project received its initial funding in late-1998 from the Cooperative Research Centre for the Sustainable Development of Tropical Savannas (TS-CRC) under its North Australia Landscape research theme. The theme focuses on defining the biophysical, social, cultural and economic attributes of the tropical savannas (TS-CRC 1999). By funding the project the TS-CRC has contributed to the study of the vegetation of Australian tropical savannas through the development of this seamless map coverage, a product not available at this scale until now.

A team from the Queensland Herbarium coordinated the project, which involved close collaboration with the agencies that contributed data directly to the map, specifically the Queensland Environmental Protection Agency (EPA), the Northern Territory Department of Lands Planning and Environment (NTDLPE); Agriculture Western Australia (AGWA); and the Western Australian Department of Conservation and Land Management (CALM). These agencies and their officers are thanked.

Peter Brocklehurst (NTDLPE) willingly assisted with interpretation of the data for the Northern Territory, provided detailed comments on the draft maps and assisted the collation of photographs for this report. Angas Hopkins, Judith Harvey and Graeme Behn (CALM) and Greg Beeston and Damian Shepherd (AGWA) provided assistance with the Kimberley map data. John Beard is thanked for his advice on the methods used to map the vegetation of the Kimberley and Great Sandy Desert regions, for his comments on the draft Kimberley map and for providing information about the botanical history of the Kimberley. Tanya Vernes (CALM) assisted greatly with Kimberley site data and photographs of the map units.

We wish to thank all authors of the component maps that were used to compile the final map of the Australian tropical savannas. In particular we thank botanists from the Queensland Herbarium (EPA) who contributed a great deal of time to generalising detailed Queensland vegetation maps. The development of a 1:1 million scale map of north Queensland would not have been possible without the assistance of those mapping professionals who not only provided their maps but also aggregated their map units to a suitable scale for the project. In particular Tim Ryan, Simon Thompson and Helen Cartan helped to develop unique Queensland vegetation codes, while John Thompson, Don Butler and Eda Addicott not only developed new codes but also re-interpreted large-scale maps in preparation for digitising. Bruce Wilson provided advice on broad vegetation groups and comments on draft legends. The authors thank all of these people.

Staff of the Queensland Herbarium provided valuable technical assistance to the project and in particular Arnon Accad and Jack Kelley are thanked for their help and advice on map production, for processing the Landsat TM satellite imagery used to map areas of northwest Queensland and for technical advice on handling large map datasets. Jeff Middleton (Queensland Herbarium) assisted greatly in the northwest Queensland mapping, carrying out data processing and providing technical assistance in the field and Heather Walker (postgraduate, James Cook University) also provided valuable field assistance.

A number people, including staff of the Identification Room at the Queensland Herbarium, the Western Australian Herbarium, the Australian National Herbarium and the Darwin Herbarium, provided taxonomic advice for the project. The many individuals who gave freely of their botanical expertise are thanked, especially Tony Bean, John Clarkson, Lyn Craven, Jenny Milson and Kevin Kenneally. Tim Willing helped greatly in our understanding of the floristics and in the interpretation the vegetation patterns of northwest Australia.

A number of agencies provided reference data for the project. All these agencies hold copyright over their data. Queensland Department of Natural Resources (State Landcover and Trees Study) supplied Landsat TM imagery for northwest Queensland. The Australian Surveying and Land Information Group (AUSLIG) supplied topographic data and the 1:1,000,000 vegetation compilation sheets and data files from the Queensland section of the 1:5,000,000 map of John Carnahan's Present Vegetation of Australia (AUSLIG 1990) and Susie Salisbury is thanked for assisting the data extraction and interpretation. Environment Australia (EA 2000) supplied Version 5.0 of the Interim Biogeographic Regionalisation of Australia (IBRA) used to delineate the southern boundary of the map extent and Ann Hardy is thanked for help with the most recent release of the data. The Bureau of Rural Sciences (BRS 2000) provided the landcover change data used to complete the analyses of remnant vegetation and Lucy Randell is thanked for providing advice on interpreting the data.

The administration staff at the Centre for Tropical Agriculture in Mareeba are thanked for undertaking photograph scanning and word processing, often at very short notice. We would also like to thank Ben Collyer (Queensland Herbarium) who assisted in locating photographs of a number of Queensland vegetation types. Wil Smith is thanked for the drawings of Gondwana and the Australian landmass used in section 2.3.1. Paul Sattler and Rebecca Williams are thanked for permitting the reproduction of land zone definitions and icons.

Draft maps were circulated in 2000 and valuable comments were received from Judith Harvey, Tim Willing, Peter Brocklehurst, John Beard, Angas Hopkins and the mapping teams at the Queensland Herbarium. Eda Addicott is thanked for her valuable comments on a preliminary draft of this report. Tony Bean is thanked for his thorough review of the vegetation descriptions and commenting on species nomenclature. Rosemary Niehus and Arnon Accad are thanked for handling the task of taking the draft manuscript to pre-production stage.

In March 2001 a draft technical report was released for review. John Carnahan, Kath Dickinson, Kevin Kenneally and Garry Werren are thanked for their valuable comments on that draft.

Photographs

The authors supplied most of the photographs used, with additional photographs provided from the Queensland Herbarium photographic collection and by Lynne Bailey, Graeme Behn, Peter Brocklehurst, Allan Burbidge, Helen Cartan, Brian Carter, John Clarkson, Kevin de Witte, Kevin Kenneally, Jeff Middleton, Jenny Milson, Mark Newton, Rod Silburn, Peter Stanton, Bruce Swain, John Thompson and Tanya Vernes.

1. Introduction

".....the term 'savanna' designates a tropical grassland with scattered trees. Defined this way, savannas are the most common tropical landscape unit. They are found on all four tropical continents and in more than 20 countries".

(Solbrig, O.T. and Young, M.D (1993), in the Introduction to O.T. Solbrig and M.D. Young (eds), *The World's Savannas*. Man and the Biosphere Series Vol. 12, United Nations Educational, Scientific and Cultural Organisation, Paris)

Savanna vegetation occurs widely across the tropics of the world and is the result of a marked seasonal pattern of tropical monsoon rains in the summer followed by a distinctly dry period in the winter. It occupies a distinct part of the tropical landscape between rainforests and arid areas. In areas where the summer rains occur over a longer period of the year the vegetation tends to be dominated by rainforest and where the seasonal dry period is longer, arid vegetation dominates. Fire is an important ecological feature of savannas during the dry season and, as with most Australian vegetation, the savannas are adapted to periodic burning (Beadle 1981, Huntley and Walker 1982, Walker and Gillison 1982, Solbrig 1993) and perhaps reliant upon it.

People have occupied savannas in Africa for more than a million years while in the American savannas human occupation is less than 30,000 years (Solbrig and Young, 1993). In the Australian savannas, which occur across the northern third of the continent, Aboriginal people have been present for perhaps 60,000 years and charcoal evidence suggests that they utilised fire to exploit savanna flora and fauna. The first European settlers were graziers who arrived in Australian savannas about 100 years ago. Since then, agricultural development of the biome has met with mixed and generally limited success. There is now recognition of the ecological and economic constraints confronting land-use options in the savannas (Holmes and Mott, 1993).

In order to maintain the ecological integrity of Australian savannas, land managers require a greater understanding of savanna ecological processes. Biological inventory is a necessary first step in this process, with an understanding of vegetation distribution a key component. This understanding, however, has been substantially restricted by a lack of compatible savanna-wide vegetation data, and specifically map data, at a scale of better than 1:5 000 000 for the most recent national vegetation map (AUSLIG 1990). A number of smaller maps produced over many years and for different purposes existed across the region, but the diversity of interpretation techniques, variations in scale, and the lack of adequate edge-matching between the maps, has meant that a whole-of-region approach has been problematic.

The Cooperative Research Centre for Sustainable Development of Tropical Savannas (TS-CRC), Darwin, Australia, identified the need for the compilation of a seamless map of the vegetation of northern Australia and provided initial funding for production of the map. Completion of the map relied on substantial contribution of resources and staff time from the Queensland Herbarium.

1.1 Map extent and savanna definition

The map described by this report represents the grassland and wooded grassland vegetation of the Australian tropics as it may have existed prior to disturbance since European settlement (see 5. Descripton of the Vegetation). The map extent for the project was defined by the boundaries used by the TS-CRC and was based on 22 bioregions from the Interim Biogeographic Regionalisation of Australia (IBRA) Version 5.1 (Environment Australia 2000). The bioregions used are listed in 2.3, Biogeographic regionalisation. Figure 1.1 shows the mapped area in relation to the Australian continent.

The ways in which the vegetation of the area defined by the map extent fits into definitions of savannas is difficult to state with any certainty, given the various ways in which defining savannas, and specifically the Australian savannas is dealt with. Solbrig (1993) recognised that as a consequence of the heterogeneity of their ecosystems, savannas are difficult to define. Despite those inherent difficulties he presented a definition following Sarmiento (1984) and Frost *et al.* (1985) in which a savanna is defined as:

> *'an ecosystem of the warm (lowland) tropics dominated by a herbaceous cover consisting mostly of bunch grasses*[1] *and sedges that are more than 30cm in height at the time of maximum activity, and show a clear seasonality in their development, with a period of low activity related to water stress. The savanna may include woody species (shrubs, trees, palm trees), but they never form a continuous cover that parallels the grassy one'* (Solbrig 1993: 22).

1. The term bunch grasses is synonymous with the term tussock grasses used throughout this report.

To describe the Australian situation, a broad structural approach has been taken which describes savannas in terms of tree savannas and shrub savannas (Beadle and Costin 1952, Beadle 1981, Walker and Gillison 1982), with both structural forms having a projective foliage cover within the range between closed (70-100%) and very open (<30%) (Beadle 1981, Specht 1970). Gillison (1994) suggested that because of their structural similarity, especially in the upper strata, the terms 'savanna' and 'woodland' are often interchangeable. For example, Specht *et al.* (1974) use the structural formation of low open-woodland to encompass the tree and low-tree savannas described by Williams (1955).

Walker and Gillison (1982) differentiated Australian savanna types within the framework of bioclimatic provinces developed by Fitzpatrick and Nix (1970) in which tropical savannas occur within the 'megatherm' region. In this region, which includes the majority of the mapped area, plant growth is most rapid during summer rains after which growth declines rapidly with the onset of the winter dry season. During this dry season, many plants undergo substantial leaf-drop, or cease growth altogether (Walker and Gillison 1982).

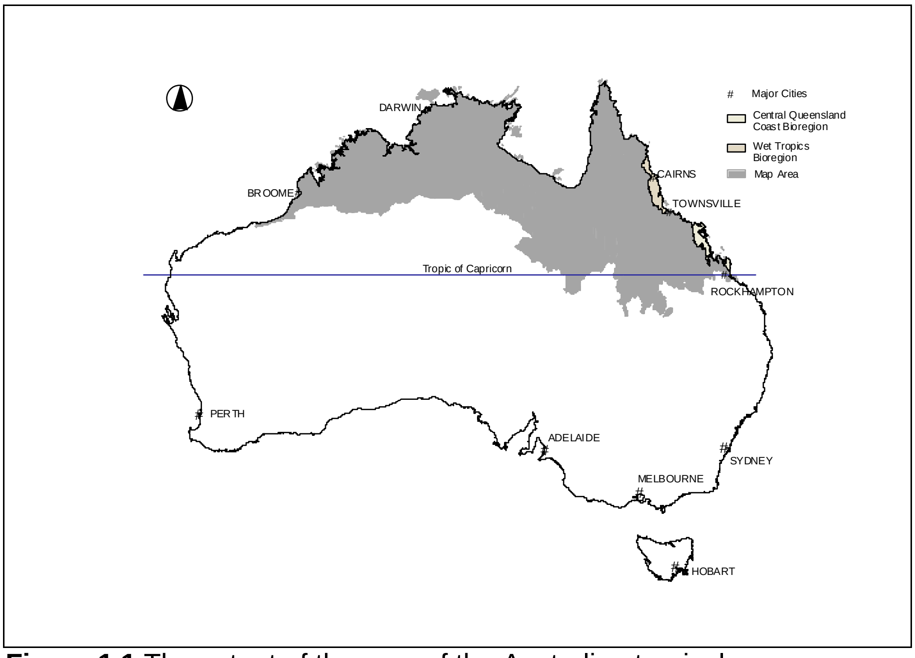

Figure 1.1 The extent of the map of the Australian tropical savannas

1.2 History of vegetation survey and mapping

The primary purpose of a vegetation map is to illustrate the geographical distribution of the various vegetation types that occur within a given area. Vegetation surveys aim at delineating and describing these vegetation types, which can intergrade along environmental gradients in a continuum (McIntosh 1967, Whittaker 1967). For descriptive and mapping purposes with practical applications, it is useful to classify and delineate plant communities, even where boundaries between communities may represent a wide ecotone of anything up to a few kilometres, while others are sharp and clearly defined. ‘Vegetation survey and mapping is therefore the meeting ground of the author’s systematic classification of the vegetation and the mosaic arrangement of plants in the field’ (Neldner 1993). In writing about the history of vegetation survey in northern Australia a number of published references were studied and are suggested for further reading on the subject. The following summary includes information presented in Beard (1979), Carr and Carr (1981), Wilson *et al.* (1990) and Neldner (1993).

1.2.1 Floristic vegetation description

A floristic method of vegetation description was adopted for most studies in Australia up until about the early 1930's. It relied on describing vegetation on the basis of species composition without reference to habit, structure or life form. The earliest record of published description of Australian vegetation followed Dampier's cruise in 1699 (Dampier 1703) in which he made the first known collection of botanical specimens from Australia (Osborn and Gardner 1939, George 1971 cited in Beard 1979). Whilst there was little botanical work in the eighteenth century, work throughout the nineteenth century resulted in vast collections of plants being gathered as the basis for the development of an understanding of the taxonomy of the Australian flora (Neldner 1993). The botanical work by people such as Brown (1810), Mueller (1858-82) and Bentham (1863-78) formed the basis for national botanical study that continues to the present day.

A number of regional expeditions into northern Australia were conducted over the period, adding to the collective botanical knowledge. These people were explorers themselves, or botanists accompanying explorers (Wilson *et al* 1990). These included the work in the Northern Territory by Stuart in 1860, Gosse in 1873, Leichhardt in 1845 and Cunningham in 1924 (Willis 1981). In the Kimberley region the 1801 and 1803 French coastal expeditions led by Baudin had on board the botanist Leschenault de la Tour (Beard 1979). Later expeditions included those by King in 1818, 1820 and 1821 (Beard 1979), Grey in 1837 (Grey 1841 cited in Beard 1979) and Gregory from 1855-56 (Beard 1979).

Through the late nineteenth and early twentieth centuries, a number of Australian states published systematic floras, which were the result of earlier and ongoing botanical work. Amongst those works were floras for New South Wales (Moore and Betche 1893), Queensland (Bailey 1899-1902), Tasmania (Rodway 1903), Northern Territory (Ewart and Davies 1917), South Australia (Black 1922-29), Victoria (Ewart 1930) and Western Australia (Gardner 1931).

With one or two notable exceptions such as the maps of Australian vegetation by Diels (1906), the map of the Victorian forest trees by Everett 1869, (Powell 1967) and the map of the Western Australian vegetation by Jutson (1914), this emphasis upon individual species rather than broader groupings of vegetation effectively meant that vegetation mapping was virtually non-existent in Australia in the early twentieth century. Field investigations basically resulted in floristic lists, from which information on the vegetation types was interpreted (Neldner 1993).

1.2.2 Ecological vegetation description

Recognition of distinct plant groupings was the result of the growth in ecological studies in the early twentieth century, notably through the work of Schimper (1903), Cowles (1899, 1901), Clements (1904, 1905, 1907) and Warming (1909). There was a growing awareness that distinct plant groupings or communities could be recognised, not only by floristic composition, but also by their distinct life forms, their habitat and their structure. It was realised that the plant habitat influences its life form, in other words, climatic, edaphic, physiographic and biotic factors in the environment all affected the vegetation. It was recognised that every plant species had specific environmental requirements and tolerance ranges for its existence. The climax plant community concept developed by Clements (1916), in which climate was considered the primary determinant for a monoclimax vegetation in a given area, dominated ecological thought at that time (Neldner 1993).

Perhaps the earliest vegetation map of the whole Australian continent (Figure 1.2) was by Diels (1906) in which the map formed part of the end papers of his book 'Die Pflanzenwelt von West-Australien südlich des Wendekreises' (Beard 1979, Beard 2001). Unfortunately the map exists without a full description of the map units, or of their derivation, however the eight units used by Diels to describe the Australian vegetation at a scale of 1:27 000 000 include three units that occur across northern Australia, *Savannen-wald*; *Savanne*; and *Brigalow-Scrub, Mallee-Scrub od Sand-Heide*. Jutson's (1914) 1:5 000 000 scale sketch map of the vegetation of Western Australia in which the Kimberley was described as 'savannah forests and woodlands'; 'savannah' and 'low rainfall tropical woodlands' (Beard 1979) and was useful at a regional scale but lacked a national context.

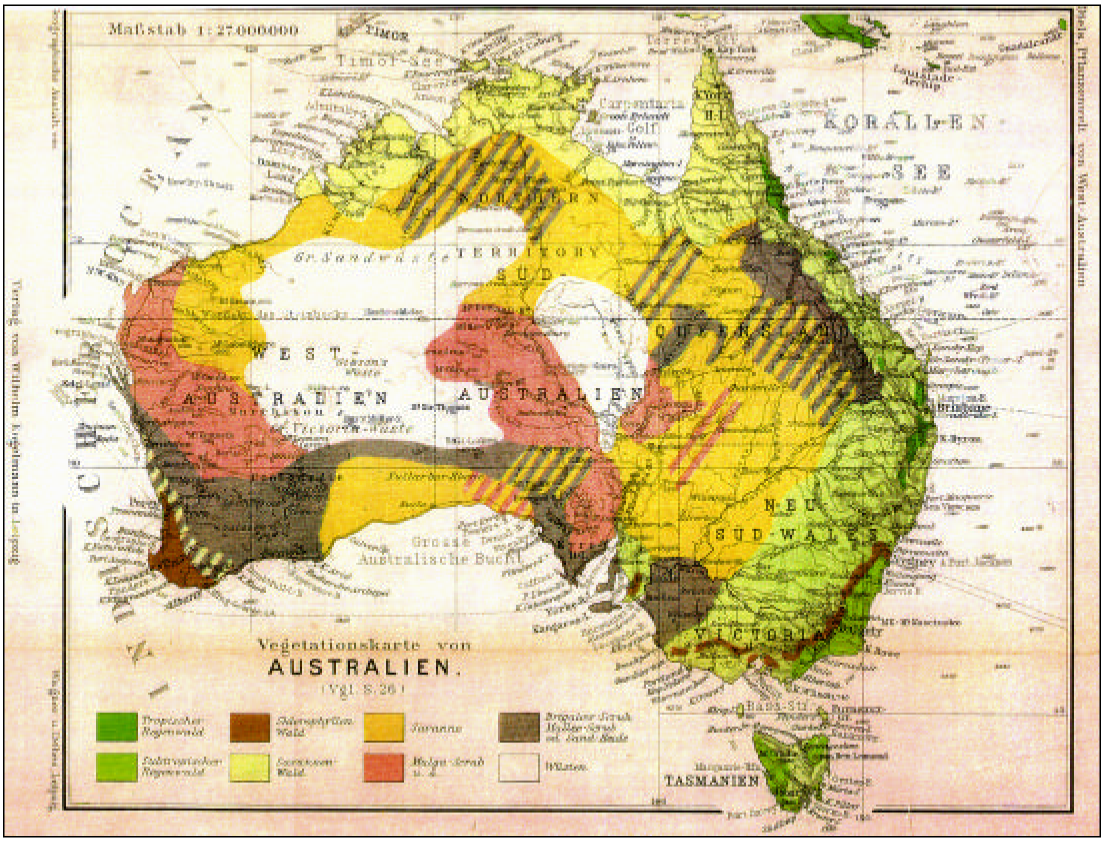

Figure 1.2 An early vegetation map of the whole Australian continent. Taken from an original by F.L.E. Diels (1906), courtesy of J.S. Beard.

As knowledge of the Australian flora grew, vegetation description moved towards an ecological approach. The 1:10 000 000 map of the vegetation of Australia (Prescott 1931), although generalised, provided evidence of the usefulness of a vegetation map. Over the decade after the publication of Prescott's map, a number of plant communities were described in ecological terms (eg. Patton 1933, 1934, 1936, Wood 1936, 1937, Blake 1938), however many of these studies showed that the monoclimax plant community concept developed by Clements (1916) did not to apply in Australia (Wood 1939). That the Australian vegetation did not fit the expected patterns for climax vegetation was explained by a number of characteristics typical to the Australian context including physical factors, relief, drainage and soil differences, and particularly mineral deficiencies. These environmental characteristics, along with climate and the variable physiological tolerances of individual plant species were used to explain departures from the expected climax vegetation (Crocker 1959, Crocker and Wood 1947, Specht 1957, 1963, Cochrane 1967).

Through the 1940s maps of plant communities were often accompanied with soil and geological maps (Neldner 1993), however the mapping suffered from a lack of uniformity in the classifications used and in the use of terms. This largely held back any comparative study of the Australian vegetation (Cochrane 1963) among maps. There were many different interpretations of the concept of the 'association', which was the fundamental vegetation unit. Similarly, there was lack of agreement on the basic concept of what constitutes the dominant species. Some recognised the tallest stratum as dominant, for example a grassland wooded with sparse low trees would still be classed with the trees as the dominant. Others recognised that the dominant species could occur in the tallest stratum, such as in a eucalypt grassy woodland in which eucalypt dominates or in the lower layers, such as in a sparsely wooded tussock grassland in which the grassland is the dominant (Crocker and Wood 1947, Beadle and Costin 1952).

As with botanical exploration, vegetation classification in northern Australia did not always focus on the region as a whole and there were numerous projects taking place throughout, most of which did not conform to an agreed national approach to mapping. In the Kimberley the work of Gardner (1942) which showed relationships between vegetation, climate and soil, built upon the 'Botanical Provinces' recognised and mapped by Diels (1906) by adding the Northern Botanical Province into which most of the Kimberley fell, and later dividing the province into 'Districts' (Beard 1979). The work of Blake (1938) resulted in the production of a vegetation map and account of the vegetation of western Queensland (Neldner 1993). A 1948 regional survey describing the plants, climate, geology, soils, plant ecology and ethnobotany of Arnhem Land was published by Specht in 1958.

The first uniform classification scheme for Australian vegetation was proposed by Beadle and Costin (1952) and it described the vegetation purely in terms of its floristics and structure and did not refer to the complex environmental factors affecting the community. This classification scheme was modified from international systems, and allowed the vegetation to be described without having to take account of factors such as successional status. It allowed a flexibility in emphasis from essentially floristic to essentially structural, although the combined floristic-structural classification was considered most valuable for Australian studies. Beadle and Costin (1952) considered that the mapping of vegetation units was an integral part of ecological description' (Neldner 1993).

Following the work of Beadle and Costin, vegetation classification was greatly influenced by the numerical method objective classification developed by Goodall (1953a, 1953b, 1954, 1961) and since that time, numerical methodologies have been at the forefront of techniques used worldwide. These methods provide the ability to interpret the relationships among sites, the validity of the classification for a site and the validity of species groupings (Neldner 1993). Numerical classification techniques have been widely used in the analysis and description of regional vegetation patterns, although most vegetation mappers in Australia have proceeded in a largely intuitive fashion (Kirkpatrick and Dickinson 1986). Numerical techniques are, however, increasingly being used in Australian vegetation mapping to assist in defining map units, for example in the Northern Territory by Wilson *et al.* (1990) and in the Ipswich region of Queensland by Elsol (1991).

1.2.3 Physiognomic vegetation survey and mapping

The prominence given to plant-environmental relationships rather than to an objective vegetation description created a degree of dissatisfaction amongst some mappers resulting in physiognomy gaining prominence from the 1950s as the basis for vegetation study. The importance of describing vegetation by its own characteristics and not by its habitat was emphasised by, amongst others, Du Rietz (1930, 1931) and Küchler (1947, 1949, 1956, 1967). The 1931 vegetation map of Australia by Prescott was fundamentally based upon structural vegetation units (Neldner 1993). Williams (1955) and Wood and Williams (1960) developed physiognomic vegetation maps of Australia based on the classification of Dansereau (1951) while Cochrane (1963) used Küchler's physiognomic classification (Neldner 1993) to develop another national vegetation map.

In 1970, Specht proposed a two-way structural classification scheme for vegetation, based on the life form, height, and projective foliage cover of the tallest stratum. He defined projective foliage cover (PFC) as the proportion of land covered by one or more layers of photosynthetic tissue directly above it (Specht 1970). Terms such as ‘wet’ and ‘dry’ were not used in this scheme, whereas previously they had been in use in describing Australian vegetation. It was further noted by Neldner (1993) that Specht (1981) maintained that the PFC of the tallest stratum provides a ready assessment of the photosynthetic potential of the plant community, and that the above-ground biomass is an important measure of how environmental factors may affect growth, although Specht’s hypotheses have yet to be subjected to adequate testing or experimental evaluation.

Webb (1959) produced a physiognomic classification of Australian rainforests, which first broke the rainforests into the divisions of tropical, subtropical and temperate, and then further on the basis of leaf size, tree layers and canopy closure, species dominance, emergents and special growth forms. He recognised 12 subformations that were later expanded to 20 by Webb (1968) and then to 23 structural types (Tracey and Webb 1975, Webb 1978, Webb and Tracey 1981). The classification of rainforest in Walker and Hopkins (1984, 1990) uses some of the structural/physiognomic features of Webb's classifications, plus the species composition of the tallest stratum and the structural formation.

Using height and foliage cover boundaries but with different class boundaries from those of Specht (1970), Gillison and Walker (1981) produced a classification of Australian woodlands. Gillison (1981, 1984, 1988) proposed that the modal attributes of leaf size, leaf angle, leaf type, and structural units of life form as the basis for a modal approach for surveys designed to develop predictive functions. This system allowed vegetation to be described using only physiognomic attributes, but did not classify the vegetation using a finite number of classes. Physiognomic attributes of growth form and foliage type, plus floristic and spatial attributes (height and density) were used by Johnston and Lacey (1984) for another classification for tree dominated vegetation in Australia.

As part of the project to map the vegetation of Western Australia, Beard and Webb (1974) developed a physiognomic classification system based primarily on Beard (1944, 1955), but using some features of Küchler (1949) and Dansereau (1951) and having PFC classes as defined by Specht (1970) (Beard and Webb 1974, Beard 1979, Neldner 1993). The vegetation map of the Kimberley region, with its Beard and Webb classification, formed the basis for the Western Australian section of this map.

The Queensland regional vegetation maps of Boyland (1984), Neldner (1984, 1991) and Neldner and Clarkson (1995) used a modified Specht (1970) structural classification which classified vegetation on the structure of the characteristic stratum, specifically the stratum which contributes most to the biomass of the site (Neldner 1993). Wilson *et al.* (1990) used a similar structural classification for the 1:1 000 000 vegetation map of the Northern Territory, while Carnahan (1976) and AUSLIG (1990) used a structural classification that combines features of Specht (1970) and Beard and Webb (1974). A structural classification scheme devised by Walker (1976), which is similar to that of Specht (1970), uses more height categories and has different limits for each category. Walker and Hopkins (1984, 1990) used the classification in the Australian Soil and Land Survey Handbook (McDonald *et al.* 1984) that is currently in use in Queensland land resource and ecosystem mapping programs. Sun *et al.* (1996, 1997) reviewed the classification systems being used in the major research organisations across Australia and identified the need for compatible data and classification systems to allow for comparison of vegetation data across jurisdictions.

The National Vegetation Information System (NVIS) was developed under the National Land and Water Resources Audit. This system uses a hierarchical approach to allow the capture of vegetation information at six levels. It is based on structural attributes and the dominant species of each layer (National Land and Water Resources Audit 2000). The most detailed level recorded is the sub-association level, as described by Beadle and Costin (1952). Much of the original vegetation mapping used in this project has already been compiled in NVIS.

1.2.4 Land resources and land systems mapping

During the period following the Second World War, the Division of Land Research and Regional Survey of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) commenced scientific research surveys and mapping as part of a land research series in Australia and New Guinea (e.g. Christian and Stewart 1953, Perry 1964, Perry *et al.* 1964, Galloway *et al.* 1970). The maps produced from the surveys showed landscape units, known as ‘land systems’, based on recurring patterns of topography, soils and vegetation. For each land system, land units based on particular soil types and vegetation types were described in detail, but not mapped (Beard 1979). The CSIRO approach was replicated in other areas including the Western Arid Region Land Use Study (WARLUS), which covered large areas of central and western Queensland, and in Papua New Guinea (Boyland 1974, 1980, Beeston 1978, McDonald 1981, Purdie 1990, Purdie and McDonald 1990, Turner *et al.* 1993) and in part is still in use today. In the Northern Territory, the former Conservation Commission of the Northern Territory undertook land system mapping in the 1980s. This work continues under the Northern Territory Department of Lands, Planning and Environment.

In many instances these land research studies are particularly relevant to the regions of northern Australia included this mapping project, as they preceded much of the north Australia vegetation mapping. Vegetation mappers often used the vegetation information in those reports as a reference (e.g. Beard and Webb 1974, Beard 1979, Boyland 1984, Wilson *et al.* 1990, Neldner 1991, Fox and Middleton *unpubl.*).

2. Study Area

Introduction

In this chapter we present an overview of the study area. Because of the distinctive nature of the current Australian vegetation, the long period of its evolution, and the extensive area of the continent covered by tropical savannas we initially present a continental overview, then focus on the mapped area. We first review the geological processes that have shaped the continent, then the changes in palaeoclimate and palaeoenvironments, before providing details of the current climate and modifying processes. We then discuss the way that these data combine to provide a phytogeographical view of Australia before presenting a brief review of the methods used to distinguish and define the discrete regions, ecological systems, and vegetation units used in the mapping of the Australian tropical savannas.

2.1 Geology

The Australian continent is generally geologically stable and made up of three major structural components (Mabbutt and Sullivan 1970, cited in Beadle 1981), the Precambrian Shield; the central basin of relatively young sedimentary rocks; and the eastern uplands (Figure 2.1).

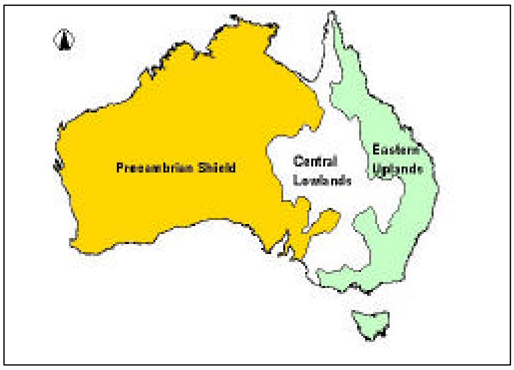

Figure 2.1 Australia's Physiographic Structure

The development of the Australian landmass occurred in different parts of the world, with the present continent being made up of several pieces of continental crust, which later joined together over a long period (DMEWA 2000). For example, about 1830 million years ago the Kimberley region existed as part of a separate continent that collided with the rest of northern Australia. Tectonic movement caused upheavals of the earth's crust leading to the deformation and metamorphism characteristic of the North Australia Craton (NTGS 2000).

The cratons and craton covers that form the Australian continent date from two structural regimes. The Precambrian Shield dates from orogenies in the Archaean and Protozoic Eras and the Eastern Uplands and Central Lowlands from orogenies in the Palaeozoic, Mesozoic and Cainozoic. A brief review of the geological history of the Australian continent during the Phanerozoic Eon, characterised by the proliferation of life, is presented below.

PALAEOZOIC 545 – 250 Ma

Cambrian: Widespread volcanism in northwest Australia and limited volcanism in the Tasman Fold Belt System in the east. This was followed by a marine transgression of the North Australia Craton with areas of deposition, e.g. in the Bonaparte basin, the formation of evaporates in northern and central lowlands, and extensive volcanic activity commencing in the east.

Ordovician: Uplift in the southeast, marine conditions persist in the Bonaparte Basin and return to the central lowlands. The Larapinta Sea establishes across the North Australia Craton with the deposition of organic-rich shales and siltstones. Volcanism continues in the east. The end of the Period sees warm and dry conditions, withdrawal of the sea, and a re-establishing of depositional and evaporitic processes, and extensive igneous activity and broad regional uplift in north Queensland.

Silurian: Uplift and erosion of the craton continues with extensive deformation along the east margin, central and western Australia have an arid climate and thick salt beds and wind blown sands are deposited, and in eastern Australia marine volcanic activity continues. Late in the Period the first known land plants in Australia appear.

Devonian: Fluctuations in sea levels, deposition of evaporates and sands during dry periods and the growth of reefs and deposit of sands and carbonates during wet periods. It is generally warm and dry in the northwest, and shallow seas persist and coral reefs grow, particularly in the Bonaparte Basin and Arafura Sea. In the central lowlands block, uplifting results in the formation of extensive alluvial fans, and on the east coast a coastal plain separates deep ocean trenches and inland basins containing east-flowing river systems.

Carboniferous: Shallow seas persist in north and west Australia. In northeast Queensland, extensive vulcanism continues and gives rise to the Newcastle Range and Featherbed Volcanics. An extensive system of lakes and rivers is established in the Galilee Basin. A dramatic cooling marks the close of the Period and there is glaciation in southern Australia with intrusions of ice from the Antarctic. Further north uplift and erosion around the Bonaparte Basin result in fast flowing rivers and the deposition of deltaic alluviums. Volcanism continues in northeast Queensland.

Permian: Ice covers the south of the continent but conditions are temperate elsewhere, a volcanic belt stretches from Sydney to Cairns. Conditions warm, the ice retreats and drops sediments that are washed into basins and onto continental shelves. A return of a cooler climate sees glaciers in southern areas but then gradual warming and an increase in sea levels causes the inundation of coastal areas, particularly in the Bowen, Carnarvon and Bonaparte Basins. Late in the Period large areas of eastern Australia are uplifted and folded and a prolonged retreat of the sea begins with the formation of extensive deltas, particularly in the Fitzroy Trough and Bonaparte Gulf, from material eroded from the central highlands. Volcanic activity continues in northeast Queensland.

MESOZOIC 250 – 65 Ma

Triassic: shallow marine conditions persist in the west and northwest but by the end of the Period these areas are uplifted, elsewhere the continent is generally above sea level. In central and eastern Australia sands and silts accumulate in deltas and lowlands, uplift occurs in the east and vulcanism continues along the coast. Wetter conditions and the deposition of coal forming material recommence late in the Period.

Jurassic: river systems expand and deposit alluviums into coastal basins that also accumulate coal forming deposits and then a sandstone capping. Mid Period Gondwana starts to rift and sedimentation occurs in the resulting intervening lowlands. Shallow marine incursions and sedimentation of coastal basins occurs in the late Jurassic.

Cretaceous: Sedimentation in rivers and lakes continues with coal formation in swampy areas. Mid-period worldwide sea level rises cause most of the continent to be covered by shallow seas but in the east uplift and volcanism form mountain ranges. Later the seas retreat and in the east a major fracture gives rise to the Lord Howe Rise and the formation of the Tasman Sea.

CAINOZOIC 65 – 0 Ma

Tertiary: By the start of the period most continents had assumed their present global positions but Australia and Antarctica remain linked until the Mid-Tertiary. Australia begins a period of isolation that extends to the end of the Period when it collides with the Eurasian terranes. In the south limestone is deposited in a shallow sea over the current Nullarbor Plain; in the southeast warm wet and humid conditions that extend through the Mid-Miocene result in extensive deposition of coal forming materials. Mid-Tertiary major tectonic activity uplifts eastern Australia with vulcanism along the coast. The climate dries in the latter part of the period.

Quaternary: Broad scale tectonic activity abates but in central regions downwarping and faulting results in the formation of a series of lakes, now restricted to the playas in the Lake Eyre Basin, while in south-eastern and northern Queensland volcanic activity continued until c. 5000 years ago. Pleistocene glaciation events caused sea level and climate fluctuations with land bridges to New Guinea and Tasmania existing until the last few thousand years, and the Great Barrier Reef formed on the eastern coastal shelf.

2.2 Soils

A determinant of the vegetation at a site is the soil. Harris (*in prep.*) observes that this parameter 'may have a major affect on [the] biota because of differences … in structure and composition resulting from varied lithologies modified by climatic factors'. Soil type, chemical characteristics and nutrient levels affect the vegetation that grows on it (Fox, M.D. 1999) and in other broad scale vegetation mapping, e.g. in the GAP Analysis Program (Scott *et al.* 1993), these parameters have been found to discriminate among different vegetation types in the same ecoregion.

Australian soils have "a number of unusual morphological features, either not evident or rarely seen in the soils of other continents" (Stephens 1977) and in the study area, deep cracking Grey and Brown Soils, clays, Black, Grey and Brown soils with gilgai formation, and laterised and leached soils are common and widespread. Australian soils are generally old, and often shallow and nutrient poor, particularly in respect to nitrogen, phosphorus and potassium and in a range of trace elements (Williams and Raupach 1983) – a fact made obvious by the brief but dramatic effects of the nutrient 'pulse' that follows fires on the savannas. In the study area the lateritic podzols, red earths, and desert sandplains are particularly impoverished in respect to potassium, copper, zinc and manganese (Stephens 1977). The reasons for this are that Australia is an old and stable landmass with little recent tectonic, volcanic or glacial activity to replenish and/or produce young and fertile soils, that the ineffectual and often seasonal continental drainage is poor and tends to flow into central areas which experience high summer temperatures and evaporation rates, and that the presence of extensive areas of limestone and basic igneous rock substrate limits the types of weathering that can occur during the formation of soil.

In the Australian tropical savannas, the alternating warm wet and dry periods and the associated conditions of oxidation and reduction interact with metal-rich soils, e.g. bauxite on Cape York Peninsula in Queensland and in Arnhemland in the Northern Territory, and haematite in northern Western Australia, to produce duricrusts and texture-contrast soils that present difficult habitats for plants and which have a tendency to erode when disturbed. In some areas leaching of nutrients during periods of seasonally high rainfall further reduces the productivity of soils. This has resulted in the extensive diversification of tolerant and resilient taxa, e.g. *Aristida* and *Triodia* in the Poaceae, *Banksia* and *Grevillea* in the Proteaceae, *Eucalyptus* and *Corymbia* in the Myrtaceae and *Acacia* in the Mimosaceae. Many of the grasses contain lower levels of nutrients than exotic species while many of the trees and shrubs have scleromorphic and often-unpalatable foliage and an intolerance of artificially elevated levels of some soil nutrients. These facts present the conundrum that in order to pursue many farming and grazing activities the prevailing soil nutrient regimes and plant species compositions often need to be modified. This is part of the reason for many of the changes in the vegetation observed both in the mapped area, and more particularly in adjoining areas, e.g. the Brigalow Belt South in Queensland.

The landforms and associated soils of the area map are broadly defined in the land zone description (Appendix 1.1). Specific data on both are included on detailed site survey forms and in databases for the Queensland portion of the map. Soil descriptions generally follow Stephens (1962) Great Soil Groups although land zone descriptions use Isbell's (1996) Soil Orders format (see Appendix 2.2 for a comparison). Soil data for the Northern Territory and northern Western Australia portions are derived from Northcote *et al.* 1960-68, Beard and Webb (1974), Beard (1979), Wilson *et al.* (1990) and BRS (1991b). The dominant soil types (from Stephens 1977) in the map area are summarised in Table 2.1 that relates soil types to bioregions. For information on bioregions see 2.6 Biogeographic regionalisation and 5.3 Vegetation of the bioregions.

Table 2.1 Summary of dominant soil types in the area of the map of the vegetation of the Australian tropical savannas.

Soil Type	**Distribution by bioregion**
Skeletal	Einasleigh Uplands, Gulf Fall and Uplands, Pine-Creek Arnhem, Victoria Bonaparte and North, Central Kimberley and Mt Isa Inlier.
Deeply leached siliceous sands	Eastern Cape York Peninsula
Podzols and Solodic Soils	Low-lying areas in eastern Cape York Peninsula, the Gulf Plains and Darwin Coastal
Lateritic Podzols	Arnhem Coast, Central Arnhem and Arnhem Plateau
Lateritic Red Earths	Northeast Cape York Peninsula, Darwin Coastal, Pine-Creek Arnhem, Sturt Plateau and Ord-Victoria Plains
Yellow Earths, Grey Earths and Solonetzic Soils	Central Cape York Peninsula and Central Kimberley
Heavy texture Grey, Brown and Red Soils	Gulf Plains, Mitchell Grass Downs, Gulf Fall and Uplands and North Kimberley
Desert Sandplains and Desert Sandridge Soils	Dampierland and Ord-Victoria Plains

2.3 Climate

2.3.1 Changes in the Australian palaeoclimate and environments.

The current Australian environments and their flora are the result of evolutionary processes based on landforms, changes in global climate and the palaeolatitude of the Australian landmass (Frakes 1999). These processes have modified the flora of this continent over a period of >540 million years and a summary of them is presented here.

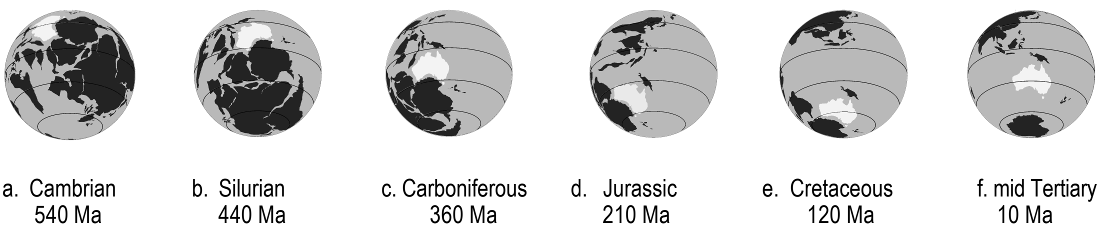

Figure 2.2 Position of the Gondwana and Australian landmasses during the Phanerozoic.

Precambrian This is the period of the origin of life, of photosynthesis, eukaryotic cell organisation and multicellular life on the planet. By the end of the period the protective ozone layer had formed (Beeunas and Knauth 1985, cited in Hill *et al.* 1999), atmospheric oxygen levels were sufficiently high to allow oxygenic photosynthesis to occur, algal life forms were well established and the transition from aquatic to terrestrial existence had taken place (Hill *et al.* 1999). At the end of the Proterozoic the Australian landmass was located in low to middle northern latitudes and was part of a super-continent centred on the equator and extending to the South Pole. The climatic data for the Precambrian are sparse but extensive glaciation of the Australia segment is thought to have occurred a few tens of millions of years before the start of the Phanerozoic Eon.

Palaeozoic This is the first era of the Phanerozoic and saw the diversification of the terrestrial flora. The initial periods, the Cambrian (Figure 2.2a) and Ordovician, were warm. The Australian segment of Gondwana lay between 5° and 30°N in the Cambrian and 20°N and 20°S in the Ordovician, and precipitation was higher than now.

The earliest vascular plants, the herbaceous Baragwanathia Flora, appeared by the Late Silurian (Edwards and Fanning 1985) (Figure 2.2b). In this and the Devonian periods the Australian segment started a slow but accelerating movement south, being between 5° and 35°S for most of the period; the climate remained warm but northern areas showed signs of drying. Plant life on the Australian segment increased dramatically in the Late Devonian with increased pedogenesis and stabilisation of landforms, increased marine fertility and burial of organic matter, and a draw down of atmospheric CO_2 levels and a consequent global cooling (Algeo *et al.* 1995 cited in Frakes 1999).

The Late Palaeozoic is characterised by the rapid movements of crustal sections in the Carboniferous; Pangaea accreted from Gondwana and Laurasia (Figure 2.2c) and the Australian segment moved to higher latitudes (50-80°S). A cooler and drier phase commenced and extensive glaciation occurred. Late in the Permian the climate warmed again, precipitation increased and extensive coal forming materials were deposited. Some models (Kutzbuch and Ziegler 1994; Fawcett *et al.* 1994) indicate that monsoonal conditions extended over much of Australia during this period.

Mesozoic This was an Era of change, although the Australian landmass remained at high latitudes the climate warmed through the Triassic to the mid Jurassic (Figure 2.2d) before a drop in temperatures in the Late Jurassic and Early Cretaceous sufficient for the formation of coastal ice off the east coast of Australia. Pangaea, Gondwana and Laurasia started to fragment in the mid Mesozoic. Temperatures rebounded in the Late Cretaceous (Figure 2.2e) through to the mid/late Miocene of the Tertiary. The deposition of coal forming material continued through much of this Era and is indicative of mild temperatures and lush vegetation growth. While the earlier Periods of this Era witnessed the zenith of the gymnospermous flora, by the Late Cretaceous the angiosperms were well established (Douglas 1994) and spreading across the landscape (Drinnan and Crane 1990, Dettmann 1992). The Mesozoic was brought to an abrupt halt by the impact of a large asteroid with the Earth in the K-T Boundary Event, this augmented environmental changes already underway due to extensive vulcanism and sea level fluctuations (Hill *et al.* 1999).

Cainozoic (Tertiary) The palaeoclimate data from this Period is extensive and supported by a fossil record that is largely derived from extant taxa, and other data sets, e.g. atmospheric gas isotope analyses, and ocean-bed cores. The continent began a rapid move northward and as a consequence experienced warming and higher levels of humidity that contrasted with overall global cooling and drying. These opposing trends saw an overall warming from the Palaeocene through to the mid Miocene (65 –10 Ma) when cooling became the norm. Australia separated from Antarctica during this period (Figure 2.2f). The late Tertiary, from the mid Miocene onwards, is characterised by drier conditions and increasing aridity. This change was substantially complete by 6.6 Ma and by 2.5 Ma the climatic and vegetation conditions approached those currently prevailing.

Cainozoic (Quaternary) The period from 1.8 Ma to the present and the climatic data for it are similar to those described below for the contemporary climate. The continent had arrived at its present location with a third of the land mass north of the Tropic of Capricorn and a continuing northward movement of c. 3 cm per year (AGSO 1999). The Period was subject to fluctuating temperatures; periods of glaciation, and sea level rise and fall. The arrival of aboriginal people in Australia in the late Holocene changes fire regimes and possibly results in the demise of the 'megafauna', although the cause of these extinctions is by no means certain (Nicholson 1981). The arrival of Europeans in the last 250 years initiates a period of rapid change in natural ecosystem functions (Boulter *et al.* 2000).

2.3.2 Contemporary Climate

The interaction between vegetation and climate, particularly rainfall and temperature, are important factors in determining plant community distribution (Beadle 1981 and Fox, M.D. 1999). Northern Australia experiences a range of climatic influences that are largely tropical, although inland parts, especially areas of higher altitude, can experience cold minimum temperatures (<3^0 C) commonly associated with the temperate regions further south. In general the region has warm to hot (25-30^0 C) and rainfall is influenced by summer monsoon low pressure systems along the north coast and by the south easterly trade winds along the east coast, although these do not penetrate much more than about 500 kilometres inland (Ellyard 1994, Beadle 1981). The monsoons, which are highly reliable, are active from about November to March and are followed by a distinct seasonal drought for the remainder of the year (Fox, M.D. 1999). It is this distinct seasonal 'wet' and 'dry' pattern that typifies savannas around the world.

In addition to monsoon activity, tropical cyclones form over the oceans surrounding northern Australia and while generally tracking southwards their paths are often erratic (Holland and McBride 1997). After crossing the coast they can form rain-bearing depressions that travel great distances inland and produce extreme rainfall events.

Rainfall

A map of generalised annual rainfall isohyets for northern Australia is presented in Figure 2.3. It shows a decrease in annual precipitation from coastal areas to the interior of the continent. These isohyets subdivide the project area into several rainfall zones.

A semi-arid zone receiving 250 to 500 mm rainfall per annum occurs in southern parts of the project area (Figure 2.3), particularly central and western Queensland and the Kimberley coast south of Broome. The rainfall is highly variable depending on the extent to which moist air associated with monsoonal and cyclonic activity penetrates inland.

A sub-humid zone, which receives between 500 and 1000 mm of rain per annum, forms an extensive band from about Broome, Western Australia, across northern Australia to about Rockhampton in Queensland (Figure 2.3). This sub-humid zone includes the variably wooded grassy landscapes that typify tropical savannas.

A humid zone, which receives between 1000 and 1500 mm rainfall per annum, stretches from the northwest coast of the Kimberley across the 'Top End' of the Northern Territory and through much of Cape York Peninsula (Figure 2.3). Seasonal rainfall variation in this zone is less pronounced than further inland.

A wet tropical zone receiving in excess of 1500 mm occurs on the northeast coast and although most of this zone is within the Wet Tropics bioregion and not part of the project area, some wet tropics outliers do occur. These are primarily found in the Einasleigh Uplands and Brigalow Belt Bioregions as well as important and significant areas on northern and northeastern Cape York Peninsula (Figure 2.3). This zone is influenced by both the southeast trade winds and the summer monsoon, while the orographic effect associated with coastal mountains also contributes to high rainfall in some areas.

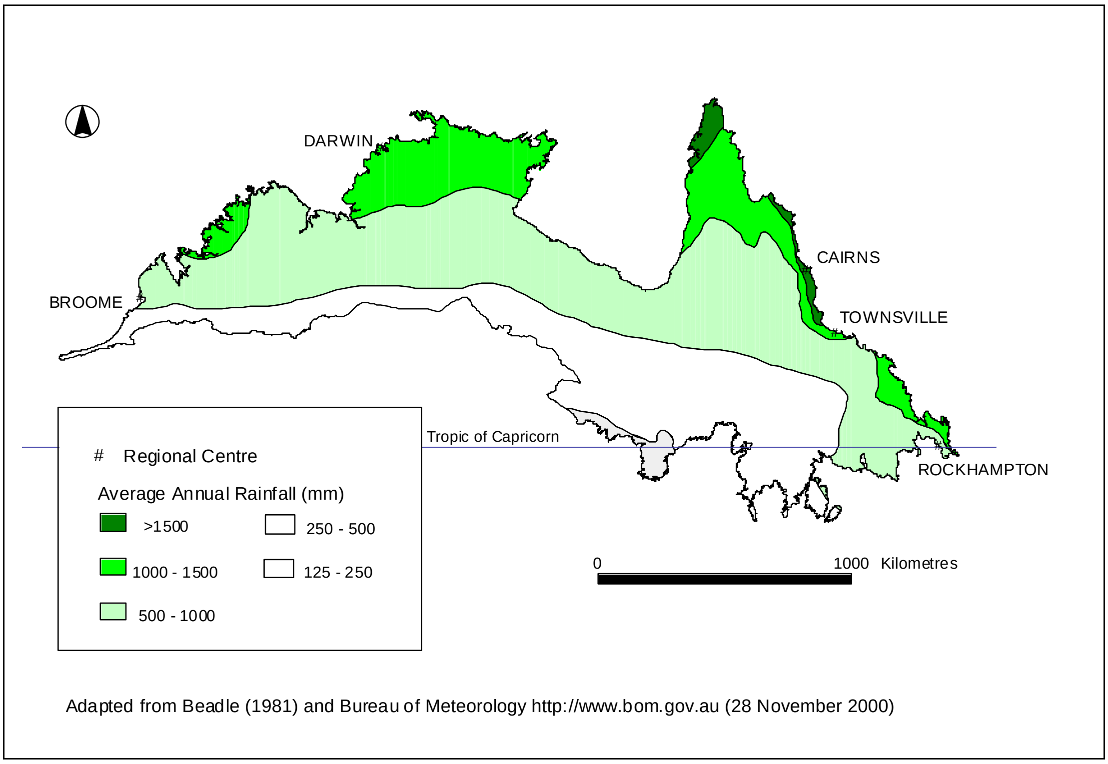

Figure 2.3 Generalised rainfall isohyets for northern Australia.

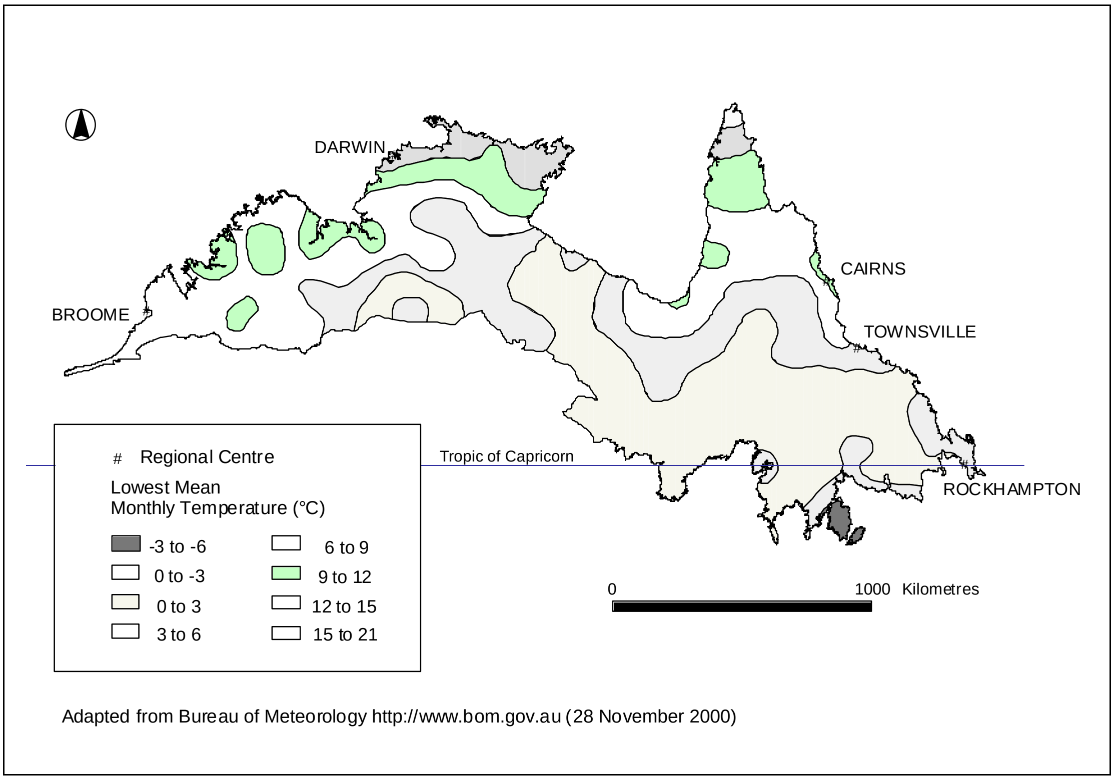

Figure 2.4 Lowest minimum mean monthly temperatures for northern Australia

Temperature

Temperatures over the whole of the Australian continent are relatively high (Beadle 1981) with tropical areas much warmer than equivalent tropical regions elsewhere in the world (Fox, M.D. 1999). Summer maximum temperatures in northern Australia are consistently high, but daily and seasonal variations increase with distance from the coast. This becomes significant when considering minimum temperatures.

The importance of minimum temperature with regard to plant distributions (Beadle 1981) has particular relevance in the project area. In northern Australia, the wet tropics and coastal zones are predominantly frost-free, but further inland, especially at higher altitudes, frosts are a regular occurrence. These low night temperatures and frosts may restrict the growth of tropical-adapted species during the winter period (Neldner 1991). Areas with the potential for frost are evident in the <3 °C lowest mean monthly isotherms shown in Figure 2.4. They are largely found in the eastern half of the project area, extending from central Queensland along the west of the Mt Isa highlands to the Gulf of Carpentaria, with another intrusion extending northward along the high ranges on the western side of the Great Dividing Range.

2.4 Fire

Apart from Antarctica, Australia is the driest continent and as a consequence fire is an integral part of the environment. Adaptation to fire by the Australian flora has occurred over a long geological period, with much of the flora and most of the major vegetation types being scleromorphic and regarded as fire-tolerant and some even as fire-promoting (Kemp 1981, Singh *et al.* 1981, Beadle 1981, Lacey *et al.* 1982, Hodgkinson *et al.* 1990, Fox, M.D. 1999). Fires caused by lightning strike are likely to have always played an important role in the ecology of tropical savannas, especially at the beginning of the wet season when lightning activity is at its peak - the implication is that fire adaptation was an integral part of the evolution of pre-human Australian flora (Wilson *et al.* 1990, Beadle 1981).

In historical terms the present and past characters of the Australian savannas is the result of interactions between fire, grazing and climate (Lacey *et al.* 1982, Wilson *et al.* 1990). The Australian indigenous people, the Aboriginals, are likely to have been using ‘fire-stick farming’ as a land management tool for tens of thousands of years and the probable increase in fire frequency as a result of burning by them is likely to have shaped the essential character of the present day vegetation (Jones 1969, Nicholson 1981, Stocker and Mott 1981, Wilson *et al.* 1990).

Hill *et al.* (1999) propose that the current superdominance of *Eucalyptus* and *Corymbia* in Australia may be the result of the fire adaptive abilities of the genus in coincidence with the increase in burning associated with the arrival of Aboriginal people, although fire is not the only determinant for tropical Eucalypt distribution. While fire is thought to be the major factor controlling the spatial distribution of fire-sensitive species such as *Callitris intratropica* (Bowman and Panton 1993a), its influence on the distribution of tropical Eucalypts is not as pronounced. In tropical areas, fire is widely believed to be the major factor controlling the monsoon rainforest/savanna boundary (Hopkins 1983). However in northern Australia, only low numbers of rainforest seedlings establish in fire-protected Eucalypt woodlands (Bowman *et al.* 1988, Fensham 1992, Bowman and Panton 1995). Soil fertility, soil moisture and mycorrhiza may also control rainforest seedling establishment (Bowman and Panton 1993b). Eucalypt regrowth is extremely resilient to burning; Wilson and Bowman (1987) reported 83% recovery of woody sprouts less than two metres tall despite them experiencing 50-100% crown scorch (Neldner 1996).

Fire intensity increases with time after the last summer rains. Bowman (1988) and Bowman *et al*. (1988) report little floristic or structural change in woodland vegetation with different experimental burning regimes after 12 years. These authors propose that dry season moisture supply and overstorey competition (Bowman 1988) or edaphic factors (Bowman *et al*. 1988) primarily determine the structure and floristics of eucalypt woodland understoreys. However Lonsdale and Braithwaite (1991) state that more caution is required in interpreting these fire experiments and that it is premature to conclude that the timing of annual fires has little effect on vegetation structure or floristics. They report that a single unusually intense fire caused changes in the relative abundance of species; no species were lost but a substantial loss of biomass and vegetation structure occurred. Braithwaite and Estbergs (1985) proposed that regular fires caused the absence of well-developed sapling layers in *E. tetrodonta* woodlands. Results for most woody species in the Bowman and Panton (1995) study supported this conclusion. However these authors suggest that other factors such as intraspecific competition may also be involved (Neldner 1996).

Further changes to the floristic composition of Australian tropical savannas due to the introduction of new pasture species and the subsequent grazing pressure on the savannas have coincided with a change in fire regimes throughout the Australian continent since European settlement. Changed fire regimes are reported to have a number of effects but the significance of these and certainly their management, are not necessarily well understood. They do serve, however, as indicators of changes that are occurring. For example:

- In parts of the tropical savannas fire exclusion and intense grazing patterns may result in an increase in the presence of woody shrubs (Stocker and Mott 1981, Wilson *et al.* 1990, Russell-Smith 1996, Russell-Smith *et al. in press*).
- In Kakadu National Park comparisons between plots that were burnt and plots from which fire was excluded over a twenty year period indicated that rainforest tree species do not readily colonise unburnt savanna wooded with *Eucalyptus* spp. (Bowman and Panton 1995).
- In a review of data on the effects of fire in relation to rangeland management in the high-rainfall Kimberley rangelands, Craig (1997) concluded that "an increase in broad-scale early dry season burning is likely to reduce the extent of later more destructive fires while providing other benefits for cattle enterprises".
- Intense, late-season wildfires are having a catastrophic effect on native fire-sensitive species, communities and habitats (Russell-Smith *et al. in press*).

The dynamics of Australia savannas are influenced by the combined effects of fire frequency, fire intensity, season of burning, grazing and rainfall (Lacey *et al.* 1982). In discussing the temporal variability of vegetation, Wilson *et al.* (1990) point out that the long-term effects of fire are unclear, as few fire-exclusion studies have been reported. In an effort to identify and define key fire management issues across northern Australia, a major research project led by J. Russell-Smith is underway into broad scale patterning of fire using satellite imagery. Part of this research involves examining fire history over a number of years. Data from monitoring plots on lands of various tenures are used to explore relationships between fire regimes and vegetation responses (TS-CRC 1998). This type of study, particularly the component that documents fire history, is needed to develop an understanding of changes in vegetation pattern and distribution as a result of fire.

In order to assist building an understanding of human burning regimes over a far longer period, Craig (1997) highlights the urgent need to document the traditional knowledge of Aboriginal people in relation to landscape and fire. One issue to be resolved before traditional burning can resume in many areas is the perception within some non-Aboriginal communities that regard Aboriginal landscape burning as uncontrolled (Cooke 1998, Cooke *in press*).

2.5 Phytogeography of Australia

In previous sections of this chapter we presented details of the geophysical history and processes and climate that gave rise to the Australian environment and the floristic components of them. In this section we present a synthesis of the data to explain the characteristics and distribution of the contemporary Australian vegetation.

J. D. Hooker (1860) was the first to present a phytogeographical analysis of the Australian flora, recognising elements that he named for their affinities, i.e. Indian, Australian, New Zealand and Polynesian, Antarctic, South African and European. Hooker's analysis was remarkably prescient considering the state of knowledge of plate tectonics, continental drift and palaeoecology and palaeoclimatology at the time. He recognised that the pattern of trans-oceanic affinity amongst floras was an ancient one and that they were the relics of a previous widespread and possibly global flora. It was not until Wegener's (1915) presentation of the theory of continental drift that the reason for biological distribution patterns became apparent to biologists, although it took substantially longer for the concept to gain universal support.

In 1896 Spencer used faunal grouping to divide Australia into three subregions, Torresian, Bassian and Eyrean. Subsequent authors recognised the validity of these regions in studies of the distribution of both the flora and the fauna, although Burbidge (1960) preferentially used the names Tropical, Temperate and Eremaean for them. Schodde (1989) produced a modified version (Figure 2.5) that is most widely used today; it retains the three previously described subregions, but reflecting recent advances in our understanding of the derivation of the current Australian vegetation and the effects of plate tectonics, included the Tumbuna and Irian rainforest elements.

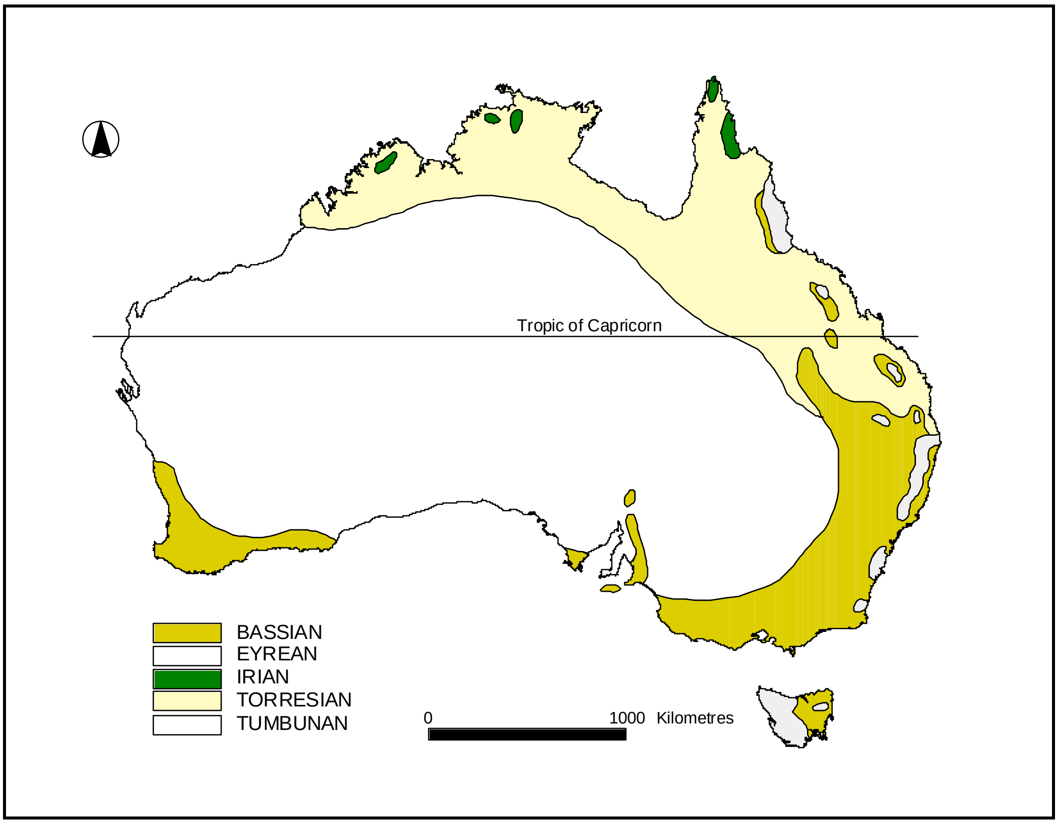

Figure 2.5 Biotic regions of Australia

The Torresian element comprises tropical eucalypt woodlands and semi-deciduous forest growing in northern areas with a monsoon climate. Areas of this element also occur in lowland New Guinea and in Malesia.
The Bassian element comprises the temperate woodlands and forest with a sclerophyll understorey dominated by *Eucalyptus* (Myrtaceae), *Acacia* (Mimosaceae), Proteaceae and Epacridaceae. The Eyrean element consists of arid-adapted vegetation including Chenopods, hummock-grasses (*Triodia*) and shrublands and woodlands of *Eucalyptus* and *Acacia* spp. These three units equate to Barlow's (1981) Autochthonous element.

The Tumbuna element is cool temperate to subtropical rainforest dominated by *Nothofagus*, and Podocarpaceae, Lauraceae, Myrtaceae, Proteaceae, Cunoniaceae, Eleocarpaceae and Winteraceae that is found in fragments of Gondwana with suitable climates, e.g. upland southern New Guinea, New Zealand, upland Africa and southern South America. In north Australia the Tumbuna element is present only in the Wet Tropics and accordingly does not appear on the map of the Australian Tropical Savannas. The Irian element represents rainforest with Malesian affinities and while of restricted extent in Australia small areas of it occur in the mapped area, they include the closed forest communities on Cape York Peninsula, in Arnhem Land in the Northern Territory and in the Kimberley of Western Australia.

The biotic subregions suggested by Spencer and amended by Schodde relate well to the broad vegetation elements (Barlow 1981; Nelson 1981) but each contains disjunct representations of other groups, for example outliers of cold climate flora in northern montane refugia and of Irian components in the Torresian.

Beadle (1981) recognised three ancestral components of the Australian flora; they were the *Nothofagus* assemblage, the broad-leaved '*Cinnamomum'* assemblage, and the herbaceous cold-climate assemblage. Barlow (1981) subdivided these assemblages into five floristic elements

- Pangaean
- Gondwanan
- Autochthonous
- Post-Miocene, and
- Recent Invasive.

These elements were utilised by Specht (1981) in his description of the major Australian plant formations that were used by us in the mapping of the Australian Tropical Savannas. More recently Barlow (1994) summarised the phytogeographic composition of the Australian vegetation as indicated in Table 2.2.

Table 2.2 Phytogeographic composition of the Australian vegetation.

Element	Subelement	Description
1. Gondwanan		Derived directly from the original Gondwanan flora present in Australia.
	1a. Relict	Present day survivors of the humid Gondwanan flora.
	1b. Autochthonous	Highly endemic, derived in response to climatic cycles under geographic isolation.
2. Intrusive		Reached Australia after separation from Gondwanaland.
	2a. Tropical	Malesian plants of post-Miocene inception, although probably ultimately of Gondwanan derivation
	2b. Cosmopolitan	Widely dispersed taxa of high dispersibility
	2c. Neoaustral	Temperate species of northern hemisphere derivation

The Relict subelement is the least common but most widely distributed; most of the taxa from this period are now extinct but recognisable elements extant in Australia are *Callitris*, *Agathis*, *Wollemia*, *Cyathea* and *Macrozamia* species. A few taxa, e.g. *Cycas,* reflect a pre-Gondwanan derivation and may be referred to a 'Pangaean' element.

The Gondwanan elements are restricted to areas previously part of the supercontinent and extant taxa often extend across several continents, e.g. *Nothofagus* and representatives of the families Lauraceae, Moraceae, Myrtaceae, Proteaceae and Mimosaceae, although several distinctive families, e.g. Idiospermaceae and Austrobaileyaceae, are now restricted to single species in Australia. Elements of Gondwanan closed forest vegetation persist in small areas of northeast Queensland with 40% of the 165 genera present being endemic (Barlow and Hyland 1988 cited in Barlow 1994).

The Autochthonous element is derived from ancestral Gondwanan taxa that diversified in response to changing environmental conditions on the Australian plate with mid-Miocene drying. These taxa are typically scleromorphic, have a high level of endemism and many, e.g. *Eucalyptus*, *Grevillea*, *Casuarina*, *Xanthorrhoea, Triodia* and *Astrebla,* typify the contemporary Australian vegetation.

The intrusive elements of the Australian vegetation consist of three discrete units; the first is the tropical Malesian plants of predominantly Gondwanan derivation, Schodde's Irian Element, which entered from the north as the Australian continent closed on the Eurasian terrains. This element includes taxa now part of the tropical rainforests of the northeast, e.g. *Rhododendron, Agapetes, Licuala* and some *Poa* species but many of the taxa typical of the Asian rain forests, e.g. of the Family Dipterocarpaceae, do not extend to mainland Australia. Closed forest communities including those taxa that do reach Australia occur on Cape York Peninsula, for example in the Lockerbie Scrub, in small patches in the Northern Territory and the Kimberley and in the case of *R. lochiae* and *Licuala* in the Wet Tropics, as far south as Tully.

The second intrusive element is the cosmopolitan taxa that are easily dispersed. Twenty- five percent of the flora of the arid zone Eyrean element is representative of families, e.g. Poaceae, Aizoaceae, Asteraceae and Brassicaceae that are widespread in similar habitats around the world. Much of the remaining vegetation e.g. *Acacia* spp, is derived from genera more common in adjoining more mesic areas. The species composition in this zone supports the relatively recent evolution of it, c. 35 Ma, and Schodde's suggestion that it is a 'sink' with species primarily derived from the surrounding scleromorphic vegetation.

The third intrusive element is of northern hemisphere temperate species. Some earlier workers considered that the Australian alpine flora primarily consisted of Neoaustral taxa but data supporting this hypothesis is not as strong as initially thought (see Barlow 1994). There is little evidence to suggest extensive migration of temperate northern hemisphere plant species into Australia and of those that have many are of Gondwanan origin. As in the Eyrean Zone the flora is dominated by species derived from long-established Autochthonous vegetation associations (Barlow 1994).

In addition to the above sources and associations there is one other aspect of the phytogeography of Australia that needs to be recognized. This is the species introduced, either inadvertently or deliberately, by people. Some species, e.g. the tamarind *Tamarindus indica*, probably introduced by visiting Macassan fishermen prior to the arrival of Europeans, form a minor part of the flora but others, e.g. *Mimosa pigra, Acacia nilotica* and *Prosopis** spp. are sufficiently numerous and widespread to substantially modify the vegetation of the mapped area.

2.6 Biogeographic regionalisation

In his book on biogeography, Dansereau (1957) described environmental processes as being essentially of three kinds: “climate, soil (or site) and the living organisms themselves”. This concept was a continuation of the awareness amongst ecologists that had been developing through most of the first half of the twentieth century about the intrinsic relationships between vegetation and environmental factors.

The concept of plant groupings has existed in Australia for many years. In 1926, for example, Clarke (cited in Beard 1979) recognised and delineated 16 ‘natural regions’ in Western Australia and over the years others such as Burbidge (1960) developed groupings such as phytogeographic zones, which generally equated to Clarke’s earlier natural regions. There was, however, no clear match between the work of Clarke (1926) and that of Beard (1979) in the Kimberley region, perhaps due to the fact that knowledge of the vegetation in that region had increased since Clarke’s time. Beard refined the delineation of these zones with the vegetation mapping series of Western Australia and the development of Botanical Districts that became the basis for ‘bioregions’ in Western Australia.

In Queensland, Stanton and Morgan (1977) built on earlier work, including that of Burbidge (1960), and the substantial land system mapping information produced by the CSIRO, to develop 13 bioregions for that state. The bioregions were based on broad landscape patterns derived from major structural lithologies, climate and changes in floristic and faunistic assemblages (Sattler and Williams 1999).

Establishing a framework for the assessment of conservation status and to set priorities for a national reserve system depended on cross-jurisdictional agreement about the division of Australia into biogeographic regions. The development of that framework resulted in the Interim Biogeographic Regionalisation of Australia (IBRA) (Figure 2.6). This regionalisation summarised patterns and aggregated information across State and Territory boundaries (Thackway and Cresswell 1995).

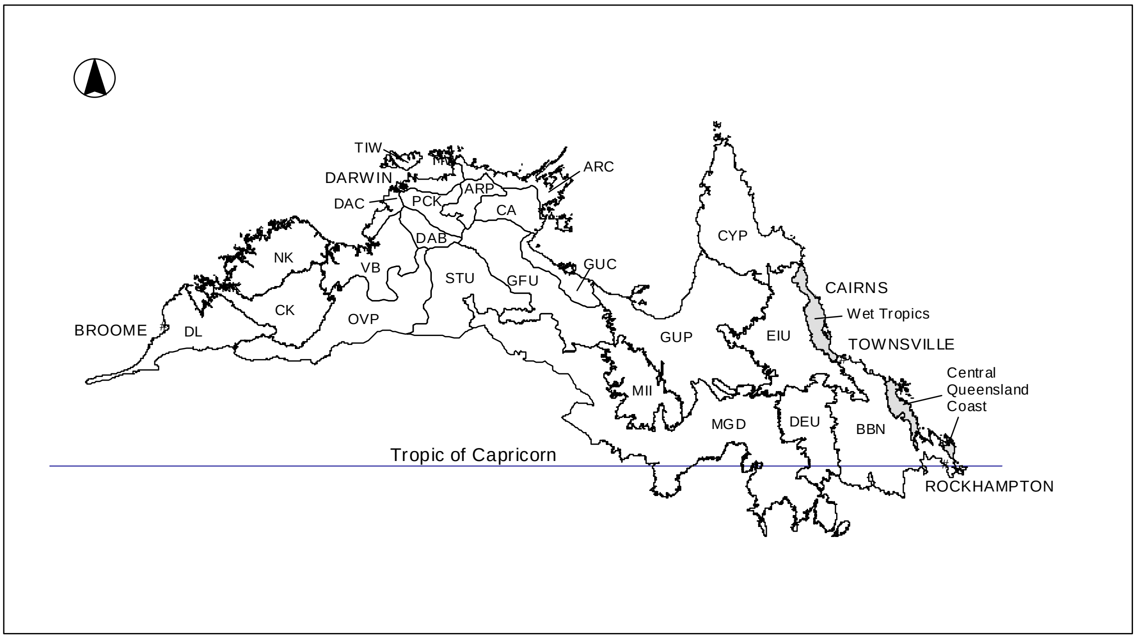

Figure 2.6 The biogeographic regions used to define the area of the map of the Australian tropical savannas. Adapted from the Interim Bioregionalisation of Australia v.5.0 (Environment Australia 2000).

Prior to the national approach of IBRA, biogeographic regions had been defined for some Australian States and not others. A national focus provided the opportunity to interpret and integrate bioregions across State and Territory boundaries. Attributes used in developing IBRA were climate, geology, lithology, landform, vegetation and flora and fauna (Thackway and Cresswell 1995). The use of bioregions to define the extent of tropical savannas is possible because of the interpretation of ecological patterns. However, Thackway and Cresswell (1995) warn that because of the different methodologies used by each State and Territory to derive the individual regionalisations, there may be attribute and boundary inconsistencies that need revision. The bioregions in the Australia tropical savannas vegetation map are listed in Table 2.3.

Table 2.3 IBRA bioregions in the map of the vegetation of the Australian tropical savannas.

- Arnhem Plateau (ARP)
- Brigalow Belt North (BBN)
- Central Arnhem (CA)
- Central Kimberley (CK)
- Cape York Peninsula (CYP)
- Daly Basin (DAB)
- Dampierland (DL)
- Desert Uplands (DEU)
- Einasleigh Uplands (EIU)
- Gulf Coastal (GUC)
- Gulf Fall and Uplands (GFU)
- Gulf Plains (GUP)
- Mitchell Grass Downs (MGD)
- Mount Isa Inlier (MII)
- Northern Kimberley (NK)
- Ord-Victoria Plains (OVP)
- Pine-Creek Arnhem (PCK)
- Sturt Plateau (STU)
- Tiwi (TIW)
- Arnhem Coastal (ARC)
- Darwin Coastal (DAC)
- Victoria Bonaparte (VB)

2.7 Land zones - vegetation and the environment

Harris (*in prep.*) defines 'land zones' as "geological and geomorphological categories that describe the major geologies and landforms" and Sattler (1999) observes that each land zone 'represents a significant difference in geology and in the associated landforms, soils and physical processes that gave rise to distinctive landforms or continue to shape them'. Land zones occur across bioregion, map sheet and state boundaries and are used to identify areas of similar type and landform in the landscape. Land zone definitions are independent of vegetation and land use, and differ in this regard to the land systems (Christian and Stewart 1953, 1968) also used in Australia, and mid-level ecoregions (Bailey 1983, Omerick 1995) used in similar mapping elsewhere, e.g. GAP Analysis Program vegetation maps (Scott *et al.* 1993) in northwest USA.

The twelve land zones of Queensland have been extended across the map using the same criteria as applied in Queensland. The Queensland Land Zone Working Group defined Land zones in 1997 by using underlying geology and the age of that geology as the primary determinants (Figure 2.7). They are further differentiated by differences in origin and function, or landforms and soil (Harris *in prep*). The land zones were identified using the numbers 1 – 12, however in this report they are assigned a prefix letter (Appendix 1.1). Land Zone 6 does not occur in the mapped area.

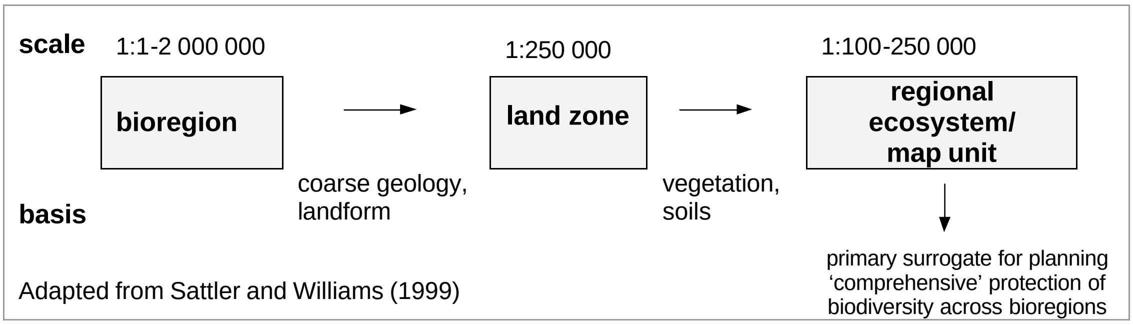

Figure 2.7 Landscape classification showing derivation and scale of land zones.

3. Methods

The production of this map was essentially an exercise in re-processing existing data, albeit a complex exercise. The methods and steps used to carry out the re-processing are presented here, as is the method used to map the vegetation of northwest Queensland. Vegetation classification and plant nomenclature are also presented.

3.1 Collation and analysis of existing maps

Vegetation map data to cover the study area were obtained from a number sources, principally from government agencies within Queensland, Western Australia and the Northern Territory. The preferred source data for the project were digital maps in a format that could be analysed and re-processed for inclusion in the final map. Table 3.1 lists and Figure 3.1 illustrates the maps available in this format at the start of the project.

Table 3.1 Vegetation map data available in digital format at the start of the project.

VEGETATION MAP	SCALE	
Kimberley and Great Sandy Desert (Beard and Webb 1974, Beard 1979, Hopkins *et al.* 1999)	1:1 000 000	Fig. 3.1a
Northern Territory (Wilson *et al.* 1990)	1:1 000 000	Fig. 3.1b
Central Western Queensland (Neldner 1991)	1:1 000 000	Fig. 3.1c
Cape York Peninsula (Neldner and Clarkson 1995)	1:250 000	Fig. 3.1d
Mitchell Grass Downs (part) (Boyland, 1984, Neldner 1984 and see Appendix 3.1a)	1:1 000 000	Fig. 3.1e
Eastern and central Queensland (see Appendix 3.1)	1:100 000 and 1:250 000	Fig. 3.1f

Vegetation maps in digital format varied in scale. A large area of central and eastern Queensland (Fig. 3.1f) and Cape York Peninsula (Fig. 3.1d) was available as a number of component map sheets at the scale of 1:100 000. The methodology used by the Queensland Herbarium to produce that data had ensured a consistency of line work and attributing that allowed it to be re-processed in its entirety using a single method. This method is presented below in 3.6 Queensland map.

Much of the remaining data was at a scale of 1:1 000 000, however, there was considerable variation in the levels of detail contained within each data set. For example, when analysed against the vegetation map of the Northern Territory (Wilson *et al.* 1990), the vegetation map of Central Western Queensland (Neldner 1991) presented information in far greater detail. It was therefore necessary to generalise the Central Western Queensland data. The steps for generalising individual map sheets across the project extent were determined on a case-by-case basis.

In addition to the digital data, several hard copy maps were analysed for their usefulness. Pedley and Isbell (1971) produced a map of Cape York Peninsula vegetation that was a useful reference. The 1:1 000 000 compilation sheets and data files used by Carnahan and others to produce the 1:5 000 000 Australian vegetation map (AUSLIG 1990) were supplied by AUSLIG on clear acetate sheets. The maps were digitised and, although not used as source data for the final map, were used as reference material. The following sections detail how the units were classified and aggregated and also explain the individual processing steps used to simplify the various data used.

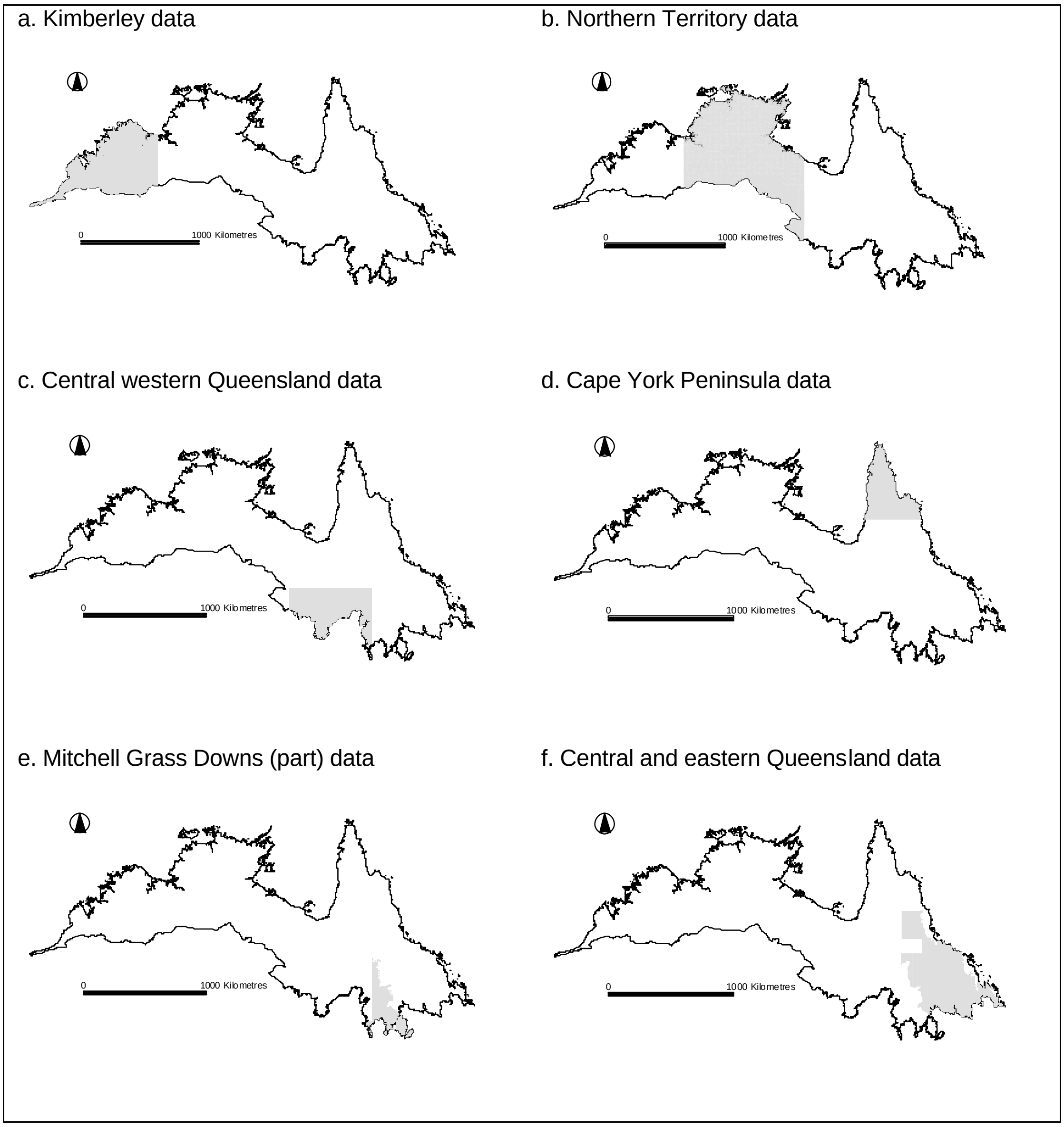

Figure 3.1 Vegetation map data available in digital format at the start of the project.

3.2 Vegetation classification

The vegetation classification system used for the map involved an initial interpretation of the classifications used by the authors of each of the component maps. For the most part these individual maps were classified firstly on structure and secondly on floristics and followed the classifications either of Specht (1970), Beard and Webb (1974) or Walker and Hopkins (1984, 1990).

The classification used for the project was one modified from Specht (1970) and has been used extensively by mappers from the Queensland Herbarium (Neldner 1984, 1991, 1993); a notable modification being that the vegetation was classified on the characteristic stratum rather than the tallest stratum as in Specht (1970). The structural formations used to describe the vegetation in this map are presented in Table 3.2.

Table 3.2 The structural formations used in the descriptions. After Neldner (1993) modified from Specht (1970).

Life form and height of characteristic stratum+	Projective foliage cover of characteristic stratum			
	Dense (70-100)%	**Mid-dense (30-70)%**	**Sparse (10-30)%**	**Very sparse (<10)%**
Trees* > 30 m		tall open-forest	tall woodland=	
Trees* 10-30 m	closed-forest	open-forest	woodland	open-woodland
Trees* < 10 m	low closed-forest	low open-forest	low woodland	low open-woodland
Shrubs# 2-8 m	thicket/closed shrubland	open-scrub	tall shrubland	tall open-shrubland
Shrubs# 1-2 m		open-heath	shrubland	open-shrubland
Shrubs# < 1 m		dwarf open-heath		
Succulent shrub				
Hummock grasses			hummock grass-land	open-hummock grassland
Tussock grasses	closed-tussock grassland	tussock grassland	open-tussock grassland	sparse-tussock grassland
Herbs		herbland°	open-herbland°	sparse-herbland°
Sedges		sedgeland		

\+ Characteristic stratum is the layer that contributes most to the biomass.
* Tree is a woody plant more than 5 m tall usually with a single stem.
\# Shrub is a woody plant less than 8 m tall either multi-stemmed or branched close to ground level, infrequently with a single stem.
° herbland refers to associations in which species composition and abundance is dependent on seasonal conditions, and at any one time grasses or forbs may predominate.
= Lower height limit for tall woodland reduced to 25 m for Cape York Peninsula study.

Each map unit was assigned an alphanumeric code that relates the unit to a full vegetation and land zone description. The letter prefixing each number represents the land zone (see Appendix 1.1), for example in the unit K4, ‘K’ represents land zone 12, igneous rocks, predominantly granites. As the numeric part of the unit code, ‘12’ represents the number assigned to the unit on the basis of structure so that the map units circumscribing the tallest, most dense vegetation communities are allocated the lowest numbers in contrast to the highest numbers specifying the more open vegetation communities (see 5.4 Key to map units).

3.3 Land zones and map unit aggregation

The grouping of the individual units of each map on the basis of land zone (Appendix 1.1) enabled the map units with similar environmental characteristics to then be grouped on the basis of structure and floristics. This formed the basis for describing new map units at 1:1 000 000 scale. Queensland source maps contained regional ecosystem information and by definition (Sattler and Williams 1999) this provided the required land zone information.

Land zone information was not available for the Northern Territory and Kimberley map data. The presentation of the map units in groupings based on land zones depended upon developing that that information for every map unit. Many references were used with geology, landform and soil information used as a guide for determining land zone.

The major references were Christian *et al.* (1954), Perry *et al.* (1964), Gunn *et al.* (1967), Northcote *et al.* (1960-1968), Speck *et al.* 1968, Galloway *et al.* (1970), Beard and Webb (1974), Webb (1974), Beard (1979), Wilson *et al.* (1990), Neldner (1991), BRS (1991, 1991a, 1991b), Neldner and Clarkson (1995); Sattler and Williams (1999) and Harris (*in prep.*).

Given that map units occur across many polygons in the map, by assigning land zone information to each polygon the consistency of the relationships between plant communities and the landscape (as defined by land zone) could be investigated. In some cases there was a very good correlation, that is, polygons of a given map unit were consistently found on the same land zone. In a number of map units, however, this relationship was not so clearly defined and decisions were made about the land zone that the map unit was most likely to be found on. The descriptions of each map unit (5.5 The map unit descriptions) indicate the land zones on which a given map unit may be found.

The final aggregation of map units was achieved by sorting first to land zone and then on the basis of dominant structure and floristics. Units occurring on the same land zone and having a close structural and floristic relationship were assigned a unique map unit code.

3.4 Cartographic procedures

The map data from each State or Territory covered by this project were available in different formats and at different scales. Classification schemes also varied. To a large extent, the project involved re-working individual map datasets into a consistent format at a consistent scale. A number of basic procedures were established at the earliest stages of the work in relation to polygon size and a standardised map base to which all data would be fitted. These procedures were also used during the production of a new map of northwest Queensland for which there was no seamless vegetation map at a scale suitable to the project. The 1:1 000 000 scale vegetation map of the Northern Territory (Wilson *et al.* 1990) was taken as the base against which other maps were compared before attribute data and lines were re-processed.

3.4.1 Polygon size

In an attempt to retain as much detail as possible from the source mapping, the minimum polygon size was set at 1000 hectares but it quickly became apparent that, whilst this was satisfactory for the digital coverage at 1:1 000 000, it was difficult to represent on a hard copy 1:2 000 000 map. As a general guide to the botanists involved in the project, minimum size was increased to 2000 hectares with that size to be used during the processing of individual maps. Some allowance was made for ecologically complex areas in which case the minimum of 1000 hectares applied, but this was not adopted generally.

3.4.2 Standardised map base

All datasets used were fitted to a standard map base. The coastline used came from the 1:2.5 000 000 topographic map of Australia (AUSLIG, 1998). The southern extent of the final map was derived from IBRA version 5.0 (Environment Australia 2000).

Geographical information system (GIS) tasks for the project were carried out using software produced by Environmental Systems Research Institute Inc. (ESRI). ArcView Version 3.2 for PC was used for minor editing and production of the linework for the northwest Queensland map (ESRI 1996). Final editing, building and joining of the major data sets were undertaken in ARC/INFO Version 8.0.2 for Unix.

3.4.3 Generalising small polygons, narrow polygons and setting tolerances.

To reduce the density of linework within source maps, polygons smaller than 1000 hectares in extent were selected in the GIS and look-up tables to describing the attributes of those polygons were created. The polygons were then dissolved in ARC/INFO (ESRI 1994) GIS by the following process:

- It was determined whether the adjacent or surrounding polygon was to acquire the attributes of the dissolved polygon,
- In the edit coverage, polygons were merged with the desired adjacent or surrounding polygon,
- The coverage was edited to remove narrow polygon slivers (for example, river polygons less than 250m in width), and
- Complex line work was smoothed using minimum tolerance settings in editing; the smallest gap between lines was set at 0.25mm (250m at 1:1 000 000 scale). The ARC/INFO (1994) automated computer processes of weed tolerance, node tolerance, and arc snap distances were set to this level.

3.5 Processing existing maps

At the outset of the project it was felt that an automated technique, utilising GIS tools to simplify the detailed source maps, would provide a straightforward method of data processing. Cape Weymouth and Coen, two of the detailed vegetation map sheets from the Cape York Peninsula data (Neldner and Clarkson 1995) were selected for testing an automated method of simplification. Despite a number of techniques being tried, including re-assigning polygon attributes and computerised merging of small polygons, the approach failed to produce a useful representation of the vegetation at the required scale. Re-assigning attributes merely resulted in polygons with new attributes but still having linework that was too detailed for representation at the map scale. Allowing the computer to automatically merge small polygons resulted in new polygons but not necessarily polygons with the attributes of the dominant vegetation, with the computer unable to intuitively re-assign the attributes correctly. Given the difficulties experienced with the automated approach, a method of re-interpreting the maps was developed and is described below in 3.6 Queensland map.

Differences in scale, classification and format of the many maps that were used as the base data for this project required the development of methods for processing attribute and line data to ensure compatibility at the scales of 1:1 000 000 and 1:2 000 000. These issues were relatively simple to resolve in the Northern Territory map which already existed as a seamless coverage and at a suitable scale, however for the Kimberley and Queensland map data there were significant issues to resolve, including:

- Generalising the 1:250 000 and 1:100 000 scale vegetation maps of Cape York Peninsula and central and eastern Queensland,
- Simplifying heterogeneous polygons in the Queensland data,
- Resolving edge inconsistencies and the need to generalise the 1:250 000 Kimberley map data,
- Representing small but ecologically important map units, such as Kimberley rainforests, that were desirable for inclusion at the 1:1 000 000 or 1:2 000 000 scales, regardless of spatial extent,
- Developing a consistent set of environmental and structural characteristics to assist the grouping of the detailed vegetation/map units even where the units themselves may have floristic differences,
- Resolving the lack of environmental information for the map units of the Northern Territory and Kimberley maps, and
- Generalising small polygons, narrow polygons and setting tolerances for processing.

A number of processing steps were used to ensure that the many component maps used in this project were at a uniform scale and classified in a consistent way. In this way adjoining maps were able to be edge-matched. The individual map units from the many maps used were classified using a modified Specht (1970) classification (see chapter 3.1 Vegetation classification). The result was that a map for each State and Territory was developed at a scale of 1:1 000 000, with modified Specht (1970) classification and land zone information in each unit (see Introduction: Land zones).

3.6 Queensland map

3.6.1 Generalising the 1:100 000 vegetation maps of central and eastern Queensland.

The map data for central and eastern Queensland (Fig. 3.1f) and Cape York Peninsula (Fig. 3.1d) were available at a scale of 1:250 000 although linework for much of that data was at a more detailed scale of 1:100 000. The first stage in generalising the data was the grouping of the attributes in the map legends on the basis of land zone. Once sorted to land zone, units were analysed for floristic and structural similarities and sorted into new aggregated groupings. These were then assigned a new map code, called the Qcode; Table 3.3 shows an example of the method used to group sort units by land zone and then to group on structure and floristics. The data were taken from the attribute table of the Cape York Peninsula vegetation map (Neldner and Clarkson, 1995).

Table 3.3 Example of Qcode sorting

MAP UNIT	DESCRIPTION_CYP	Qcode	DESCRIPTION_Qcode	Land zone
78	*Eucalyptus leptophleba + E. clarksoniana + Erythrophleum chlorostachys* (Sandstone colluvium, Laura) W	**Q23**	*Corymbia clarksoniana/polycarpa +/- Eucalyptus leptophleba +/- Erythrophleum chlorostachys +/- Eucalyptus* spp. +/- *Melaleuca* spp. (Plains, floodplains) W-OW	3
114	*Eucalyptus clarksoniana + Melaleuca viridiflora + E. platyphylla* (Plains & floodplains, yellow earths) OW	**Q23**	*Corymbia clarksoniana/polycarpa +/- Eucalyptus leptophleba +/- Erythrophleum chlorostachys +/- Eucalyptus* spp. +/- *Melaleuca* spp. (Plains, floodplains) W-OW	3
80	*Eucalyptus leptophleba, E. tessellaris + E. clarksoniana* (Riverine levées) W	**Q24**	*Eucalyptus leptophleba +/- Corymbia polycarpa/clarksoniana +/- Corymbia tessellaris +/- Eucalyptus acroleuca +/- Corymbia dallachiana* (levées, floodplains and coastal areas) OF-W	3
88	*Eucalyptus polycarpa* (or *E. clarksoniana*) + *E. papuana + E. curtipes* (*E. papuana* OW on edge) (levées, Mitchell floodplain) W	**Q24**	*Eucalyptus leptophleba +/- Corymbia polycarpa/clarksoniana +/- Corymbia tessellaris +/- Eucalyptus acroleuca +/- Corymbia dallachiana* (Levées, floodplains and coastal areas) OF-W	3
91	*Eucalyptus tessellaris + E. clarksoniana + E. acroleuca + E. leptophleba* (Lakefield levées) W	**Q24**	*Eucalyptus leptophleba +/- Corymbia polycarpa/clarksoniana +/- Corymbia tessellaris +/- Eucalyptus acroleuca +/- Corymbia dallachiana* (Levées, floodplains and coastal areas) OF-W	3
44	*Eucalyptus tessellaris*, *E. clarksoniana + Lophostemon suaveolens + Acacia crassicarp*a (coastal areas) OF-W	**Q25**	*Corymbia tessellaris* and/or *Corymbia clarksoniana* and/or *Eucalyptus tetrodonta +/- Corymbia novoguinensis* (Coastal areas, lowlands) OF-W	3
84	*Eucalyptus novoguinensis + E. tessellaris + E. nesophila* (northern CYP) W	**Q25**	*Corymbia tessellaris* and/or *Corymbia clarksoniana* and/or *Eucalyptus tetrodonta +/- Corymbia novoguinensis* (Coastal areas, lowlands) OF-W	3
94	*Eucalyptus tetrodonta + E. clarksoniana + E. tessellaris* (Coastal lowlands) W	**Q25**	*Corymbia tessellaris* and/or *Corymbia clarksoniana* and/or *Eucalyptus tetrodonta +/- Corymbia novoguinensis* (Coastal areas, lowlands) OF-W	3
87	*Eucalyptus platyphylla +/- E. clarksoniana* (Flat wet plains) W-OF	**Q26**	*Eucalyptus platyphylla +/- Corymbia clarksoniana* (Flat wet plains) OF-W	3
1	*Eucalyptus tetrodonta + E. hylandii* var. *campestris + Erythrophleum chlorostachys* (The Desert) TW	**Q27**	*Eucalyptus tetrodonta + Erythrophleum chlorostachys +/- Corymbia hylandii* var. *campestris +/- Corymbia nesophila* (Bauxite plateau and The Desert) TW	5
2	*Eucalyptus tetrodonta*, *E. nesophila + Erythrophleum chlorostachys* (Bauxite plateau) TW	**Q27**	*Eucalyptus tetrodonta + Erythrophleum chlorostachys +/- Corymbia hylandii* var. *campestris +/- Corymbia nesophila* (Bauxite plateau and The Desert) TW	5

New 1:250 000 maps coloured to Qcode were plotted. Botanists then re-interpreted the maps and circumscribed new polygons based on the Qcode colouring. Figure 3.2 shows a section of the 1:250 000 vegetation map of Cape Weymouth (Neldner and Clarkson 1995) on Cape York Peninsula after Qcoding and prior to digitising. The botanists then assigned new Qcode attributes to the polygon, with up to 3 attributes assigned to each heterogeneous polygon. This technique enabled the botanists to consider retaining important landscape and vegetation characteristics on the small-scale map, even where polygon size was marginal. Templates with polygons of 2000 hectares were used to guide the work.

The new Qcode linework was then manually digitised using ARC/INFO (ESRI 1994) and once the linework was cleaned and checked in the GIS, the Qcode attributes were added to each polygon before topology was built. To enable checking of the new lines and attributes, check plots at 1:500 000 were compared to the original 1:250 000 maps.

3.6.2 Simplifying heterogeneous polygons in the Queensland 1:100 000 data.

Many of the polygons in the detailed Queensland maps contained heterogeneous attributes, with up to five vegetation map units described in each polygon. These attributes were represented in decreasing order of dominance within the polygon, for example, where the attributes were v1/v2/v3/v4/v5 then the v1 attribute represented the plant community with the highest proportion. During the Qcode process, new maps were printed with the v1 attribute coloured by Qcode and each polygon was labelled with its heterogeneous label (Figure 3.2). Attributing was limited to a maximum of three codes per polygon. The attributes were maintained as heterogeneous for the Queensland data.

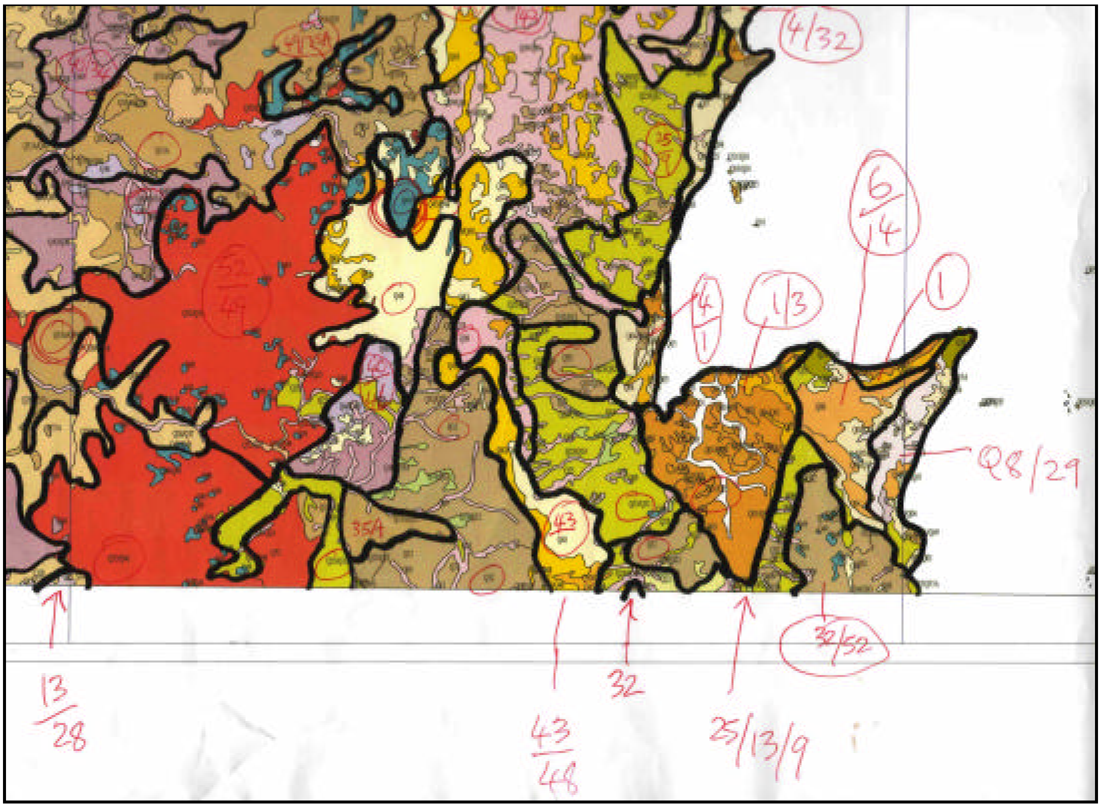

Figure 3.2 Example of a re-interpreted Qcode map.

3.7 Kimberley (Western Australia) map

3.7.1 Resolving edge inconsistencies and the need to generalise the 1:250 000 Kimberley map data.

The newly digitised (Hopkins *et al.* 1999) version of the 1:1 000 000 vegetation maps of the Kimberley (Beard 1979) and the Great Sandy Desert (Beard and Webb 1974) were used as the basis for developing the vegetation map of the Kimberley used in this project (see Fig. 3.1a). This digital data comprised numerous 1:250 000 maps (known as tiles) joined into one map coverage. Inconsistencies within the digital data, such as mismatching boundaries of individual map tiles, were resolved by reference to the original 1:1 000 000 paper maps by Beard (1979) and Beard and Webb (1974).

Linework for the map retained its original detail with many polygons of a very small area or with highly complex boundaries. In some cases, clusters of small polygons with the same attributes were re-drawn into a larger polygon to ensure that those plant communities retained some degree of representation in the landscape. Once this task was completed, the 2000 hectares standard limit was applied to the data and smaller polygons were merged with larger polygons. Complex polygon boundaries were smoothed manually on screen in the GIS.

3.7.2 Representing small but ecologically important map units regardless of spatial extent.

The issue of representing small (<2000 hectares) but ecologically important map units was considered for the Kimberley map since it was still in the process of development and the data could be added during re-processing. Rainforest often occurs in small patches, but the patches do occupy a predictable niche in the landscape (Kenneally *et al.* 1991). Some rainforest patches were represented in the existing Northern Territory and Queensland maps so for consistency the decision was made to include some of the Kimberley rainforest areas on the map. The raster version of the Kimberley rainforest map (CALM 1987) was used in the GIS as a back coverage and the most dense clusters of rainforest patches were used as the basis for a number of generalised polygons of exaggerated size representing rainforest areas.

3.7.3 Resolving the lack of environmental information for many of the map units of the Kimberley map.

The 1:1 000 000 Kimberley (Beard 1979) and the Great Sandy Desert (Beard and Webb 1974) maps did not contain enough information to determine the land zone for every map unit and the new digital versions of these maps did not contain any of this information. The Kimberley and Great Sandy Desert printed maps did contain some broad geology, soil and landform descriptions, but again the data were not presented comprehensively across them. The reports accompanying the original maps did contain such information and these were used as a key reference.

To overcome this lack of comprehensive landscape information in the digital map additional digital data were used as a reference. The 1:2 000 000 scale map of Australian Soils (Northcote *et al*. 1960-68), and the 1:2.5 000 000 maps of Australian Bedrock Geology (BRS 1991) and Australian Surficial Geology (BRS 1991a) were used as a back drop in ArcView GIS. For each polygon in the digital vegetation maps, the backdrop data sets were interrogated for geology, landform and soil information; this information was then used to derive a land zone for each polygon.

The Kimberley map units generally had good correlation between vegetation and land zone, with most vegetation types occurring on the same land zone consistently across the region. However, some vegetation units occurred across a number of land zones and decisions were made about which one the unit was most likely to occur on.

3.8 Northern Territory map

3.8.1 Resolving the lack of environmental information for many of the map units of the Kimberley map.

The 1:1 000 000 maps of the Northern Territory (Wilson *et al.* 1990) did not contain enough information to determine the land zone for each map unit. The Northern Territory map unit descriptions referred to geology, soil and landform but not in a comprehensive way and not for all map units. The digital versions maps did not contain this information.

To add land zone information to the Northern Territory map the 1:2 000 000 scale map of Australian Soils (Northcote *et al*. 1960-68), and the 1:2 500 000 maps of Australian Bedrock Geology (BRS 1991) and Australian Surficial Geology (BRS 1991a) were used as a back drop in ArcView GIS. For each polygon in the digital vegetation maps the backdrop datasets were interrogated for geology, landform and soil information. This information was then used to derive a land zone for each polygon.

Given that map units occur across many polygons in the map, by assigning land zone information to each polygon the consistency of the relationships between plant communities and the landscape (as defined by land zone) could be investigated. In some cases there was a very good correlation, that is, polygons of a given map unit were consistently found on the same land zone. In a number of map units this relationship was not so clearly defined and decisions were made about the land zone on which the map unit was most likely to be found. The descriptions of each map unit in Section 5.5 indicate the variation in land zones on which a map unit may be found.

3.9 Production of a vegetation map of northwest Queensland

In addition to the task of re-interpreting existing maps, this project was required to fill gaps in vegetation data, specifically a substantial area of northwest Queensland (Figure 3.3) not previously mapped as a seamless vegetation coverage at a scale suitable for joining to other northern Australian map data. This area of approximately 300,000 km^2 was a major focus for the Queensland Herbarium mapping team during 1999. The mapping was based on data gathered during a major field-sampling program. Lines were then digitised on screen using PC ArcView GIS, with a Landsat TM (thematic mapper) satellite image backdrop and with reference to other maps and to the site data.

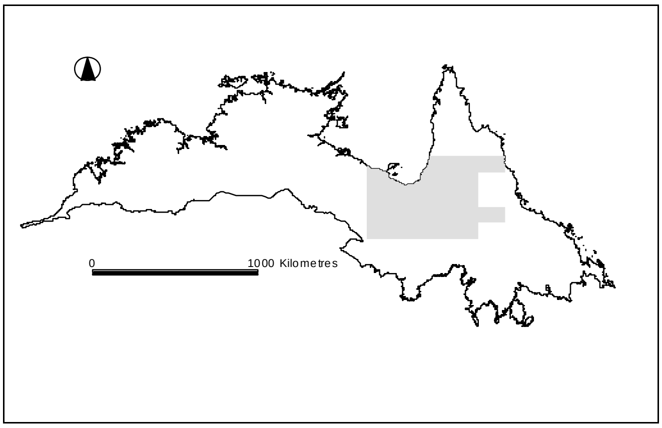

Figure 3.3 Previously unmapped areas of northwest Queensland

Accurate and adequate site data were essential to the validity of the classification of any new map units developed. Pre-selected field sites were chosen on the basis of anticipated vegetation, geographic distribution, and ease of access. Information about anticipated vegetation was derived from CSIRO land-system maps and reports. The landsystem maps used as references covered the Barkly Regions (Christian *et al.* 1954), the Leichhardt-Gilbert Region (Perry *et al.* 1964) and the Mitchell-Normanby Region (Galloway *et al.* 1970). A major drawback with this and other older map information is that it was produced prior to the advent of digital mapping technology; consequently much of the data, whilst having ecological integrity, did not necessarily have spatial accuracy.

Additional reference material used included the 1:5 000 000 (AUSLIG 1990) map of the vegetation of Australia, digital geology data for the region (DME 1999) and recently captured Landsat Thematic Mapper satellite image data. See Appendix 3.2 for the Landsat TM scenes used.

Having reached a selected field site, data collection followed the Queensland Herbarium's standard field methodology (McDonald and Dillewaard 1994, Neldner *et al.* 1999a). Typical information collected from the 50 metre by 10 metre plot for each site included the species present in each structural layer, the foliage projective cover and basal area, and soil, geology, slope and aspect data. An averaging GPS was used to record the position of each site. The data were recorded manually in the field and then entered into the Herbarium's CORVEG database for analysis. Data from 295 of these plot-based sites were collected between May and October 1999 (Figure 3.4).

In addition to these plot-based sites, observational data were collected during vehicular traverses. One of the botanists in the vehicle used the vehicle GPS and an audio recording tape to record the position and broad-scale vegetation data whilst the vehicle was in transit. This information was later transcribed from the tape into a database. With recordings at one kilometre intervals, these observational sites provided a second layer of field data for use in the GIS. These data formed a critical component of the final analysis of the vegetation patterns by providing a point-by-point description of the country traversed in the field (Fox 1999). Data from 6419 sites were collected between May and October 1999 (Figure 3.5).

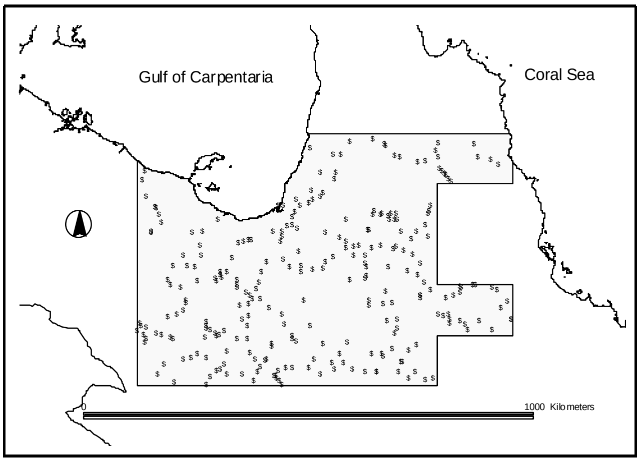

Figure 3.4 Northwest Queensland plot-based sites

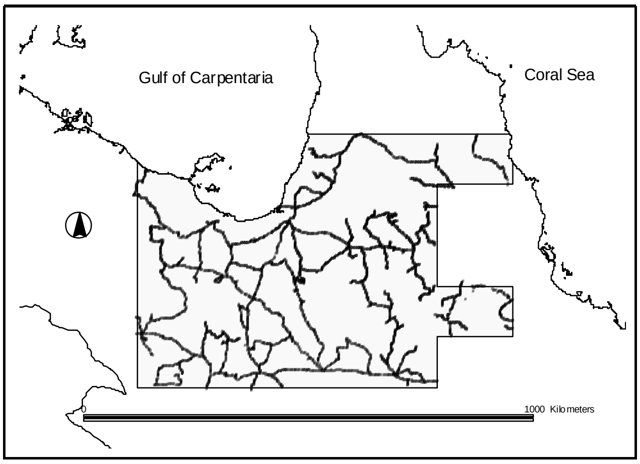

Figure 3.5 Northwest Queensland observational sites

A draft map of the vegetation of northwest Queensland (Fox and Middleton *unpubl.*) was distributed for comment in July 2000. Once comments had been received Qcodes were added. An integral part of developing this map was to edge match to surrounding vegetation maps for central western Queensland, Northern Territory, Cape York Peninsula and maps of central and eastern Queensland.

3.10 Joining component data sets

Once all of the smaller component maps had been generalised and edited they were joined to make three individual maps, one for the Kimberley, one for the Northern Territory and one for Queensland. These maps and their associated data became the base data for the final map. The map units within each of these maps were assigned a code prefixed by a letter ‘N’ for Northern Territory, ‘Q’ for Queensland and ‘W’ for Western Australia. Tables of these unit descriptions are given in Appendices 3.3, 3.4 and 3.5. Differences in map attributes along common boundaries between state maps were resolved in the individual datasets. Each map was clipped to the IBRA boundaries used to define the extent of the final map.

When each map was fitted to the coastline base from the 1:2 500 000 Australian topographic map (AUSLIG, 1998) a number of problems became apparent. The Kimberley map had originally been fitted to a Western Australian Mines Department topographic base (Beard, 1979) but that was not consistent with the current (AUSLIG 1998) national coastline adopted for the project. A new coastline was fitted to the Kimberley map but this created many unclosed polygons. The inconsistencies in these coastal polygons and some of the rectification inconsistencies were corrected in collaboration with the Department of Conservation and Land Management Land Information Branch (Remote Sensing) who hold Landsat TM data for the Kimberley region.

The Northern Territory vegetation map was originally produced by interpretation of patterns on Landsat TM imagery (Wilson *et al.* 1990) and only minor adjustments were required to fit the national coastline (AUSLIG 1998). Queensland map data were already fitted to the AUSLIG topographic coastline.

3.11 Landcover change

The vegetation of Australia has undergone significant change since European settlement, with approximately half the forest vegetation and a third of the woodland vegetation cleared by the 1980s (AUSLIG 1990, Barson *et al*. 2000). Within the Australian tropical savannas the most substantial areas of clearing occur in eastern and central Queensland. Less extensive, but nevertheless significant areas of clearing are present in the Ord River region in the Kimberley and around Darwin and Katherine in the Northern Territory. A map showing a single class for clearing was produced for the project (see 4, Landcover and vegetation change). Clearing was taken to be land that has had its landcover converted from native vegetation to other land uses such as pasture, cropping, urban, water, plantation and orchard, and mining.

The Queensland section of the map showing clearing was produced using data from the Queensland Herbarium’s remnant regional ecosystem mapping program for 1997. The available data was a GIS coverage and it was edited in ARC/INFO (ESRI 1994). The Kimberley and Northern Territory clearing map was derived from land cover information published in raster format by the Bureau of Rural Sciences and its ‘Remote Sensing of Agricultural Land Cover Change Project 1990-1995’ (Kitchin and Barson 1998, Barson *et al*. 2000). Lines were digitised in ARC/INFO (ESRI 1994) around those classes that represent clearing on the raster data.

Once completed the maps of clearing for each State and Territory were joined into a single north Australian landcover map coverage. This was then intersected in the GIS with the vegetation map (Fox *et al.* 2001) to generate statistics on remnant vegetation. The data were refined to produce statistics for each map unit, for each land zone and for each bioregion (see chapter 4 Landcover and vegetation change).

3.12 Map review

The vegetation map was produced in collaboration with a number of agencies and individuals who have produced or continue to produce vegetation data for northern Australia. In this project, an integral part of the map production was the process of consultation during the processing work and then of submitting draft map outputs and reports to reviewers for comment. Table 3.4 shows the sequence of review.

Table 3.4 Map review process

DATE	OUTPUT FOR REVIEW	REVIEWER
April 2000	Edit suggestions for joining Kimberley and Northern Territory vegetation data	Conservation and Land Management (Perth, Kimberley), Agriculture Western Australia, and Northern Territory Department of Lands, Planning and Environment
May 2000	Draft map of the vegetation of the Kimberley	Conservation and Land Management (Perth, Kimberley), Agriculture Western Australia and J.S. Beard.
July 2000	Draft map of the vegetation of northwest Queensland vegetation	Queensland Department of Primary Industries (Longreach, Mareeba, Mt Isa), Northern Gulf Resource Management Group Inc., Southern Gulf Catchments Inc. and Environmental Protection Agency (Biodiversity Assessment and Services)
October 2000	Draft map of the vegetation of northern Australia	Cooperative Research Centre for Tropical Savannas, Conservation and Land Management (Perth, Kimberley), Agriculture Western Australia, Northern Territory Department of Lands, Planning and Environment, Parks and Wildlife Commission of the Northern Territory, Environmental Protection Agency (Biodiversity Assessment and Services), Queensland Department of Natural Resources (Forest Ecosystem Research and Assessment), Queensland Department of Primary Industries (Tropical Beef Centre), J.S. Beard and G. Morgan (EPA)
March 2001	Draft technical report and map on the vegetation of the Australian tropical savannas	J.A. Carnahan (Australian National University, retired), K.J.M. Dickinson (University of Otago), K.F. Kenneally (Department of Conservation and Land Management), and G.L. Werren (Australian Centre for Tropical Freshwater Research)

3.13 Nomenclature

The base data used for the project date from 1954 to 2000. During that period, largely as a result of increased field sampling and advances in Australian plant systematics, many of the plant names used by earlier authors have changed. One of the best-known changes, and perhaps the most contentious, was the revision of the Myrtaceous bloodwoods, formerly genus *Eucalyptus,* to genus *Corymbia* by Hill and Johnson (1995). In order to present all plant species data within the report in a consistent format, the authors have followed the Queensland Herbarium's current census of plant names (Queensland Herbarium, 2001). In the case of *Corymbia*, at the time of writing the Queensland Herbarium accepted the Hill and Johnson (1995) revision and it is used throughout this report.

Where the Queensland Herbarium census did not list a species or where it did not list the full geographical extent of a species or group of species, a number of other references were used. For tracking changes to species names and distributions additional references were needed. The key references used were Wheeler *et al.* (1992), Brooker and Kleinig (1994), Hill and Johnson (1995), Henderson (1997), Western Australian Herbarium (1998), Queensland Herbarium (2001), and Australian National Botanic Gardens (2001). Introduced species are indicated with by the symbol *.

Whilst the use of common names is generally avoided in ecological studies, the likelihood of widespread use of the map and this report prompted the inclusion of common names in the vegetation descriptions (see Appendix 3.6). Common names were derived from a number of sources including Wheeler *et al.* (1992), Brock (1993), Brooker and Kleinig (1994), Milson (2000, 2000a), Clarkson (*in draft*) and Neldner and Clarkson (*in prep.*).

3.14 Digital covers

This report describes vegetation map units at the scale of 1:2 000 000 and the methods used to develop those units. The three maps for the individual States and Territory that were developed during data processing were joined and new attributes assigned to each unit. These formed the basis for a digital coverage at the scale of 1:1 000 000 which were then aggregated to form the final vegetation map units for the 1:2 000 000 map. The 1:1 000 000 scale data has been maintained as a separate digital dataset which will provide a practical tool for research and planning at the regional scale. A lookup table relating the vegetation units in that digital coverage to the vegetation units described in this report is presented in Appendix 3.7.

The scale of the base maps and the methodology used to develop the Queensland data has resulted in heterogeneous (multiple) vegetation attributes within each Queensland polygon. That heterogeneity was maintained in the digital coverage, however for consistency across the entire map the Queensland data was also prepared with homogeneous (single) vegetation attributes.

4. Landcover and vegetation change

In this chapter we discuss in broad terms landcover change in the Australian tropical savannas. Satellite image technology has enabled the gross changes brought about by broad acre clearing to be identified and quantified and this information forms the basis of the following discussion. We also recognize there has been a long term change in the structure of vegetation communities due to the increasing density of woody shrubs in the sub-canopy layer of many woodlands and as a new shrub overstorey in grassland communities. A full study of this issue is beyond the scope of this project, but it is nevertheless recognised in the context of land management and is discussed briefly.

4.1 Landcover change

The area of vegetation mapped in this study is 190 million hectares and is allocated to 125 map units across 11 land zones and 22 bioregions. The vegetation map of the Australian tropical savannas (Fox *et al.* 2001) was used as a *pre-clearing* base-map. In addition a *remnant* map was produced from 1997 land clearing data. A land clearing map, Figure 4.1, was derived as a composite of data from different sources. The methodology used to produce the map is explained in 3.11 Landcover change. An intercept of *pre-clearing* and the 1997 *remnant* maps results in a statistic showing that 8.76 million hectares (4.61%) of the project area had been cleared of native vegetation in 1997; this is an area greater than that of the state of Tasmania in Australia, Maine in the USA, and of the country of Scotland in the UK.

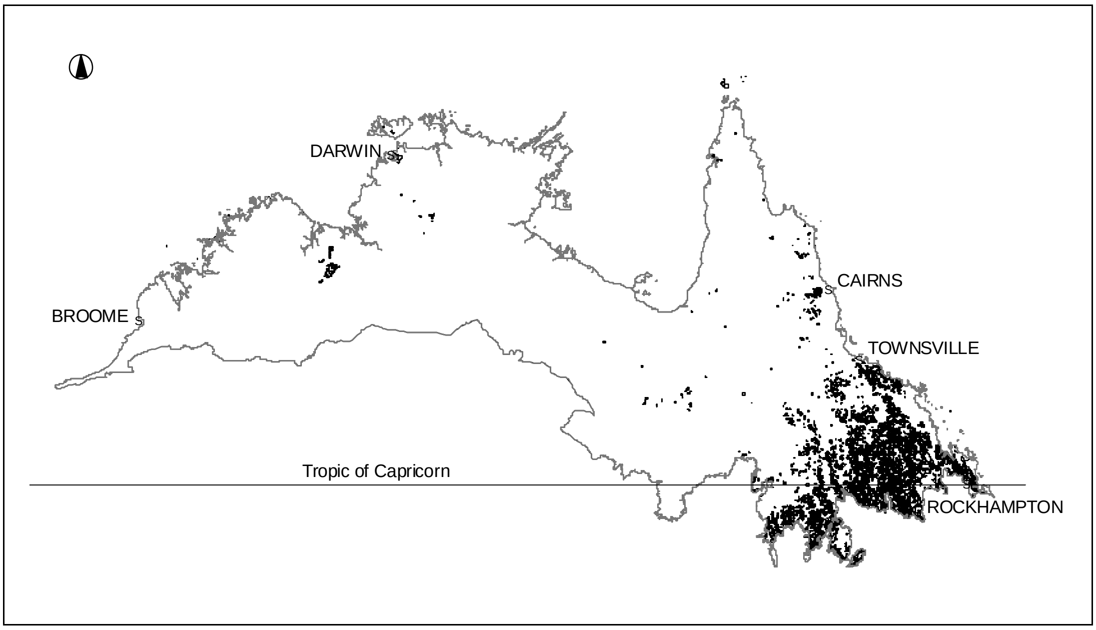

Figure 4.1 Extent and location of land clearing in the Australian Tropical savannas.

Ninety-six (76.8%) of the 125 map units have been cleared to some extent (range 0.01 – 73.31%). Most clearing has been for grazing and cropping with more limited areas cleared for mining, plantations, and dams construction. More extensive clearing of some vegetation types closely related to those within the map area has occurred beyond the map extent, e.g. in the Brigalow Belt South. When considered in a wider context, the clearing outside the map extent substantially changes the status of the map units within the project area and this fact should be considered in land use and biodiversity conservation planning.

4.1.1 Most affected bioregions

Eight (36.4%) of the 22 bioregions (see 2.6 Biogeographic regionalisation) included in the mapped area had no areas of clearing of greater than 3000 hectares that could be graphically displayed on the maps. The clearing of vegetation in the remaining 14 bioregions ranged from 0.03 to 47.14%. Six bioregions had areas of greater than 1.0% cleared (range 1.06 – 47.14) and the same bioregions contributed the greatest area of vegetation cleared (Figure 4.2).

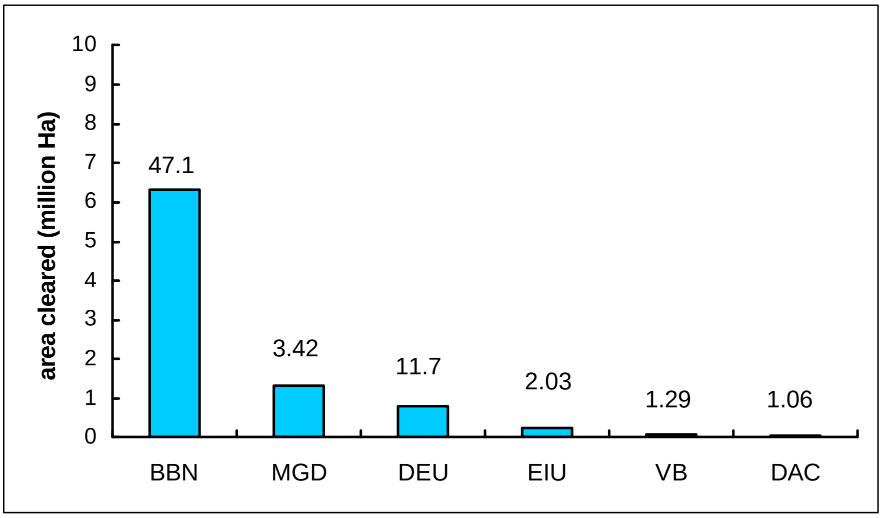

Figure 4.2 The area and percentage of total area cleared of vegetation in the six most affected bioregions in the map area.

The most affected bioregions are four in Queensland (BBN, DEU, MGD and EIU) with one each in the Northern Territory (DAC) and Western Australia/Northern Territory (VB).

4.1.2 Most affected Land zones

Clearing has been most intensive on Land zones 3 and 4 (Unit C in Figure 4.3); these constitute the areas of Quaternary and Tertiary alluvia and colluvia on low-lying flat and gentle slopes in the landscape and, in particular, the floodplains of rivers.

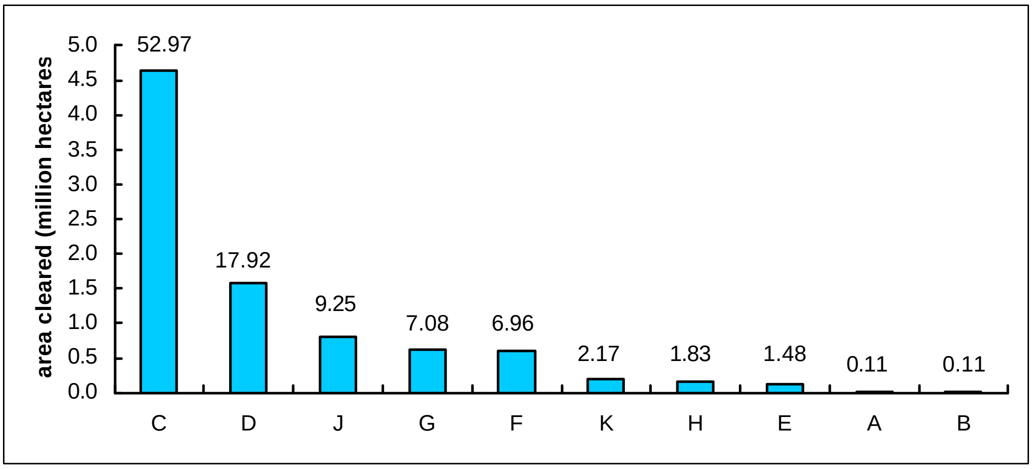

Figure 4.3 Total area and percentage of vegetation cleared in each land zone (N =10 as LZ3 and 4 treated as a composite in Unit C).

4.1.3 Most affected Map Units

The data presented above give an indication of the location and extent of vegetation loss in the mapped area but do not show which vegetation types or vegetation units are most affected by clearing or change. This information is required for effective resource management and biodiversity conservation, particularly in respect to the research, management and conservation of distinct vegetation ecosystems (Sattler 1999).

The great proportion of clearing in the map area is restricted to a small number of units; 18 units with a clearing area of greater than 100 000 hectares each contribute 90.99% of the total clearing (Figure 4.4) and 19 units with vegetation clearing of greater than 10% contribute 79.0% of the total clearing (Figure 4.5).

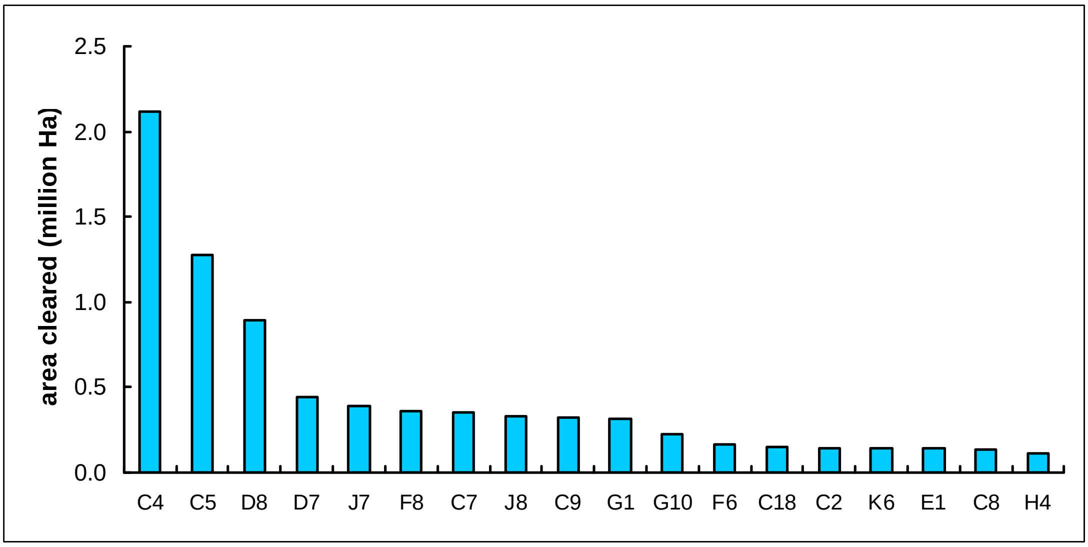

Figure 4.4 Australian tropical savanna map units with clearing of greater than 100 000 hectares.

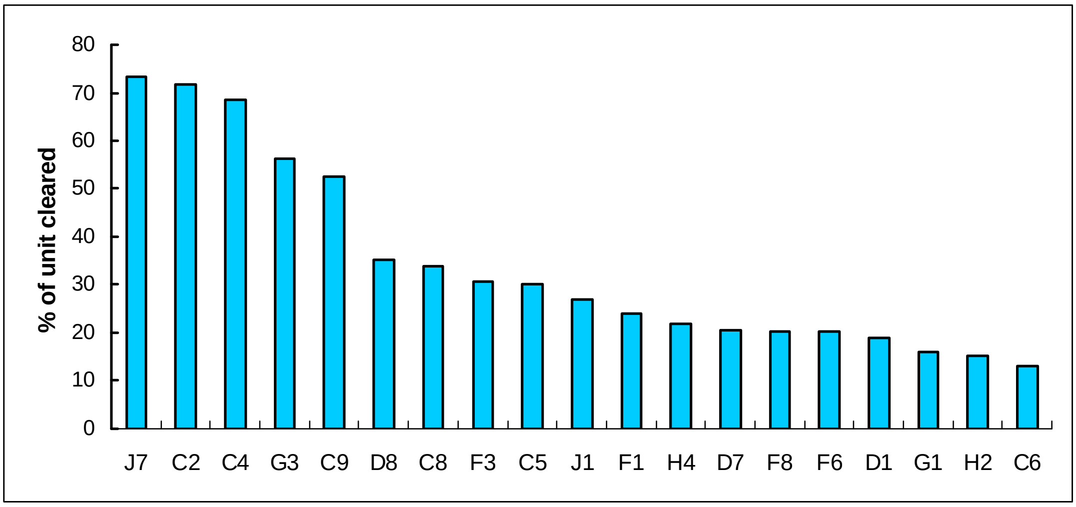

Figure 4.5 Australian tropical savanna map units with greater than 10% of original vegetation cleared.

It is important to note that the units identified in the two graphs above are not synonymous and that the Land zones in which they occur also vary considerably (Figure 4.6 and 4.7).

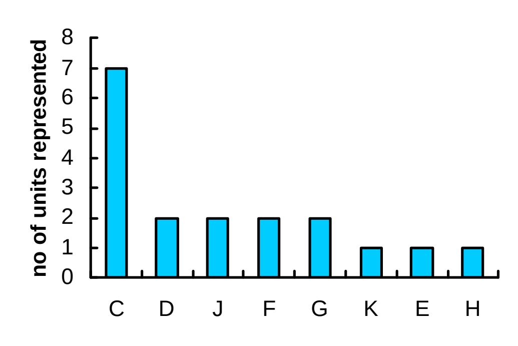

Figure 4.6 Land zone of map units with greater than 100 000 ha of clearing.

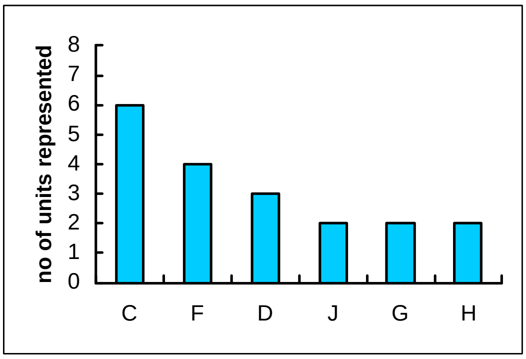

Figure 4.7 Land zone of map units with greater than 10% of original vegetation cleared.

While the data above account for the greater percentage of the clearing of vegetation in the map area they do not provide a complete view of the state of the vegetation units on the map, these data are presented in Table 4.1.

Table 4.1 The number and percentage of total number, rank, and percentage by class of vegetation remaining in map units with clearing (N = 96) in the Australian tropical savannas.

Number of units with clearing and (%) of total number of units	Rank	class (%) of vegetation remaining
77 (61.6)	1	90 – 99.9
4 (3.2)	2	80 – 89.9
7 (5.6)	3	70 – 79.9
3 (2.4)	4	60 – 69.9
0 (0.0)	5	50 – 59.9
2 (1.6)	6	40 – 49.9
1 (0.8)	7	30 – 39.9
2 (1.6)	8	20 – 29.9

Two vegetation units have been cleared to ≤30% remaining, the threshold for “Of Concern” ecosystems in Sattler and Williams (1999), and the level at which the available area of habitat becomes too small to maintain viable populations of the endemic biota. They are,

J7 – *Eucalyptus thozetiana* (Napunyah) and/or *Acacia harpophylla* (brigalow) ± softwood species woodland with *Eremophila mitchellii* (false sandalwood) shrubs and a sparse ground layer, and

C2 –*Eucalyptus tereticornis* (blue gum) and/or *Eucalyptus molucanna* (gum-topped box) and/or *Corymbia intermedia* (pink bloodwood) and/or *Corymbia tessellaris* (Moreton Bay ash) open forest.

A further three vegetation units require close monitoring, they are

C4 - *Acacia harpophylla* (brigalow) and/or *A. cambagei* (gidgee) ± *A. argyrodendron* (blackwood) ± *Eucalyptus cambageana* (Dawson gum) grassy woodland with 31.4 % remaining,

G3 - *Eucalyptus orgadophila* (mountain coolibah) ± *E. melanophloia* (silver-leaved ironbark) grassy open woodland with 43.8% remaining, and

C9 - *Eucalyptus populnea* (poplar box) or *E. brownii* (Reid River box) or

E. melanophloia (silver-leaved ironbark) grassy woodland with 47.6% remaining.

All of the units are restricted to Queensland and three of them to Unit C (Land zone 3).

4.2 Comparison of datasets

Data on landcover and vegetation change for parts of the map area are also produced by other state and national agencies, however none provides a cover of the whole area and due to differences in reporting procedures comparisons among them is difficult. The Bureau of Rural Sciences nation-wide 'remote sensing of agricultural land cover change project 1990 – 1995' (Barson *et al*. 2000) data covers the greatest portion of the map area but not all areas, while the Queensland Department of Natural Resources State Landcover and Tree Study (SLATS) report for 1997 – 99 covers all of the map area in Queensland but none of it in the Northern Territory or Western Australia.

The land cover data for common areas in the BRS, SLATS and our studies are broadly comparable in that they are primarily obtained by interrogation of Landsat TM imagery. However some differences in the methods and the parameters in the data collection and truthing, and in the reporting of them, does exist. For example, BRS and SLATS surveys use the definition of 'woody' vegetation from McDonald *et al*. (1990) as having a 20% crown cover that equates to a 12% foliage projective cover (fpc) in Specht *et al*. (1974) while this study used a modified Specht classification with a open-woodland minimum value of 10% fpc. The effect of this difference is likely to be small and SLATS indicate that they were able to extend their analysis to 5% fpc in lower rainfall areas. An additional problem in comparing the three datasets is that the BRS data are for the period 1990 – 95 and the clearing values reported in it, particularly for some Queensland bioregions, will be substantially less than those from SLATS and this study. A ranked data comparison of most affected bioregions as determined by this study, the SLATS 1997-99 and the BRS 1990-95 land cover data for bioregions with predominantly woody vegetation in the mapped area in Queensland shows similar results (Table 4.2).

Table 4.2 A ranked data comparison of land cover in the most affected bioregions reported by this study, SLATS and BRS for the Queensland portion of the Australian tropical savannas.

most affected bioregions in descending order of amount of vegetation cleared[1]		
THIS STUDY	SLATS	BRS
Brigalow Belt North	Brigalow Belt[3]	Brigalow Belt North
Mitchell Grass Downs[2]	Desert Uplands	Desert Uplands
Desert Uplands	Mitchell Grass Downs	Mitchell Grass Downs
Einasleigh Uplands	Einasleigh Uplands	Einasleigh Uplands

[1] the order may change with additional data as SLATS report against a 1991 baseline while we report on a *pre-clearing* cover.
[2] our ranking is higher due to our more detailed 'on-ground' recording of changes in grass cover in this bioregion.
[3] SLATS report for the whole Brigalow bioregion while BRS and this study report for the BBN only.

A comparison of the BRS and our data for the whole of the map area shows that both agree that the next most affected bioregions are the Victoria Bonaparte (VB), Darwin Coastal Plain (DAC) and Daly Basin (DAB). While the area cleared is not as extensive in the four most affected bioregions, the comparison does show an increase in area cleared of 25, 10 and two times respectively on the BRS 1990 – 1995 figures. Unfortunately it is not possible at all to compare datasets on the basis of land zones or vegetation unit. This is because SLATS and BRS do not use land zones or compatible vegetation units for reporting in the areas of the map covered by them, and for the rest of the map area, because we do not have any prior contiguous datasets to which the land zone concept or the units reported on here could be fitted. As a baseline has been established by this project these problems should not arise in future revisions of maps of the Australian tropical savannas.

4.3 Vegetation change

We report on changes in vegetation due to clearing from pre-existing vegetation or regrowth of it but may not distinguish changes due to some other causes, e.g.

- Change of grassland composition from endemic to exotic species, e.g. in 'improved pastures'
- Natural tree death due to drought (SLATS 1999; Fensham 1999)
- The invasion of native grasslands by woody species, e.g. *Acacia nilotica** and *Ziziphus mauritiana**, or
- The domination of wetlands by exotic species, e.g. *Mimosa pigra** and *Hymanachne amplexicaulis** and
- The invasion of *Melaleuca viridiflora* into natural grasslands (Neldner *et al*. 1997, Crowley and Garnett 2000).

* Introduced species

Some of these changes, particularly the first, may be extensive but difficult to quantify in Landsat TM images. Similarly, change at a fine scale, e.g. in vegetation about springs, and tree death due to drought, is important and locally obvious but not reported at the scale of mapping presented here. Changes due to some of these causes are likely to be viewed differently by different authorities, for example SLATS will report the invasion of grasslands by exotic shrub and/or tree species as an increase in 'woody' vegetation cover and biomass whereas we report it as a loss of the original grassland. On the other hand some industry extension officers and landowners would view the occupation of wetlands by hymanachne *H. amplexicaulus** as desirable due to its use as cattle fodder, whilst others, e.g. some shires, have it as a declared 'noxious weed'.

The matter of regrowth of previously cleared vegetation in the map area requires specific comment. This is because land cover maps produced by the Queensland Herbarium and analyses by both SLATS and BRS all report it, because it is a topic of considerable debate in the rural sector, and because regrowth of previous vegetation has ramifications for reporting on Australia's commitment to the Kyoto Convention on the emission of greenhouse gases. The 1995-97 SLATS report indicates that 33% of clearing in Queensland in that period was of regrowth; much of this clearing was of *Acacia harpophylla* in the Brigalow bioregion because this species has the propensity to re-shoot from root stock and regular clearing is needed to maintain grassland cover.

In addition to the regrowth of vegetation, woodland thickening is a noted phenomenon in northern Australia. The effect on the vegetation from changed fire regimes and increased grazing pressure has been a structural change due to a thickening of the woody understorey in many communities. This trend has been noted since European settlement (e.g. Gill *et al.* 1981, Burrows and Scanlan 1983, Hodgkinson *et al*. 1990, Burrows 1991, 1995, Russell-Smith 1996, Craig 1997, Fensham and Fairfax 1997, Harrington *et al.* 1997, Noble 1997, Fensham 1998a, Crowley and Garnett 2000) but requires specialised input that has not been incorporated at this scale of mapping. The level of research required and the logistical difficulties involved in resolving the issue of temporality were beyond the scope of the project and for this reason the vegetation as presented here is regarded as similar to vegetation in an undisturbed state apart from the land cover change reported previously.

4.4 Vegetation management and biodiversity conservation

The difficulties in reporting the results of two surveys in Queensland, and our and the BRS datasets for the whole of map area is partially due to the different criteria used for them. Our inability to provide comparisons of data for the remainder of the map area is indicative of a lack of data in suitable format or of an absence of previous survey data. Both of these circumstances have ramifications for effective vegetation management at bioregional and land zone levels, particularly across state and municipal boundaries, and for the conservation of biodiversity.

5. Description of the vegetation

This report and the accompanying maps describe the undisturbed vegetation of the Australian tropical savannas, although it is recognised by us that there are shortcomings in describing vegetation as undisturbed. The dynamic nature of vegetation and the temporal variability within plant communities was recognised by the authors of the maps used in this project. The term ‘pre-European’ describes the temporal status of Queensland vegetation data (Neldner 1984, Sattler and Williams, 1999), while the term ‘natural’ (Carnahan 1976) is used to describe the Western Australian data (Beard 1979). This implies that those maps represent the vegetation existing prior to European settlement. On the other hand, Wilson *et al.* (1990) use the term ‘present’ vegetation to describe the present day vegetation of the Northern Territory, presumably at the time of mapping in 1990, recognising the often-subtle recent and longer-term changes that have occurred since the arrival of people on the continent.

Given the difficulties in resolving the question of the extent of change over time and given that this work is the result of a compilation of various interpretations, the vegetation as presented here is regarded as vegetation in an ‘undisturbed’ state. Apart from the data presented in Chapter 4, there has been no attempt to produce a map showing landcover change over time.

The vegetation is presented here in a hierarchical classification (Figure 5.1) relating the Broad Vegetation Groups (BVGs) (representing groups of alliances and in some cases a single alliance), to the Australian tropical savannas map units (representing sub-alliances and alliances) and also to the original units from the component maps used within the project (representing associations). A lookup table relating all of the units is presented as Appendix 3.7. Within the BVGs a number of floristic terms are used; these generally follow Beadle (1981). Association is applied here to the basic floristic units as presented in each of the 1:1 000 000 scale component maps. These associations have been grouped into alliances, or sub-alliances for some associations, at the scale of 1:2 000 000. The BVGs represent groupings of alliances, or in some cases as a single, widespread alliance, at the scale of about 1: 5 000 000.

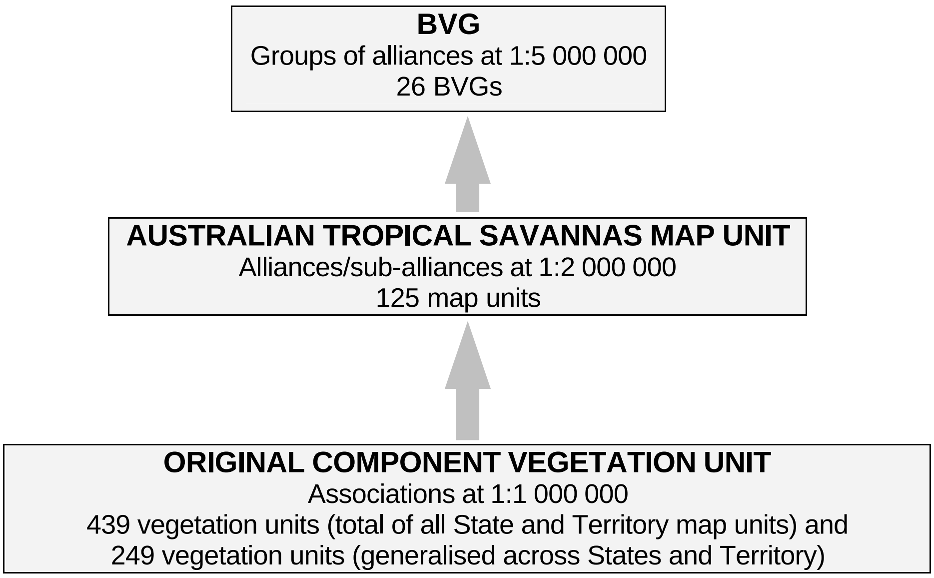

Figure 5.1 Relationship between BVG, Australian tropical savannas unit and original map unit.

5.1 Structural formations

The structural formations that dominate the Australian vegetation require a uniquely Australian classification system (Barlow 1994). The Australian tropical savannas have been mapped in part by a number of authors using different classification schemes. The vegetation classification used in this project followed those used by the mappers of each of the individual component maps. For the most part these individual maps were classified firstly on structure and secondly on floristics according to Specht (1970), Beard and Webb (1974) or Walker and Hopkins (1984, 1990). Table 3.2 was modified from Specht (1970) and lists the structural formations described for the map of the vegetation of the Australian tropical savannas (Fox *et al.*, 2001).

5.2 Broad vegetation groups

The vegetation map units have been combined into a higher-level classification of broad vegetation groups (BVGs), to allow for national and regional analyses, and as an aid to map presentation and interpretation. Some BVGs encompass groupings of vegetation types that are generally dominated by only one or two species, e.g. low woodlands dominated by *Melaleuca viridiflora* or *M. nervosa* on depositional plains or alluvium. A suite of species within a range of structural types, e.g. *Acacia* spp. dominated associations on dissected residuals may also dominate a BVG. Other BVGs are dominated by a distinct structural formation, such as tussock grasslands, or by a combination of a structural formation and habitat, e.g. *Acacia* spp. dominated shrublands on sandplains.

In addition, two broad regional climatic groupings termed 'monsoon' and 'eastern sub-humid' have been incorporated in the BVG categories. The groupings are generally dominated by *Eucalyptus* spp. and *Corymbia* spp. and are used to separate the plant communities that occur across the most northern, monsoon-influenced parts of the map area from those communities in the eastern sub-humid zone that lies largely west of the Great Dividing Range. Because of the desire to reduce the number of BVGs, some units, notably some ironbark and northern box woodlands in the Einasleigh Uplands and Cape York Peninsula bioregions have been placed within the eastern sub-humid grouping rather than the monsoon grouping. A separate, minor monsoon grouping includes a number of mixed species woodlands that, although limited in extent, are scattered throughout northern Australia.

The BVG descriptions refer to structural categories (Specht 1974) that have been used to define subdivisions within a structural formation.

'Alliance' refers to a series of climax plant communities that have the same structural characteristics, related species as dominants in the uppermost stratum and possibly the same or related species in the understorey.

'Sub-alliance' refers to the distinct but related species groups that occur as dominants in the upper stratum of an alliance.

'Association' refers to a series of climax plant communities that have the same structural characteristics, the same dominant species in the upper stratum and possibly different floristic composition in the lower strata.

Within the vegetation descriptions several common names are used. These are based on the bark characteristics of the dominant trees that are used to describe groups of species within the genus *Eucalyptus* or the genus *Corymbia*.

'Ironbark' refers to any one of a number of eucalypt species with a readily identifiable hard, grey to black, furrowed rough bark. Ironbarks occur most extensively in

Queensland and form woodlands throughout much of the eastern half of that state. A number of species within the group, including the widespread *Eucalyptus crebra,* are currently under revision. Other species in the group include *E. fibrosa, E. granitica, E. exilipes, E. cullenii, E. melanophloia, E. xanthoclada, E. whitei* and *E. quadricostata.*

'Yellowjacket' is used here to describe a group of *Corymbia* spp. known as the yellow bloodwoods and a single eucalypt species, *E. similis*. The bark of these trees is characteristically yellow and in the *Corymbia* spp. is loose and flakes off exposing yellow beneath while in *E. similis* the bark does not flake off but occurs as a tight, rough and fibrous yellow bark.

'Poplar box' is used to describe woodlands of eastern Australia that are dominated by the species *E. populnea* and, in more northern parts, by *E. brownii.* Poplar box woodlands frequently occur in association with ironbark woodlands (Beadle 1981).

'Northern box' refers to the species *E. leptophleba, E. chlorophylla* and *E. microneura* and to a lesser extent *E. tardecidens* and *E. persistens* that are all restricted to north Queensland.

'Paperbark' refers to a number of *Melaleuca* spp. associated with permanently wet areas. In some cases 'paperbark' is synonymous with other names applied to *Melaleuca* spp. including 'teatree'.

'Pindan' is used to describe grassy low open-woodlands that have a characteristic, dense, mid-layer of unarmed, phyllodal *Acacia* spp. or of shrublands dominated by *Acacia* spp. (Beard 1979) that occur on sandplains in the western Kimberley region.

'Bylong woodland' was used by Perry *et al.* (1964) to describe a distinctive group of mixed-species communities that occur on broad sandplains to the southeast of the Gulf of Carpentaria.

BVG 1. Closed-forest communities.

This group consists of all of the rainforest-dominated communities within the map area and as a consequence is highly diverse. In the high rainfall northeast Queensland tropics and to a lesser extent in the Arnhem Land region, mesophyll and notophyll vine forests occur on a range of substrates including coastal sands, alluvial systems, metamorphic and sandstone hills and granite hills and ranges. Emergent trees are common and include *Araucaria cunninghamii* (Queensland) and a number of *Eucalyptus* spp., *Corymbia* spp., *Acacia* spp. and rainforest species. Small patches of closed-forest communities occur on scree slopes on a wide range of geologies throughout the map area. On residual plains, semi-deciduous vine forests occur as small patches. The Quaternary basalt flows of northeast Queensland carry deciduous vine thickets with broken and frequently sparse canopies.

BVG 2. Open-forests dominated by *Eucalyptus* spp. and *Corymbia* spp..

Open-forests occur in the high rainfall eastern coastal and sub-coastal areas of the map. Tall open-forests are confined to areas close to the Wet Tropics and Brigalow Belt North bioregions and are dominated by *Eucalyptus tereticornis* and *Corymbia intermedia* alliances. Shrubby open-forests dominated by *C. citriodora* and *Eucalyptus* spp. (ironbark) alliance are common and extensive on Tertiary remnant plateaux in the east of the Einasleigh Uplands bioregion. On eastern Cape York Peninsula *Corymbia* spp. open-forests occur as patches on erosional plains.

BVG 3. Open-forests and woodlands dominated by *Eucalyptus* spp. and *Corymbia* spp. on drainage lines and alluvial plains.

This widespread group comprises a number of alliances associated with river channels, levees and floodplains. Sandy channels and levees are frequently dominated by a *Eucalyptus camaldulensis* alliance, whereas heavier clay channels and levees are dominated by an *E. microtheca* or *E. coolabah* or *E. gymnoteles* alliance. *Melaleuca* spp. alliances occur along many river channels. Floodplains carry a number of alliances including a *C. clarksoniana, E. leptophleba* alliance on southern Cape York Peninsula and an *E. platyphylla* alliance in eastern sub-coastal regions. Floodplains on heavy clay adjoining the larger river systems such as in the Gulf of Carpentaria, Victoria River, and the Ord River regions, carry an extensive of alliance of *E. microtheca* or *E. coolabah* or *E. gymnoteles* with low *Excoecaria parvifolia.*

BVG 4. Monsoon woodlands dominated by *Eucalyptus tectifica* and *Corymbia* spp..

This is a widespread and diverse group comprising alliances of *Eucalyptus tectifica.* Across the northwest Northern Territory and northeast Kimberley an alliance of *E. tectifica* and *Corymbia foelscheana* is common on sandplains over limestone. An alliance of *E. tectifica* and *C. terminalis* occurs on clay loam and podzolic plains in the southern Gulf of Carpentaria and central Northern Territory. In the southeast Gulf of Carpentaria an alliance of *C. polycarpa* with *E. tetrodonta* and *E. miniata* occurs on sandy plains and old levees.

BVG 5. Monsoon woodlands and open-woodlands dominated by *Eucalyptus tetrodonta* and *E. miniata.*

The group is made up of several alliances dominated by *Eucalyptus tetrodonta* and *E. miniata*. On Cape York Peninsula, an alliance of *E. tetrodonta* and *Corymbia* spp. (without *E. miniata*) occurs on Tertiary and Quaternary sandplains. In the southern Gulf of Carpentaria an alliance of *E. tetrodonta* with *Melaleuca viridiflora* occurs on sandplains. A broad band of an alliance of *E. tetrodonta, E. miniata* and *Corymbia* spp., such as *C. dichromophloia* and *C. bleeseri,* occurs on sandstone hills and sandy red earth plains from the Gulf of Carpentaria across Arnhem Land and the Mitchell Plateau to Yampi Sound in the Kimberley. The group includes small areas of an *E. tetrodonta, C. nesophila* sub-alliance and an *E. leptophleba, C. clarksoniana* sub-alliance that occur on Cape York Peninsula.

BVG 6. Monsoon woodlands to low open-woodlands dominated by *Corymbia dampieri* and *Eucalyptus tectifica* (pindan woodland).

This *Corymbia dampieri, C. zygophylla* and *C. flavescens* alliance dominates the sandplains of the Dampierland region of the western Kimberley. *Acacia eriopoda, A. ancistrocarpa* and *A. tumida* open-scrub is a frequent and characteristic mid-layer. On the sandplains of the Dampier Peninsula, a *Eucalyptus tectifica, C. flavescens* or a *C. dampieri* low open-woodland alliance with a characteristic *Acacia* spp. mid-layer also occurs. The alliances of this group are closely associated with a shrubland alliance grouped into BVG 18.

BVG 7. Monsoon low open-woodlands dominated by *Eucalyptus brevifolia* or *E. leucophloia.*

Whilst much of this widespread alliance occurs in the semi-arid zone it is still regularly influenced by cyclonic and monsoonal weather patterns and has therefore been included in the monsoon woodlands. *Eucalyptus brevifolia* dominates in western Northern Territory and Western Australia and *E. leucophloia* in northwest Queensland and eastern Northern Territory. The canopy is frequently sparse and generally monospecific, although in some areas *Corymbia* spp. may be present. The ground layer is dominated by *Triodia* spp. hummock grass.

BVG 8. Monsoon low open-woodlands dominated by *Eucalyptus leucophylla* or *Corymbia terminalis*.

The group consists of an alliance of *Eucalyptus leucophylla* or *Corymbia terminalis,* generally as co-dominants, on sandplains over clay and on low hills on fine-grained sediments. *E. leucophylla* is restricted to the Mt Isa area of northwest Queensland and *E. chlorophylla* replaces it in associations in the Northern Territory and the Kimberley. In central Queensland, *C. terminalis* dominates without *E. leucophylla.* The ground layer dominated by tussock grasses. A small area of *C. opaca* in eastern Northern Territory is included in this group.

BVG 9. Monsoon woodlands dominated by *Eucalyptus pruinosa* and *Lysiphyllum cunninghamii.*

This group comprises a widespread, variable *Eucalyptus pruinosa, Lysiphyllum cunninghamii* alliance, found on flat to undulating plains on residual Tertiary surfaces and outwash plains. Many other species can be present and the ground layer consists of tussock grasses or *Triodia* spp. and forbs.

BVG 10. Monsoon low woodlands to low open-woodlands dominated by *Corymbia dichromophloia* or *C. capricornia*.

This group contains a number of alliances. The most extensive is a *Corymbia dichromophloia* alliance that occurs on sandstone and conglomerate hills and extends across much of the northern plateau landscape of Northern Territory and the Kimberley. *C. dichromophloia* is used here to refer to three species, *C. dichromophloia* (northern Northern Territory), *C. capricornia* (central Northern Territory and northwest Queensland) and *C. drysdalensis* (Kimberley). Other canopy species are generally present and the ground layer is dominated by *Triodia bitextura*. In central Northern Territory on gently undulating lateritic plateaux a *C. capricornia* alliance occurs. The group also includes a *C. dampieri* alliance on low sandstone rises in the southern Kimberley region. *Triodia* spp. dominate the ground layer.

BVG 11. Monsoon low woodlands and woodlands dominated by *Corymbia* spp. or *Eucalyptus phoenicea*.

The group comprises an alliance of *Corymbia ferruginea* and *Eucalyptus phoenica* with a *Triodia bitextura* ground layer on sandstone hills and crests. It occurs extensively in the eastern Kimberley, with scattered occurrences across the Northern Territory to the Gulf of Carpentaria. The group also includes a *C. grandifolia, Corymbia* spp. alliance on gently sloping sandstone in the eastern Kimberley.

BVG 12. Eastern sub-humid woodlands and open-woodlands dominated by *Eucalyptus* spp. (poplar box and ironbark).

The poplar box alliance has *Eucalyptus populnea* (grading to *E. brownii* in the north) as the characteristic species of extensive grassy woodlands in sub-coastal eastern central Queensland. An extensive ironbark alliance dominated by any of a number of species frequently occurs in a mosaic with the poplar box. Woodlands dominated by ironbark species *E. crebra* and *E. drepanophylla* also occur in coastal regions, while in drier areas further west, *E. whitei* dominates. Both the poplar box and ironbark alliances have a tussock grass ground layer in eastern and central areas with the presence of *Triodia* spp. in the ground layer increasing to the west. A shrub layer is minimal or frequently absent. The alliances occur on plains and undulating low rises on Quaternary alluvium and Cainozoic sand deposits and are frequently associated with the *Acacia* spp. woodlands of BVG 16.

BVG 13. Eastern sub-humid woodlands and open-woodlands dominated by *Eucalyptus* spp. (yellowjacket and ironbark).

The yellowjacket alliance in this group includes the distinctive *Eucalyptus similis, Corymbia setosa* open-woodland that follows an extensive sand plain running north to south in central Queensland. The sparse ground layer is dominated by *Triodia pungens*. In close association with the *E. similis* alliance is a *C. leichhardtii* alliance on hills of sandstone and pebble conglomerate and a *Eucalyptus* spp. (ironbark) alliance on sandstone scarps and plateaux. The ironbark alliance includes associations of *E. crebra, E. melanophloia* and *E. shirleyi* in central and north Queensland and *E. cullenii* with *C. hylandii* extending through central Cape York Peninsula. The alliances within this group frequently occur together in a mosaic and can also form extensive associations of mixed species, for example broad woodlands of *Corymbia* spp. and *Eucalyptus* spp. on undulating metamorphic hills in the Desert Uplands bioregion.

BVG 14. Eastern sub-humid woodlands dominated by *Eucalyptus* spp. (northern box and ironbark) on undulating low hills on metasediments and acid volcanics.

The alliances within this group occur on acid volcanic and metamorphic hills, with some minor occurrences on undulating mudstone and siltstone hills. The northern box alliances are a *Eucalyptus leptophleba* alliance on undulating fine-grained sediments; a regionally dominant *E. microneura* alliance on metamorphic hills in the Einasleigh Uplands and eastern Gulf Plains bioregions and a scattered alliance dominated by *E. persistens* and *E. tardecidens*. The ironbark alliances occur on and immediately west of the Great Dividing Range and extend north from about Bowen to southern Cape York Peninsula. Associations within the alliance include *E. crebra (s. lat), E. melanophloia, E. drepanophylla, E. staigeriana* and *E. fibrosa* subsp. (Glen Geddes M.I. Brooker 10230), the latter being dominant on the serpentine ranges of eastern central Queensland.

BVG 15. Woodlands and open-woodlands on basalt.

The alliances of this group occur on flat to undulating plains and low basalt rises. In Queensland the basalts are generally from the Cainozoic era, while in the Northern Territory and Western Australia the basalts are older, predominantly from the Palaeozoic era. Alliances within the group have a characteristic mid-dense to dense ground layer of tussock grasses. In eastern Queensland an ironbark alliance is dominated by *E. crebra* (*s. lat.*) and includes a number of *Eucalyptus* spp. and *Corymbia* spp. The alliance is generally closely associated with small occurrences of an *E. leptophleba* association, sometimes as a mosaic, and with a more extensive alliance of *E. orgadophila.* In the Kimberley an alliance of *E. tectifica* and *C. grandifolia* occurs on plains and lower slopes with red friable earth soils.

BVG 16. *Acacia* spp. associations on clay plains

This group includes an *Acacia harpophylla* alliance, commonly known as ‘the brigalow’, that occurs in a broad band on fertile clay plains, often with shallow depressions or ‘gilgais’, in central Queensland. *A. harpophylla, A. cambagei* and *A. argyrodendron* form woodlands that are frequently associated with ironbark and poplar box woodlands (BVG 12). Also on clay plains, but in drier areas west of ‘the brigalow’ is an alliance known as gidgee or gidyea that is dominated by *A. cambagei, A. tephrina* or *A. georginae.* This alliance often occurs as isolated patches in association with the *Astrebla* spp. tussock grasslands that dominate much of the landscape in central western Queensland and central Northern Territory. Gidgee woodlands are also associated with other *Acacia* spp. and *Senna* spp. woodlands. This group includes a *Senna* spp. shrub alliance on remnant limestone and shale low rises in western Queensland, extending westwards into the Northern Territory.

BVG 17. *Acacia shirleyi* and *Acacia* spp. associations on dissected residual surfaces and sandstone hills.

A complex *Acacia shirleyi* alliance on dissected residual surfaces and sandstone hills across Queensland and in the central Northern Territory. The alliance occurs on hills where it characteristically occupies ridges, breakaways and scarp margins and also occurs on some Tertiary remnants on undulating plains. It contains many associations dominated by *Acacia* spp. including *A. catenulata, A. aneura* and *A. stowardii,* as well as a number of associations dominated by *Eucalyptus* spp..

BVG 18. *Acacia* spp. shrublands on sandplains.

The group comprises two distinct *Acacia* spp. shrubland alliances that occur on sandplains. In western Queensland and eastern Northern Territory an *Acacia aneura, Archidendropsis basaltica* alliance known as 'mulga' occurs on residual sands. In the Kimberley region, *Acacia ancistrocarpa* and *A. eriopoda* dominate a shrubland alliance known as 'pindan' that occurs on sandplains and is associated with alliances of BVG 6.

BVG 19. Open-forests and woodlands of *Melaleuca* spp. (paperbarks) associated with rivers, lagoons and swamps.

This group comprises a *Melaleuca* spp. alliance known as 'paperbark forest' that occurs on some permanently flooded areas of northeast Queensland and some northern areas of the Northern Territory. Species including *M. leucadendra. M. argentea, M. fluviatilis, M. viridiflora* and *M. cajuputi* occur, frequently with numerous other species, including rainforest species such as *Ficus* spp. and *Nauclea orientalis.*

BVG 20. Low woodlands dominated by *Melaleuca* spp. on depositional plains or alluvium.

The alliances of the group occur on flat to undulating alluvium or sandplains across northern Australia. A *Melaleuca viridiflora* alliance occurs on extensive alluvial- and sandplains adjoining the eastern Gulf of Carpentaria, with scattered patches across the remainder of the mapped area. An *M. minutifolia* sub-alliance occurs on alluvial plains to the southeast of the Joseph Bonaparte Gulf. An alliance of *M. citrolens* is often associated with the *M. viridiflora* alliance and occurs extensively in the Gulf of Carpentaria region. Both alliances generally have a continuous low canopy and may have a similarly continuous shrub layer. In areas immediately behind the littoral margin an alliance of *M. acacioides* or *M. alsophila* occurs in small depressions that are often seasonally inundated with freshwater.

BVG 21. Monsoon mixed species woodlands to low open-woodlands.

This group comprises a number of generally unrelated alliances. A *Lysiphyllum* spp. alliance comprises a sparse overstorey of numerous deciduous species with a tussock grass understorey and occurs on fine sediment plains. An alliance of *Adansonia gregorii, Lysiphyllum cunninghamii* and *Grevillea striata* occurs on sandplains in the western Kimberley. On extensive outwash plains in the Gulf of Carpentaria region, an alliance of *Lysiphyllum cunninghamii, Atalaya hemiglauca, Grevillea striata* and *Corymbia* spp. is locally dominant. On the low rainfall sandplains south of the Dampier Peninsula a *Grevillea refracta, Hakea lorea* alliance occurs that is likely to be an extension of a broader alliance that occurs outside the map area in the Great Sandy Desert. In the Kimberley and northeast Queensland, a distinctive alliance of deciduous species including *Cochlospermum* spp., *Terminalia* spp and *Erythrophleum chlorostachys* occupies granite outcrops. It is likely that similar outcrop vegetation occurs in the Northern Territory but this has not been mapped at this scale.

BVG 22. Heathlands and closed-shrublands.

An *Asteromyrtus lysicephala, Neofabricia myrtifolia* alliance is restricted to Cape York Peninsula. It occurs as open-heath on Tertiary and Quaternary sands and alluviums. Numerous other species may be present. Extensive heaths dominated by *Leucopogon* spp. also occur on Cape York Peninsula but these are generally on sand dunes in coastal areas and have been included in BVG 26.

BVG 23. Tussock grasslands.

Tussock grasslands of *Astrebla* spp. (Mitchell grass downs) form the most extensive alliance of this group. Another major alliance is the *Dichanthium* spp. (Blue grass) downs. Both alliances occur on broad and extensive clay plains across the whole map area, with the most extensive areas being in west and northwest Queensland, running into central Northern Territory. On drier and stony parts of the same clay plains an alliance of short grasses such as *Ennapogon* spp. and *Aristida* spp., often wooded with stunted low trees, can occur. On marine plains a variable alliance of mixed species such as *Sorghum* spp., *Xerochloa* spp., *Themeda* spp., *Oryza* spp. and *Chrysopogon elongatus* often occurs in association with sedgelands.

BVG 24. Hummock grasslands.

The group comprises a number of *Triodia* spp. alliances that are generally associated with more arid areas than those occupied by the tropical savannas, however they occur within the map area and are an important component of the landscape. A *T. pungens* alliance, often as a sub-alliance with other *Triodia* species, occurs on Quaternary sandplains over lateritic substrates across large areas of the central Northern Territory. The alliance also occurs on low sandstone hills and ridges in the southern Kimberley. A *T. wiseana* alliance occurs on limestone hills in the southern Kimberley and extends east into the Northern Territory and also forms a sub-alliance with *T. intermedia* on folded hills in the Hall's Creek region. In northwest Queensland a *T. molesta* alliance occurs on folded hills, acid volcanics and on some sandstone. This community frequently includes low trees.

BVG 25. Sedgelands, lakes and lagoons and ephemeral herblands and grasslands.

The group comprises several alliances that are dependent on either seasonal or permanent freshwater. In central Queensland and the Northern Territory an alliance is dominated in the wet season by ephemeral chenopod species herblands and in the dry season by tussock grassland. Scattered low trees are also a common feature of this alliance. Associated with major river systems is an alliance of fringing woodlands, shrublands and sedgelands on permanent, semi-permanent and ephemeral lakes, lagoons and swamps that may occur some distance from the watercourse, but are nevertheless dependent on seasonal flooding for the maintenance of water levels.

BVG 26. Communities of the littoral zone.

The littoral zone incorporates a number of alliances but the three alliances occurring on Quaternary marine deposits are distinctive. At the saltwater margin an alliance of mangrove communities ranges from open-forests in parts experiencing frequent tidal inundation to shrublands where inundation is less frequent and hypersalinity impedes floristic and structural diversity. The tidal flats are predominantly hypersaline and generally bare, although a number of samphire species or *Sporobolus virginicus* can occur on slightly elevated parts. A *Sporobolus virginicus* grassland alliance occurs at the landward margins of the marine deposits at the saltwater-freshwater interface.

On coastal sand masses a number of alliances occur. These have been grouped here into a complex of coastal dune communities that include a "*Casuarina* spp. and *Spinifex* spp. alliance" on foredunes, a swamp and sedgeland alliance in swales between major dunes, and on dunes and in swales a number of sub-alliances of more widespread alliances including *Melaleuca,* rainforest and *Eucalyptus*. Shrublands and heathlands on the eastern Cape York Peninsula coast are also included.

5.3 Vegetation of the bioregions

Bioregions, or biogeographic regions, describe areas in which ecosystem interactions with major structural geologies, lithologies, landform and climate occur with some consistency across the region (Stanton and Morgan 1977, Thackway and Cresswell 1995, Sattler and Williams 1999). Table 5.1 presents the Australian tropical savanna vegetation map units that occur in each bioregion. The landscape and vegetation for each unit within the bioregion shown in the table can be readily determined from the vegetation map code used in which the prefix letter in each code refers to a land zone (see 2.7 Land zones and Appendix 1.1). For example, in Table 5.1 the Arnhem Plateau bioregion units H9 and H6 are the dominant vegetation units within the bioregion. The prefix 'H' refers to land zone 10 and describes a landscape dominated by hills and plateaus of sandstone and conglomerate. Similarly, the Mt Isa Inlier has a dominant vegetation of J12 where 'J' represents land zone 11, being hills and ranges of moderately to strongly deformed and metamorphosed sediments.

Table 5.1 The vegetation map units occurring within each bioregion

BIOREGION (IBRA version 5)	Vegetation Map Units		
	Dominant vegetation units in each bioregion[1]		No. of units each <5%[2]
	>20%	5-20%	
Arnhem Coastal	D4	H6, H9, D10	7
Arnhem Plateau	H9, H6	D10, D4	6
Brigalow Belt North	-	C4, D7, D8, J8	43
Central Arnhem	H6, D4	D10, D13	7
Central Kimberley	H8	K8, H15, K7, F4	25
Cape York Peninsula	D15	C13, E2	34
Daly Basin	D10, D14, D4	H9	9
Darwin Coastal	D4, C19	H6	11
Desert Uplands	G1	D17, D16, D8, C4, C5	24
Dampierland	D23	D12, D21	29
Einasleigh Uplands	-	K6, J8, F2, J10, J5, K9	42
Gulf Fall Uplands	H9	D11, D27, D29	23
Gulf Coastal	D13	D11, H9, A3	12
Gulf Plains	-	C18, D19, C7, D20, G10, C13, D15, D18, D6	43
Mitchell Grass Downs	G10, C17	G5, C7	30
Mount Isa Inlier	J12	J11, G7, D22, D28	18
North Kimberley	H9, F4	H6	19
Ord-Victoria Plains	-	H15, F7, D26, F8, F9, C17, C18	30
Pine Creek-Arnhem	D10	H9, D14, D4	9
Sturt Plateau	D5, E1	D36, D29	13
Tiwi	D4	A1	6
Victoria Bonaparte	H9	D10, H8, K8, H6, D14, A3	26

1. Vegetation units are ranked in descending order of dominance, as measured by percentage of the area contributed by each vegetation unit to the total area of the vegetation within the bioregion.
2. Shows the number of vegetation map units whose areas contribute <5% each to the total area of vegetation within the bioregion

Of note is the fact that the Brigalow Belt North, Einasleigh Uplands, Gulf Plains and Ord-Victoria Plains bioregions have no vegetation units that each contribute more than 20% of the vegetation within the bioregion. Further, each of these bioregions, along with the Cape York Peninsula, Central Kimberley, Dampierland, Mitchell Grass Downs and Victoria Bonaparte bioregions, has 25 units or more that each contribute less than 5% to the total vegetation of the bioregion. Refer to Appendix 1 in Thackway and Cresswell (1995) or online at http://www.ea.gov.au/parks/nrs/ibraimcr/ibra_95/ibra_v4/app1.html for more detailed information on each bioregion.

5.4 Key to the map units

The following is a list of the map units occurring on the map of the vegetation of the Australian tropical savannas. The legend used on the digital version of the map contains an abbreviated legend description without the bracketed common name. Units are grouped according to land zone (Sattler and Williams 1999, Harris *in prep.*). Within each land zone, units are listed from the tallest, most dense community through to the shortest, least dense community.

In the map unit descriptions some key abbreviations are used.

Where "and/or" is used between two species either one species or the other species is present, or they may both be present.

Where "+/-" is used between two species the first species is always present and the second species is present at some sites but not at others.

Where "," and "and" are used between two species both species are always present.

Where "or" is used between two species, either one of the species is present or the other, but not both.

Introduced species are indicated with * in the vegetation descriptions that follow.

Some units in the Kimberley are a mosaic of two communities and were derived from the original mosaic map units in Beard (1979). These distinct communities are separated in the description by "or". The descriptions also include some units that naturally occur across a structural continuum between woodland and grassland. Where units contain significant proportions of more than one structural element the expression "or sometimes …" is used to indicate the minor community.

A. Units on Quaternary marine deposits, predominantly saline muds.

Map Unit A1	Mangroves
Map Unit A2	*Sporobolus virginicus* (marine couch) grassland
Map Unit A3	Saline tidal mudflats +/- samphire

B. Units on Quaternary coastal dunes, predominantly sands

Map Unit B1	Vine forest +/- emergent *Araucaria cunninghamii* (hoop pine)
Map Unit B2	Coastal dune communities

C. Units on Cainozoic alluvial plains or clay deposits, predominantly on cracking clays and loams.

Map Unit C1	Rainforest communities on alluvial systems
Map Unit C2	*Eucalyptus tereticornis* (blue gum) and/or *Eucalyptus moluccana* (gum-topped box) and/or *Corymbia intermedia* (pink bloodwood) and/or *Corymbia tessellaris* (Moreton Bay ash) open-forest.
Map Unit C3	*Melaleuca* spp. (paperbark) open-forest.
Map Unit C4	*Acacia harpophylla* (brigalow) and/or *Acacia cambagei* (gidgee) +/- *Acacia argyrodendron* (blackwood) +/- *Eucalyptus cambageana* (Dawson gum) grassy woodland.
Map Unit C5	*Acacia cambagei* (gidgee) and/or *Acacia tephrina* (boree) low woodland.
Map Unit C6	*Corymbia clarksoniana* (Clarkson's bloodwood) or *Corymbia polycarpa* (long-fruited bloodwood) +/- *Eucalyptus leptophleba* (Molloy red box) +/- *Eucalyptus* spp. grassy woodland.
Map Unit C7	*Eucalyptus camaldulensis* (river red gum) and/or *Eucalyptus microtheca* (coolibah) or *Eucalyptus coolabah* (coolibah) or *Eucalyptus gymnoteles* (coolibah) woodland on channels and levées.
Map Unit C8	*Eucalyptus platyphylla* (poplar gum) and/or *Eucalyptus* spp. grassy woodland.
Map Unit C9	*Eucalyptus populnea* (poplar box) or *Eucalyptus brownii* (Reid River box) or *Eucalyptus melanophloia* (silver-leaved ironbark) grassy woodland.
Map Unit C10	*Eucalyptus microtheca* (coolibah) or *Eucalyptus gymnoteles* (coolibah) and/or *Eucalyptus* spp. +/- *Excoecaria parvifolia* (gutta percha) grassy low woodland.
Map Unit C11	*Melaleuca minutifolia* (paperbark) low woodland with *Sorghum* spp. tussock grasses.
Map Unit C12	*Melaleuca citrolens* (narrow-leaved paperbark) or *Melaleuca acacioides* (coastal paperbark) or *Melaleuca alsophila* (coastal paperbark) +/- *Melaleuca* spp. low open-woodland.
Map Unit C13	*Melaleuca viridiflora* (broad-leaved teatree) grassy low open-woodland +/- a shrub layer +/- emergent trees.
Map Unit C14	*Livistona humilis* (fan palm) grassy tall open-shrubland.
Map Unit C15	*Asteromyrtus lysicephala* (Kennedy's heath) open-heath.
Map Unit C16	Ephemeral herblands and/or grasslands with scattered low trees.
Map Unit C17	*Astrebla pectinata* (barley Mitchell grass) closed-tussock grassland +/- low trees.
Map Unit C18	*Dichanthium fecundum* (curly bluegrass) and *Chrysopogon fallax* (golden beard grass) tussock grassland sparsely wooded with low trees.
Map Unit C19	Mixed species tussock grasslands or sedgelands +/- emergent *Pandanus* spp. (screw palm) and/or *Corypha utan* (gebang).
Map Unit C20	Swamps, lakes and lagoons, frequently ephemeral, +/- fringing woodlands, shrublands, herblands and sedgelands.

D. Units on Cainozoic sand deposits, predominantly on plains of sands and earths and often overlying lateritic profiles

Map Unit D1 Semi-deciduous vine forest.

Map Unit D2 *Corymbia citriodora* (lemon-scented gum) and/or *Eucalyptus crebra* (narrow-leaved ironbark) and/or *Corymbia clarksoniana* (Clarkson's bloodwood) grassy open-forest +/- a shrub layer.

Map Unit D3 *Corymbia tessellaris* (Moreton Bay ash) and/or *Corymbia clarksoniana* (Clarkson's bloodwood) and/or *Eucalyptus tetrodonta* (Darwin stringybark) grassy open-forest.

Map Unit D4 *Eucalyptus miniata* (Darwin woollybutt) and *Eucalyptus tetrodonta* (Darwin stringybark) +/- *Corymbia nesophila* (Melville Island bloodwood) open-forest with *Sorghum* spp. (sorghum) tussock grasses.

Map Unit D5 *Corymbia capricornia* (variable-barked bloodwood) grassy woodland.

Map Unit D6 *Corymbia polycarpa* (long-fruited bloodwood), *Corymbia* spp. and *Eucalyptus* spp. shrubby woodland with sparse tussock grasses.

Map Unit D7 *Eucalyptus crebra* (narrow-leaved ironbark) or *Corymbia setosa* (rough-leaved bloodwood) +/- *Callitris intratropica* (northern cypress pine) grassy woodland.

Map Unit D8 *Eucalyptus populnea* (poplar box) or *Eucalyptus melanophloia* (silver-leaved ironbark) +/- *Acacia harpophylla* (brigalow) woodland with tussock grasses and/or *Triodia pungens* (soft spinifex).

Map Unit D9 *Eucalyptus microneura* (Georgetown box) and/or *Eucalyptus persistens* (knotted box) woodland +/- a shrub layer of *Eremophila mitchellii* (false sandalwood) and sparse tussock grasses.

Map Unit D10 *Eucalyptus tectifica* (Darwin box) and/or *Corymbia* spp. woodland with *Sorghum* spp.(sorghum) and *Sehima nervosum* (white grass) tussock grasses.

Map Unit D11 *Eucalyptus tectifica* (Darwin box) +/- *Corymbia terminalis* (desert bloodwood) woodland with a sparse shrub layer and *Heteropogon contortus* (black spear grass), *Chrysopogon* spp. (ribbon grass) and *Sehima nervosum* (white grass) tussock grasses.

Map Unit D12 *Eucalyptus tectifica* (Darwin box), *Corymbia flavescens* (wrinkle-leaved ghost gum) woodland with *Acacia tumida* (pindan wattle) open-scrub and *Chrysopogon* spp. (ribbon grass) and *Triodia bitextura* (curly spinifex) grasses.

Map Unit D13 *Eucalyptus tetrodonta* (Darwin stringybark) and/or *Melaleuca viridiflora* (broad-leaved teatree) +/- *Callitris intratropica* (northern cypress pine) woodland with *Triodia bitextura* (curly spinifex) hummock grass.

Map Unit D14 *Eucalyptus tetrodonta* (Darwin stringybark), *Eucalyptus miniata* (Darwin woollybutt) +/- *Corymbia* spp. +/- *Livistona* spp. (fan palms) woodland with a ground layer of tussock grasses and *Triodia bitextura* (curly spinifex).

Map Unit D15 *Eucalyptus tetrodonta* (Darwin stringybark) and/or *Corymbia* spp. +/- *Eucalyptus phoenicea* (scarlet gum) woodland with sparse *Schizachyrium* spp. (fire grass) tussock grass.

Map Unit D16 *Eucalyptus similis* (Queensland yellowjacket) and/or *Corymbia setosa* (rough-leaved bloodwood) +/- *Lysicarpus angustifolius* (budgeroo) open-woodland +/- shrub layer and very sparse *Triodia pungens* (soft spinifex) hummock grass.

Map Unit D17 *Eucalyptus whitei* (White's ironbark) open-woodland with sparse *Triodia pungens* (soft spinifex) hummock grass.

Map Unit D18 *Lysiphyllum cunninghamii* (bauhinia), *Grevillea striata* (beefwood), *Atalaya hemiglauca* (whitewood) and *Corymbia* spp. low-woodland +/- emergent *Corymbia polycarpa* (long-fruited bloodwood).

Map Unit D19 *Melaleuca citrolens* (lemon-scented teatree) and *Melaleuca* spp. (teatree) low woodland with sparse *Chrysopogon fallax* (golden beard grass) tussock grass.

Map Unit D20 *Melaleuca viridiflora* (broad-leaved teatree) and/or *Melaleuca* spp. (teatree) low woodland +/- emergent *Corymbia polycarpa* (long-fruited bloodwood) or *Corymbia clarksoniana* (Clarkson's bloodwood) with *Petalostigma* spp. (quinine bush) shrubs and tussock grasses.

Map Unit D21 *Adansonia gregorii* (boab), *Lysiphyllum cunninghamii* (bauhinia) and *Grevillea striata* (beefwood) grassy low open-woodland.

Map Unit D22 *Atalaya hemiglauca* (whitewood) +/- *Grevillea striata* (beefwood) +/- *Acacia* spp. +/- *Eucalyptus* spp. +/- *Corymbia* spp. low open-woodland with *Aristida* spp. (three-awn grass) and *Enneapogon* spp. (nine-awn grass) tussock grasses or sometimes a wooded open-tussock grassland.

Map Unit D23 *Corymbia dampieri* (pindan bloodwood) low open-woodland with *Acacia* spp. shrubs and *Triodia pungens* (soft spinifex) and *Triodia bitextura* (curly spinifex) hummock grasses.

Map Unit D24 *Corymbia dampieri* (pindan bloodwood) and *Corymbia zygophylla* (rough-leaved Bloodwood) low open-woodland with *Acacia eriopoda* (pindan wattle) shrubs and *Triodia* spp. (spinifex) hummock grasses or *Adansonia gregorii* (boab), *Grevillea striata* (beefwood) and *Lysiphyllum cunninghamii* (bauhinia) low open-woodland.

Map Unit D25 *Corymbia terminalis* (desert bloodwood) low open-woodland with *Triodia pungens* (soft spinifex) hummock grass +/- tussock grasses or sometimes grassland without trees.

Map Unit D26 *Eucalyptus brevifolia* (snappy gum) low open-woodland with *Triodia* spp. (spinifex) hummock grass or sometimes a hummock grassland without trees.

Map Unit D27 *Eucalyptus leucophloia* (snappy gum) low open-woodland and/or a shrubland with *Triodia pungens* (soft spinifex) and *Triodia bitextura* (curly spinifex) hummock grasses.

Map Unit D28 *Eucalyptus leucophylla* (Cloncurry box) +/- *Corymbia terminalis* (desert bloodwood) low open-woodland with a sparse understorey of tussock grasses or *Triodia* spp. (spinifex).

Map Unit D29 *Eucalyptus pruinosa* (silver box) +/- *Lysiphyllum cunninghamii* (bauhinia) low open-woodland +/- a shrub layer and tussock grasses or *Triodia* spp. (spinifex).

Map Unit D30 *Melaleuca tamariscina* (paperbark teatree) and/or *Melaleuca uncinata* (teatree) and/or *Acacia leptostachya* (slender wattle) and/or *Thryptomene parviflora* (thryptomene) low open woodland with sparse *Triodia* spp. (spinifex) hummock grasses.

Map Unit D31 *Acacia aneura* (mulga) and/or *Archidendropsis basaltica* (dead finish) tall open-shrubland.

Map Unit D32 *Acacia ancistrocarpa* (Fitzroy wattle) and/or *Acacia eriopoda* (pindan wattle) and/or *Acacia monticola* (red wattle) tall shrubland with *Triodia intermedia* (winged spinifex) and *Triodia pungens* (soft spinifex) hummock grasses.

Map Unit D33 *Asteromyrtus lysicephala* (Kennedy's heath) and/or *Neofabricia myrtifolia* (yellow teatree) open-heath.

Map Unit D34 *Grevillea refracta* (silverleaf grevillea) +/- *Hakea lorea* (corkwood) open-shrubland with *Triodia pungens* (soft spinifex) hummock grass.

Map Unit D35 *Triodia pungens* (soft spinifex) and/or *T. intermedia* (winged spinifex) and/or *Triodia bitextura* (curly spinifex) hummock grassland wooded with *Corymbia* spp., *Eucalyptus* spp. or *Lysiphyllum cunninghamii* (bauhinia) low trees.

Map Unit D36 *Triodia pungens* (soft spinifex) and/or *T. schinzii* (feathertop spinifex) hummock grassland wooded with low trees and *Acacia* spp. shrubs.

E. Units on Cainozoic duricrusts with exposed ferrugineous, siliceous or mottled horizons

Map Unit E1 *Acacia shirleyi* (lancewood) and/or other *Acacia* spp. and/or *Eucalyptus* spp. low woodland with short tussock grasses and/or *Triodia* spp. (spinifex) hummock grasses.

Map Unit E2 *Corymbia hylandii* (Hyland's bloodwood) and/or *Eucalyptus cullenii* (Cullen's ironbark) +/- *Melaleuca stenostachya* (teatree) woodland.

Map Unit E3 *Eucalyptus brevifolia* (snappy gum) low open-woodland with *Triodia bitextura* (curly spinifex) hummock grasses or sometimes a *Triodia intermedia* (winged spinifex) hummock grassland.

Map Unit E4 *Triodia pungens* (soft spinifex) hummock grassland.

F. Units on Cainozoic to Palaeozoic igneous rocks, predominantly basalts

Map Unit F1 Deciduous vine thickets +/- emergent trees.

Map Unit F2 *Eucalyptus crebra* (narrow-leaved ironbark) +/- *Corymbia* spp. woodland +/- a shrub layer and *Heteropogon contortus* (black spear grass) tussock grasses.

Map Unit F3 *Eucalyptus leptophleba* (Molloy red box) and/or *Corymbia* spp. grassy woodland.

Map Unit F4 *Eucalyptus tectifica* (Darwin box) +/- *Corymbia grandifolia* (large-leaved cabbage gum) +/- *Corymbia byrnesii* (fan-leaved bloodwood) woodland with *Sorghum* spp. (sorghum) and *Sehima nervosum* (white grass) tall grasses.

Map Unit F5 *Eucalyptus microneura* (Georgetown box) grassy open-woodland +/- a shrub layer.

Map Unit F6 *Eucalyptus orgadophila* (mountain coolibah) grassy open-woodland.

Map Unit F7 *Corymbia terminalis* (desert bloodwood) and *Eucalyptus chlorophylla* (shiny-leaved box) low open-woodland with *Sehima nervosum* (white grass) and *Chrysopogon fallax* (golden beard grass) tussock grasses

+/- *Triodia* spp. (spinifex).

Map Unit F8 *Astrebla* spp. (Mitchell grass) and/or *Dichanthium* spp. (bluegrass) tussock grassland sparsely wooded with low trees.

Map Unit F9 *Corymbia opaca* (plains bloodwood) and *Eucalyptus chlorophylla* (shiny-leaved box) sparse low open-woodland with tussock grasses or a *Triodia pungens* (soft spinifex), *Triodia intermedia* (winged spinifex) hummock grassland wooded with *Eucalyptus brevifolia* (snappy gum) low trees.

G. Units on Cainozoic to Proterozoic consolidated, fine-grained sediments with little deformation, predominantly shale, siltstone, mudstone and calcareous sediments

Map Unit G1 *Eucalyptus melanophloia* (silver-leaved ironbark) +/- *Corymbia erythrophloia* (red bloodwood) +/- *Eucalyptus* spp. woodland +/- a shrub layer and *Aristida* spp. (three awn grass) and *Heteropogon contortus* (black spear grass) tussock grasses.

Map Unit G2 *Eucalyptus leptophleba* (Molloy red box), *Corymbia papuana* (ghost gum) and *Corymbia clarksoniana* (Clarkson's bloodwood) grassy open-woodland.

Map Unit G3 *Eucalyptus orgadophila* (mountain coolibah) +/- *Eucalyptus melanophloia* (silver-leaved ironbark) grassy open-woodland.

Map Unit G4 *Melaleuca* spp. (paperbarks) and *Eucalyptus* spp. low woodland with *Triodia bitextura* (curly spinifex) hummock grass.

Map Unit G5 *Acacia georginae* (Georgina gidgee) low open-woodland and/or *Senna* spp. (cassia) open-shrubland.

Map Unit G6 *Corymbia opaca* (bloodwood) low open-woodland with *Triodia bitextura* (curly spinifex) hummock grass.

Map Unit G7 *Eucalyptus leucophylla* (Cloncurry box) low open-woodland +/- shrub layer of *Acacia hilliana* (Hill's tabletop wattle) and *Senna artemisioides* subsp. *oligophylla* (limestone cassia) and ground layer of *Triodia* spp. (spinifex) hummock grasses.

Map Unit G8 *Lysiphyllum cunninghamii* (bauhinia) and/or deciduous species grassy low open-woodland.

Map Unit G9 *Triodia wiseana* (limestone spinifex) open-hummock grassland wooded with low trees of *Terminalia* spp. or *Adansonia gregorii* (boab).

Map Unit G10 *Astrebla lappacea* (curly Mitchell grass) and/or *Astrebla pectinata* (barley Mitchell grass) tussock grassland sparsely wooded with *Acacia* spp. low trees.

Map Unit G11 *Enneapogon purpurascens* (nine awn grass) tussock grassland.

H. Units on Cainozoic to Proterozoic consolidated medium- to coarse grained sediments with little deformation, predominantly sandstones

Map Unit H1 Semi-deciduous vine thickets on sandstone

Map Unit H2 *Acacia shirleyi* (lancewood) and/or *Acacia catenulata* (bendee) open-forest +/- emergent *Eucalyptus* spp. and *Corymbia* spp.

Map Unit H3 *Asteromyrtus brassii* and *Neofabricia myrtifolia* (yellow teatree) +/- *Allocasuarina littoralis* (black sheoak) low open-forest +/- emergent *Callitris intratropica* (northern cypress pine).

Map Unit H4 *Eucalyptus crebra* (narrow-leaved ironbark) or *Eucalyptus melanophloia* (silver-leaved ironbark) or *Eucalyptus cullenii* (Cullen's ironbark) woodland +/- a shrub layer and tussock grasses or *Triodia* spp.

Map Unit H5 *Eucalyptus tetrodonta* (Darwin stringybark) +/- *Corymbia nesophila* (Melville Island bloodwood) +/- *Corymbia hylandii* subsp. *peninsularis* (Hyland's bloodwood) +/- *Eucalyptus cullenii* (Cullen's ironbark) woodland +/- *Asteromyrtus brassii* sub-canopy and heath species.

Map Unit H6 *Eucalyptus tetrodonta* (Darwin stringybark) and *Eucalyptus miniata* (Darwin woollybutt) +/- *Corymbia bleeseri* (rusty-barked bloodwood) with *Sorghum* spp. tall-grasses.

Map Unit H7 *Eucalyptus similis* (Queensland yellowjacket) and/or *Eucalyptus tetrodonta* (Darwin stringybark) and/or *Corymbia stockeri* (blotchy bloodwood) woodland with tussock grasses or *Triodia* spp. (spinifex).

Map Unit H8 *Eucalyptus phoenicea* (scarlet gum) and *Corymbia ferruginea* subsp. *stypophylla* (rusty bloodwood) low woodland with *Triodia bitextura* (curly spinifex) hummock grassland understorey.

Map Unit H9 *Corymbia dichromophloia* (variable-barked bloodwood), *Eucalyptus miniata* (Darwin woollybutt) +/- *Eucalyptus tetrodonta* (Darwin stringybark) open-woodland with *Triodia bitextura* (curly spinifex) and *Sorghum* spp. grasses.

Map Unit H10 *Corymbia leichhardtii* (yellowjacket) or *Corymbia trachyphloia* (brown bloodwood) and/or *Corymbia* spp. open-woodland with sparse tussock grasses and/or *Triodia* spp. (spinifex).

Map Unit H11 *Eucalyptus decorticans* (gum-topped ironbark) open-woodland with sparse *Triodia mitchellii* (buck spinifex) or tussock grasses.

Map Unit H12 *Eucalyptus persistens* (knotted box) and/or *Eucalyptus shirleyi* (silver-leaved ironbark) open-woodland with sparse tussock grasses.

Map Unit H13 *Corymbia dampieri* (pindan bloodwood) low open-woodland with *Triodia pungens* (soft spinifex) and/or *Triodia intermedia* (winged spinifex) hummock grasses.

Map Unit H14 *Corymbia grandifolia* (large-leaved cabbage gum) +/- *Corymbia greeniana* (broad-leaved bloodwood) +/- *Corymbia polycarpa* (long-fruited bloodwood) low open-woodland with *Triodia bitextura* (curly spinifex) hummock grass or *Chrysopogon* spp. (ribbon grass) and *Dichanthium* spp. (blue grass) tussock grasses.

Map Unit H15 *Eucalyptus brevifolia* (snappy gum) low open-woodland with *Triodia pungens* (soft spinifex) and/or *Triodia bitextura* (curly spinifex) hummock grass and/or tussock grasses.

Map Unit H16 *Eucalyptus leucophloia* (snappy gum) low open-woodland with *Triodia molesta* (pincushion spinifex) and/or *Triodia* spp. (spinifex) hummock grasses or sometimes a hummock grassland without trees.

Map Unit H17 *Acacia ancistrocarpa* (Fitzroy wattle) and/or *Acacia eriopoda* (pindan wattle) open-shrubland with *Triodia pungens* (soft spinifex) and/or *Triodia intermedia* (winged spinifex) hummock grasses.

Map Unit H18 *Triodia pungens* (soft spinifex) and/or *Triodia intermedia* (winged spinifex) hummock grassland sparsely wooded with low trees.

J. Units on Mesozoic to Proterozoic deformed and metamorphosed sediments and interbedded volcanics

Map Unit J1	Notophyll vine forest or mesophyll vine forest +/- emergent trees on metamorphic hills.
Map Unit J2	*Corymbia* spp. and/or *Eucalyptus* spp. open-forest on metamorphic slopes.
Map Unit J3	*Corymbia* spp. and/or *Eucalyptus* spp. woodland +/- mixed shrubs and a sparse ground layer of *Triodia* spp. (spinifex) or tussock grasses.
Map Unit J4	*Eucalyptus leptophleba* (Molloy red box) and/or *Eucalyptus platyphylla* (poplar gum) +/- *Erythrophleum chlorostachys* (ironwood) woodland with *Heteropogon* spp. (spear grass) and *Themeda triandra* (kangaroo grass) tussock grasses.
Map Unit J5	*Eucalyptus microneura* (Georgetown box) +/- *Eucalyptus crebra* (narrow-leaved ironbark) woodland +/- shrub layer and *Aristida* spp. (three awn grass), *Themeda triandra* (kangaroo grass) and *Heteropogon contortus* (black spear grass) tussock grasses or sometimes tussock grassland wooded with low trees.
Map Unit J6	*Eucalyptus tectifica* (Darwin box), *Corymbia flavescens* (wrinkle-leaved ghost gum) woodland with *Chrysopogon* spp. (ribbon grass) tussock grass.
Map Unit J7	*Eucalyptus thozetiana* (napunyah) and/or *Acacia harpophylla* (brigalow) +/- softwood species woodland with *Eremophila mitchellii* (false sandalwood) shrubs and a sparse ground layer.
Map Unit J8	*Eucalyptus* spp. (ironbarks) +/- *Corymbia* spp. woodland +/- a shrub layer and vine thicket species.
Map Unit J9	*Eucalyptus brevifolia* (snappy gum), *Corymbia cadophora* subsp. *cadophora* (twin-leaved bloodwood) low open-woodland with a *Triodia bitextura* (curly spinifex) hummock grass ground layer.
Map Unit J10	*Eucalyptus persistens* (knotted box) or *Eucalyptus tardecidens* or *Eucalyptus thozetiana* (napunyah) low open-woodland +/- a shrub layer and *Triodia* spp. (spinifex) sparse-hummock grasses.
Map Unit J11	*Triodia longiceps* (porcupine spinifex) +/- other *Triodia* spp. hummock grassland sparsely wooded with *Eucalyptus* spp. and *Acacia* spp. low trees.
Map Unit J12	*Triodia molesta* (pincushion spinifex) +/- *Triodia* spp. hummock grassland sparsely wooded with *Eucalyptus leucophloia* (snappy gum) low trees.
Map Unit J13	*Triodia wiseana* (limestone spinifex) and *T. intermedia* (winged spinifex) hummock grassland sparsely wooded with *Eucalyptus brevifolia* (snappy gum) low trees.

K. Units on Mesozoic to Proterozoic igneous rocks, predominantly granites, granodiorites, andesites and rhyolites

Map Unit K1	Notophyll vine forest and semi-evergreen vine thicket +/- emergent *Araucaria cunninghamii* (hoop pine).

Map Unit K2 *Eucalyptus* spp. (ironbarks) and/or *Lophostemon suaveolens* (swamp mahogany) and/or *Corymbia clarksoniana* (Clarkson's bloodwood) +/- *Corymbia* spp. +/- *Eucalyptus* spp. grassy open-forest.

Map Unit K3 *Corymbia nesophila* (Melville Island bloodwood) and/or *Eucalyptus tetrodonta* (Darwin stringybark) and/or *Corymbia hylandii* subsp. *peninsularis* (Hyland's bloodwood) woodland with *Themeda triandra* (kangaroo grass) or *Imperata cylindrica* (blady grass) tussock grass understorey.

Map Unit K4 *Eucalyptus miniata* (Darwin woollybutt) grassy woodland.

Map Unit K5 *Eucalyptus tectifica* (Darwin box) +/- *Corymbia* spp. woodland with *Chrysopogon* spp. (ribbon grass), *Sorghum* spp. (sorghum) and *Triodia bitextura* (curly spinifex) grassy understorey.

Map Unit K6 *Eucalyptus* spp. (ironbarks) +/- *Corymbia* spp. open-woodland +/- a sub-canopy layer of *Acacia* spp. and softwood species and a sparse ground layer of tussock grasses and/or *Triodia* spp. (spinifex).

Map Unit K7 *Cochlospermum* spp. (kapok), *Erythrophleum chlorostachys* (ironwood) and *Terminalia aridicola* (arid peach) +/- *Acacia* spp. +/- *Corymbia* spp. deciduous low open-woodland with sparse-tussock grasses.

Map Unit K8 *Eucalyptus brevifolia* (snappy gum) low open-woodland with *Triodia bitextura* (curly spinifex) hummock grass +/- *Enneapogon* spp. (nine-awn grass) short-tussock grass or sometimes a grassland without trees.

Map Unit K9 *Eucalyptus shirleyi* (silver-leaved ironbark) and/or *Eucalyptus melanophloia* (silver-leaved ironbark) +/- *Corymbia peltata* (rustyjacket) low open-woodland with a patchy shrub layer and sparse tussock grasses.

Miscellaneous units

Map Unit CQC Central Queensland Coast bioregion

Map Unit WT Wet Tropics bioregion

5.5 The map unit descriptions

The map unit descriptions are presented in a standardised format and explained below. The map units presented in this report are grouped into land zones, so that all of the units that occur on the same land zone are grouped together. Within those groupings species are arranged structurally from the tallest and most dense communities to the least. Whilst the Wet Tropics and Central Queensland Coast bioregions are not part of the tropical savannas, descriptions are provided to ensure a contiguous coverage from east to west.

Map Unit
Map unit is the abbreviated description for the unit, as used in the map legend, in which the dominant species and structural formations are described. Dominant species are those that contribute most to the biomass at a site or in a layer, as well having a high frequency of occurrence. Structural formation descriptions are presented in Figure 3.2.

Description
The description refers to the typical appearance of the unit at a site. The range of structural formations was determined from the descriptions of the vegetation unit

descriptions from the original maps that made up each unit. The structural formations and the projective foliage cover (pfc) categories used are those presented in Figure 3.2 as a modification of Specht (1970). Terms normally used to describe projective foliage cover are dense (> 70%); mid-dense (30-70%); sparse (10-30%) and very sparse (< 10%). For map units with a wide range in their structural attributes, the most frequently occurring attribute is described. The species listed for each stratum were determined from an analysis of the extent of individual associations described by other authors. Where many species within a genus are present, the term 'spp." is often used in order to restrict the description to a practical length. Some units contain variants that are limited in extent or atypical in terms of structure or floristics and these are described separately. Some of those variants differ markedly from the main map unit description and hence are described in full, while generally only the major differences in variants are described. The individual references used to assist the descriptions are also provided. Introduced plant species are marked with *.

Structural formation range
Describes the most commonly occurring structural class for each unit, as well as those classes occurring less frequently. The structural classes used are presented in Figure 3.2 and follow Neldner (1984) modified from Specht (1970).

Land zone
Provides information about the broad landform, geology/lithology and soil on which a unit occurs and consequently the land zone on which a unit is most likely to be found. In many instances a unit may also have minor occurrences on other land zones and this information is also provided.

Ecological notes and distribution
This section provides broad geographical locations for the unit's distribution. Soils on which the unit is most likely to occur are also described. The soil type descriptions follow the classification of the great soil groups by Northcote *et al.* (1960-1968). A table relating those great soil groups to the Australian soil classification Orders described by Isbell (1996) is provided as Appendix 2.2. Within some map units, rare, threatened or vulnerable species or ecosystems are known to occur and where possible these have been described and a reference for each has been included. In some cases, additional notes about the ecology of the vegetation associations contained within the map unit are also included.

Area
The total area in square kilometres occupied by each unit before land clearing, as derived from the GIS, is specified.

Broad vegetation group
Each unit has been assigned to one of 26 broad vegetation groups (BVG) (see above and Appendix 3.7) and this information is provided for each unit.

Units derived from
This provides the vegetation map units from the individual State and Territory maps that were aggregated to develop the final vegetation map units (see Appendices 3.3, 3.4, 3.5). The species in those derivative units shown in the appendices are listed according to the original nomenclature for each map, whereas the species presented in this report have been updated to 2001 (see 3.13 Nomenclature).

Distribution maps
With each description is a map showing the distribution of the unit in the map area. Units that have a very limited extent are circled. Despite being within the boundary of the map area the Wet Tropics bioregion (WT) and the Central Queensland Coast bioregion (CQC) do not form part of the vegetation of the Australian tropical savannas, they are shown on the maps to indicate the areas excluded from the mapping project.

6. References

Addicott, E.P. (*pers. comm.*). This information was the result of discussions in March 2001 between the senior author and E.P. Addicott about how to describe sandplain communities whose structure is affected by fire.

Aldrick, J. and Wilson, P.L. (1990). *Land Systems of the Southern Gulf Region, Northern Territory. Technical Report No. 42.* Conservation Commission of the Northern Territory, Darwin.

Anon. (undated). 'Timetrack for schools'. Cambridge Paleomap Services Limited, Cambridge.

AUSLIG - Australian Surveying and Land Information Group (1998). *Australian Topographic Data: Digital Version*, Department of Industry, Science and Resources, Canberra.

AUSLIG - Australian Surveying and Land Information Group (1990). *Vegetation*. *Atlas of Australian Resources:* Third Series, **Vol. 6**: Australian Survey and Land Information Group, Department of Industry, Science and Resources, Canberra.

Australian National Botanic Gardens (2001). Plant Name Index. http://www.anbg.gov.au/anbg/names.html

Bailey, F.M. (1899-1902). *The Queensland Flora. Parts I-VI.* Government Printer, Brisbane.

Bailey, R.G. (1983). *Delineation of ecosystem regions*. Environmental Management **7**: 365-373.

Barlow, B.A. (1981). 'The Australian flora: its origin and evolution'. In: A.S. George (ed), *Flora of Australia Vol. 1. Introduction,* pp. 25-75. Australian Government Publishing Service, Canberra.

Barlow, B.A. (1986). Contributions to a Revision of *Melaleuca* (Myrtaceae): 1-3, *Brunonia* **9**: 163-77.

Barlow, B.A. (1994). 'Phytogeography of the Australian region'. In: R.H. Groves (ed), *Australian Vegetation* (2nd Edition), pp. 3-35. Cambridge University Press, Cambridge.

Barlow, B.A. and Hyland, B.P.M. (1988). 'The origins of the flora of Australia's wet tropics', *Proceedings of the Ecological Society of Australia* **15**: 1-17.

Barson, M.M., Randall, L.A. and Bordas, V. (2000). *Landcover change in Australia. Results of the collaborative Bureau of Rural Sciences – State agencies' project on Remote Sensing of Land Cover Change*. Bureau of Rural Sciences, Canberra.

Batianoff, G.N., Neldner, V.J. and Singh, S. (2000). 'Vascular plant census and floristic analysis of serpentine landscapes in central Queensland'. *Proceedings of the Royal Society of Queensland* **109**: 1-30

Beadle, N.C.W. (ed) (1981). *The Vegetation of Australia*. Cambridge University Press, Cambridge, UK.

Beadle, N.C.W. and Costin, A.B. (1952). 'Ecological classification and nomenclature'. *Proceedings of the Linnean Society of New South Wales* **77**: 61-82.

Bean, A.R. (2000). 'A revision of *Eucalyptus normantonensis* Maiden and Cambage (Myrtaceae) and its allies'. *Austrobaileya,* **5**(4): 679-686.

Beard, J.S. (1944). 'Climax vegetation in tropical America'. *Ecology* **25**: 127-153.

Beard, J.S. (1955). 'The classification of tropical American vegetation types'. *Ecology* **36**: 89-100.

Beard, J.S. (1979). *Vegetation Survey of Western Australia - Kimberley: 1:1,000,000 Vegetation Series Map and Explanatory Notes*, University of Western Australia Press, Perth.

Beard, J.S. (2001). 'A historic vegetation map of Australia'. *Austral Ecology* **26**, 441-443.

Beard, J.S. and Webb, M.J. (1974). *Vegetation Survey of Western Australia - Great Sandy Desert: 1:1,000,000 Vegetation Series Map and Explanatory Notes*, University of Western Australia Press, Perth.

Beeston, G.R. (1978). Vegetation (maps included). In: *Western Arid Region Land Use Study – Part IV,* Technical Bulletin No. 23, pp. 36-50. Division of Land Utilisation, Queensland Department of Primary Industries, Brisbane.

Bentham, G. (1863-1878). *Flora Australiensis*, 7 volumes. Reeve, London. Reprinted (1967), Asher and Reeve, Amsterdam.

Black, J.M. (1922-1929). *Flora of South Australia*. Government Printer, Adelaide.

Blake, S.T. (1938).' The plant communities of western Queensland and their relationships, with special reference to the grazing industry'. *Proceedings of the Royal Society of Queensland* **49**:156-204.

Boulter, S.L., Wilson, B.A., Westrup, J., Anderson, E.R., Turner, E.J. and Scanlan, J.C. (eds) (2000) *Native Vegetation Management in Queensland. Background, Science and Values.* Department of Natural Resources, Brisbane.

Bowman, D.J.M.S. (1988). ‘Stability amid turmoil?: towards an ecology of north Australian eucalypt forests’. *Proceedings of the Ecological Society of Australia* **15**: 149-158.

Bowman, D.M.J.S. and Panton, W.J. (1993a). ‘Decline of *Callitris intratropica* R.T. Baker and H.G. Smith in the Northern Territory: implications for pre- and post-European colonization fire regimes’. *Journal of Biogeography* **20**: 373-381.

Bowman, D.M.J.S. and Panton, W.J. (1993b). ‘Factors that control monsoon-rainforest seedling establishment and growth in north Australian *Eucalyptus* savanna’. *Journal of Ecology* **81**: 297-304.

Bowman, D.M.J.S. and Panton, W.J. (1995). ‘Munmarlary revisited: response of a north Australian *Eucalyptus tetrodonta* savanna protected from fire for 20 years’. *Australian Journal of Ecology* **20**: 526-531.

Bowman, D.M.J.S., Wilson, B.A. and Hooper, R.J. (1988). ‘Response of *Eucalyptus* forest and woodland to four fire regimes at Munmarlary, Northern Territory’. *Journal of Ecology* **76**: 215-232.

Boyland, D.E. (1974). ‘Vegetation’ (maps included). In: *Western Arid Region Land Use Study - Part 1*, Technical Bulletin No. 12, pp. 47-70. Division of Land Utilisation, Department of Primary Industries, Brisbane.

Boyland, D.E. (1980). ‘Vegetation’ (maps included). In: *Western Arid Region Land Use Study - Part II*, Technical Bulletin No. 22, pp. 36-67. Division of Land Utilisation, Queensland Department of Primary Industries, Brisbane.

Boyland, D.E. (1984). *South Western Queensland. Vegetation Survey of Queensland.* Queensland Department of Primary Industries Botany Bulletin No. 4**.**

Braithwaite, R.W. and Estbergs, J.A. (1985). ‘Fire patterns and woody vegetation trends in the Alligator Rivers region of northern Australia’. In: J.C. Tothill and J.J. Mott (eds), *Ecology and Management of the World's Savannas,* pp. 359-364. Australian Academy of Science, Canberra.

Brock, J. (1993). *Native Plants of Northern Australia.* Reid Books, Victoria.

Brooker, M.I.H. and Kleinig, D.A. (1994). *Field Guide to Eucalypts: Volume 3 Northern Australia,* Inkata Press, Sydney.

Brown, R. (1810). *Prodromus Florae Novae Hollandiae*, London.

BRS - Bureau of Rural Sciences after Australian Geological Survey Organisation, (1991). ‘Bedrock Geology Theme’. In: *Digital Version of the 1976 Edition of Geology of Australia, 1:2,500,000 Scale* (ARC/INFO vector format). [Online] Available HTML: http://www.brs.gov.au/data/datasets.

BRS - Bureau of Rural Sciences after Australian Geological Survey Organisation, (1991b). Digital Atlas of Australian Soils (ARC/INFO vector format). [Online] Available HTML: http://www.brs.gov.au/data/datasets

BRS – Bureau of Rural Sciences after Australian Geological Survey Organisation, (1991a). ‘Surficial Cover Theme’. In: *Digital Version of the 1976 Edition of Geology of Australia, 1:2,500,000 Scale* (ARC/INFO vector format). [Online] Available HTML: http://www.brs.gov.au/data/datasets

Burbidge, N.T. (1960). ‘The phytogeography of the Australian region’. *Australian Journal of Botany* **8**. 75-212.

Burrows, W.H. (1991). ‘A question of balance’. *Search* **22(2).**

Burrows, W.H. (1995). ‘Greenhouse revisited – land-use change from a Queensland perspective’. *Climate Change Newsletter.* **7(1)**: 6-7

Burrows, W.H. and Scanlan, J.C. (1983). ‘Managing Eucalypt woodlands and open-forests as a grazing land in north eastern Australia’, *Proceedings of Workshop on Woody Weeds of Northern Summer Rainfall Areas*. Rockhampton, October 1983. Queensland Department of Lands.

CALM - Department of Conservation and Land Management (1987). *Kimberley Rainforest Survey* (digital data). CALM Wildlife Research Centre, Woodvale

Carnahan, J.A. (1976). *Natural Vegetation. Atlas of Australian Resources. Natural Vegetation.* Second Series. Geographic Section, Division of National Mapping, Department of National Resources, Canberra.

Carr, D.J. and Carr, S.G.M. (eds) (1981). *People and Plants in Australia*. Academic Press Australia.

Christian, C.S. and Stewart, G.A. (1953). *General Report on survey of Katherine-Darwin region, 1946.* Land Research Series No. 1. CSIRO Australia.

Christian, C.S. and Stewart, G.A. (1968). Methodology of integrated surveys. In: 'Aerial Surveys and Integrated Studies', *Proceedings of the Toulouse Conference 1964*, pp. 233-280. UNESCO.

Christian, C.S., Noakes, L.C., Perry, R.A., Slatyer, R.O., Stewart, G.A. and Traves, D.M. (1954). *Survey of the Barkly Region, Northern Territory and Queensland, 1947-48*, Land Research Series No. 3, CSIRO, Melbourne.

Clarkson, J.R. (*in draft*). Common name database for north Queensland plants. Queensland Parks and Wildlife Service, Mareeba.

Clarkson, J.R. and Kenneally, K.T. (1988). 'The flora of Cape York and the Kimberley: a preliminary comparative analysis'. *Proceedings Ecological Society of Australia* **15**: 259-266.

Clements, F.E. (1904). *The Development and Structure of Vegetation.* Botanical Survey of Nebraska.

Clements, F.E. (1905). *Research Methods in Ecology*. Lincoln Press, Nebraska.

Clements, F.E. (1907). *Plant Physiology and Ecology*. London.

Clements, F.E. (1916). *Plant Succession*. Carnegie Institute Washington, Publication No. 242**.**

Cochrane, G.R. (1963). 'A physiognomic vegetation map of Australia'. *Journal of Ecology* **51**: 639-655

Cochrane, G.R. (1967). 'The description and mapping of vegetation in Australia: A contribution to the International Biological Programme'. *Victorian Naturalist* **84**: 299-316.

Cooke, P. (1998) 'Fire management and Aboriginal lands'. In: Summary Papers from the North Australia Fire Management Workshop, Darwin, 24-25 March 1998.

Cooke, P. (*in press*). *Fire management and savanna landscapes in northern Australia*. ACIAR Workshop Proceedings.

Cowles, H.C. (1901). 'The physiographic ecology of Chicago and vicinity'. *Botanical Gazette* **31**: 73-108.

Cowles, H.C. (1989). 'The ecological relations of the vegetation on the sand dunes of Lake Michigan'. *Botanical Gazette* **27**:95-391.

Craig, A.B. (1997). 'A review of information on the effects of fire in relation to the management of rangelands in the Kimberley high-rainfall zone'. *Tropical Grasslands* **31**, 161-187.

Crocker, R.L. (1959). 'Past climate fluctuations and their influence upon Australian vegetation'. In: *Biogeography and Ecology in Australia*. (ed) A. Keast, Junk Publishers, Den Haag.

Crocker, R.L. and Wood, J.G. (1947). 'Some historical influences on the development of South Australian vegetation communities and their bearing on concepts and classification in ecology'. *Transactions of the Royal Society of South Australia* **71**: 91-136.

Crowley, G.M. and Garnett, S.T. (2000). 'Changing Fire Management in the Pastoral Lands of Cape York Peninsula of northeast Australia, 1623 to 1996'. *Australian Geographical Studies.* **38(1)**: 10-26.

Dampier, W. (1703). *A voyage to New Holland in the year 1699.* Volume 3. London.

Dansereau, P. (1951). 'Description and recording of vegetation on a structural basis'. *Ecology* **32**: 172

Dansereau, P. (1957). *Biogeography: an ecological perspective*, The Ronald Press Company, New York.

Dettmann, M.E. (1992). 'Structure and floristics of Cretaceous vegetation of southern Gondwana: implications for angiosperm biogeography'. *Palaeobotanist* **41**: 224-233.

Diels, F.L.E. (1906). *Die Pflanzenwelt von West-Australien sudlich des Wendekreises. Vegetation der Erde 7.* Leipsig.

Diels, F.L.E. (1906a). 'Extra-tropical Western Australia': translated by D.J. Carr (1981), In: Carr, D.J. and Carr, S.J.M. (eds), *People and Plants in Australia.* Academic Press Australia, Canberra.

DME - Department of Minerals and Energy (1999). 'Digital Geology of North West Queensland (1:500,000)'. Department of Minerals and Energy, Brisbane.

DMEWA - Department of Minerals and Energy Western Australia, (2000). 'Geology of Western Australia'. [Online] Available HTML: http://www.dme.wa.gov.au/prodserv/pub/factsheet15.html

Douglas, J.G. (1994) 'Cretaceous vegetation: the macrofossil record'. In: R.S. Hill (ed), *History of the Australian Vegetation: Cretaceous to the Recent*, pp. 171-188. Cambridge University Press, Cambridge.

Drinnan, A.N. and Crane, P.R. (1990) 'Cretaceous palaeobotany and its bearing on the biogeography of austral angiosperms'. In: T.N. Taylor and E.L. Taylor (eds), *Antarctic*

Paleobiology, pp. 192-219. Springer-Verlag, New York.
Du Rietz, G.E. (1930). 'Classification and nomenclature of vegetation'. *Svensk Botanisk Tidskrift* **24**: 489-503.
Du Rietz, G.E. (1931). 'Lifeforms of terrestrial flowering plants'. *Acta Phytogeographica Suecica* **3**: 1-95.
Edwards, D. and Fanning, U. (1985). 'Evolution and the Environment in the Late Silurian-Early Devonian: the rise of the pteridophytes'. *Transactions of the Royal Philosophical Society* 309B: 147-165.
Ellyard, D. (1994). *Droughts and Flooding Rains. The Climate of Australia* pp. 114-115. Angus and Robertson, Sydney.
Elsol. J.A. (1991). *Vegetation Description and Map. Ipswich, South-eastern Queensland.* Scale 1:250,000. Queensland Botany Bulletin No. 10, Queensland Department of Primary Industries, Brisbane.
Environment Australia. (2000). *Interim Biogeographic Regionalisation of Australia (IBRA) Version 5.1*. Digital data downloaded from [Online] Available HTML: http://www.environment.gov.au/cgi-bin/edd/EDD.pl?action=browse_citation&id=7500
ESRI (1994). *Understanding GIS. The ARC/INFO Method.* Environmental Systems Research Institute Inc., Redlands.
ESRI (1996). *ArcView GIS. The geographical information system for everyone.* Environmental Systems Research Institute Inc., Redlands.
Ewart, A.J. (1930). *Flora of Victoria.* Government Printer, Melbourne
Ewart, A.J. and Davies, O.B. (1917). *Flora of the Northern Territory.* Government Printer, Melbourne.
Fawcett, P.J., Barron, E.J. Robison, V.D. and Katz, B.J. (1994). 'The climatic evolution of India and Australia from the Late Permian to Mid-Jurassic: A Comparison of climatic results with the geologic record'. In: G.D. Klein (ed), *Pangaea: Paleoclimate, Tectonics and Sedimentation During Accreditation, Zenith and Breakup of a Supercontinent,* pp139-158. Geological. Society of America Special Paper 288.
Fensham, R.J. (1996). 'Land clearance and conservation in north Queensland, Australia. *Biological Conservation* **75**: 289-298.
Fensham, R.J. (1998). 'Mound springs in the Dawson River Valley, Queensland. Vegetation-environment relations and consequences of a proposed impoundme nt on botanical values'. *Pacific Conservation Biology* **4**: 42-54. Surrey Beatty and Sons, Sydney.
Fensham, R.J. (1998a). 'Resolving biomass fluxes in Queensland woodlands'. *Climate Change Newsletter* **10**: 13-15.
Fensham, R.J. and Bowman, D.M.J.S. (1992). 'Stand structure and the influences of overwood on regeneration in tropical Eucalypt forest on Melville Island'. *Australian Journal of Botany* **40**: 335-352.
Fensham, R.J. and Fairfax, R.J. (1997). 'The use of the land survey record to reconstruct pre-European vegetation patterns in the Darling Downs, Queensland, Australia'. *Journal of Biogeography* **24**: 827-836.
Fensham, R.J., Minchin, P.R., Fairfax, R.F., Kemp, J.E., Purdie, R.W., McDonald, W.J.F. and Neldner, V.J. (2000_ Broad-scale environmental relations in the Mitchell grasslands of Queensland. Australian Journal of Botany **48**: 27-38.
Fitzpatrick, E.A. and Nix, H.A. (1970). 'The climatic factor in Australian grassland ecology. In: R.M. Moore (ed), *Australian Grasslands,* pp 3-26. Australian National University Press, Canberra.
Fox, I.D. (1999). 'Mapping Australian tropical savannas: How do you rapidly fill a 300,000km^2 data gap?' *Tropinet*, Vol. 10, No. 2, June 1999). HTML: http://atb.botany.ufl.edu/tropinet/v10n2.html
Fox, I.D. and Middleton, J.D. (*unpubl.*). Vegetation Map of Northwest Queensland 1:1 million. Unpublished map and legend. Queensland Herbarium, Environmental Protection Agency.
Fox, I.D., Neldner, V.J., Wilson, G.W., Bannink, P.J., Wilson, B.A., Brocklehurst, P.S., Clark, M.J., Dickinson, K.J.M., Beard, J.S., Hopkins, A.J.M., Beeston, G.R., Harvey, J.M., Thompson, E.J., Ryan, T.S., Thompson, S.L., Butler, D.W., Cartan, H., Addicott, E.P., Bailey, L.P., Cumming, R.J., Johnson, D.C., Schmeider, M., Stephens, K.M. and Bean, A.R. (2001). *The Vegetation of the Australian Tropical Savannas*. (1:2 000 000 scale map in 3 sheets). Queensland Herbarium, Environmental Protection Agency, Brisbane and the Cooperative Research Centre for the Sustainable Development of Tropical Savannas, Darwin.
Fox, M.D. (1999). 'Present Environmental Influences on the Australian Flora'. In: A.E. Orchard

and H.S. Thompson (eds), *Flora of Australia*, **Vol.1**, 2nd Edition. pp. 205-249, ABRS/CSIRO Australia.
Frakes, L.A. (1999). 'Evolution of Australian Environments' In: A.E. Orchard and H.S. Thompson (eds), *Flora of Australia*, **Vol.1**, 2nd Edition. pp. 163-203, ABRS/CSIRO Australia.
Frost, P., Menaut, J.C., Medina, E., Solbrig, O.T., Swift, M. and Walker, B. (1985). 'Responses of savannas to stress and disturbance'. *Biology International,* Special Issue No. 10.
Galloway, R.W., Gunn, R.H. and Story, E. (1970). *Lands of the Mitchell-Normanby Area, Queensland*, Land Research Series No. 26, CSIRO, Melbourne.
Gardner, C.A. (1931). *Enumeratio Plantarum Australiae Occidentalis*. Government Printer, Perth.
Gardner, C.A. (1942). 'The vegetation of Western Australia with special reference to climate and soils'. *Journal of Proceedings of the. Royal Society of Western Australia* **28:** 11-87.
George, A.S. (1971). 'The plants seen and collected in north-western Australia by William Dampier'. W*estern Australian Naturalist* **11**: 173-178.
Gill, A.M., Groves, R.H. and Noble, I.R. (1981). *Fire and the Australian Biota.* Australian Academy of Science, Canberra.
Gillison, A.N. (1981). 'Towards a functional vegetation classification'. In: A.N. Gillison and D.J. Anderson (eds), *Vegetation Classification in Australia,* pp. 30-41. CSIRO and Australian National University Press, Canberra.
Gillison, A.N. (1984). 'Gradient sampling for resource surveys – the Gradsect method'. In: K. Myers, C.R. Margules and I. Musto (eds), *Survey Methods for Nature Conservation,* pp. 349-374. CSIRO Division of Water and Land Resources, Canberra.
Gillison, A.N. (1988). *A Plant Functional Proforma for Dynamic Vegetation Studies and Natural Resource Surveys.* CSIRO Institute of Natural Resources and Environment. Technical Memorandum 88/3.
Gillison, A.N. (1994). 'Woodlands'*.* In: R.H. Groves (ed), *Australian Vegetation (2nd Edition)*. Cambridge University Press.
Gillison, A.N. and Walker, J. (1981). 'Woodlands' In: R.H. Groves (ed), *Australian Vegetation (1st Edition)*. Cambridge University Press.
Goodall, D.W. (1953a). 'Objective methods for the classification of vegetation.I. The use of positive interspecific correlation'. *Australian Journal of Botany* **1**: 39-63.
Goodall, D.W. (1953b). 'Objective methods for the classification of vegetation. II. Fidelity and indicator value'. *Australian Journal of Botany* **1**: 434-456.
Goodall, D.W. (1954). 'Objective methods for the classification of vegetation. III. An essay in the use of factor analysis'. *Australian Journal of Botany* **2**: 304-324.
Goodall, D.W. (1961). 'Objective methods of the classification of vegetation. IV. Patterns and minimal area'. *Australian Journal of Botany* **9**: 162-196.
Goosem, S., Morgan, G. and Kemp, J.E. (1999). 'Chapter 7 Wet Tropics'. In: Sattler, P. S. and Williams, R. D. (eds), *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.
Grey, G. (1841). *Journals of two expeditions of dicovery in north-west and Western Australia, during the years 1837, 8 and 9.* T. and W. Boone, London.
Gunn, R.H., Galloway, R.W., Pedley, L. and Fitzpatrick, E.A. (eds) (1967). *Lands of the Nogoa-Belyando Area, Queensland.* Land Research Series No. 18, CSIRO, Melbourne.
Harrington, G.N., Friedel, M.H., Hodgkinson K.C. and Noble, J.C. (1997). Vegetation ecology and management. In: Harrington, G.N., Wilson, A.D. and Young, M.D. (eds), *Management of Australia's Rangelands*, pp. 41-61. CSIRO Publications, East Melbourne.
Harris, W.K. (*in prep.*). *Land zones of Queensland*. Queensland Herbarium, Environmental Protection Agency, Brisbane.
Henderson, R.J.F., (ed) (1997). *Queensland Plants. Names and Distribution.* Queensland Herbarium, Department of Environment, Indooroopilly.
Hill, K.D and Johnson, L.A.S., (1995). 'Systematic studies in the eucalypts. 7. A revision of the bloodwoods, genus *Corymbia* (Myrtaceae)'. *Telopea.* **6(2-3)**: 185-504.
Hill, R.S., Truswell, E.M., McLoughlin, S. and Dettmann, M.E. (1999) 'Evolution of the Australian flora: Fossil evidence'. In: A.E. Orchard and H.S. Thompson (eds), *Flora of Australia*, **Vol.1**, 2nd Edition, ABRS/CSIRO Australia. pp. 251-321.
Hodgkinson, K.G., Harrington, G.N, Griffin, G.F., Noble, J.C. and Young, M.D. (1990). Management of Vegetation with Fire. In: G.N. Harrington, Wilson, A.D. and Young, M.D. (eds), *Management of Australia's Rangelands*, pp. 141-156. CSIRO Publications, East Melbourne.
Holland, G. and McBride, J. (1997). 'Tropical Cyclones'. In: E.K. Webb (ed), *Windows on Meteorology*. CSIRO Publishing, Collingwood.

Holmes, J.H. and Mott, J.J. (1993). 'Towards the diversified use of Australia's savannas', In: O.T. Solbrig and M.D. Young (eds), *The World's Savannas*. Man and the Biosphere Series Vol. 12, United Nations Educational, Scientific and Cultural Organisation, Paris

Hooker, J.D. (1860). *Introductory Essay.* In: *Botany of the Antarctic Voyage of the H.M. Discovery ships Erebus and Terror in the years 1839-1843, III. Flora Tasmaniae,* pp. I-cxxviii. Lovell Reeve, London.

Hopkins, A.J.M, Beeston, G.R, Harvey, J.M. (1999). 'A database on the Vegetation of Western Australia. Stage 1'. CALM Science (in press).

Hopkins, B. 1983. 'Successional processes'. In: F. Bourliere (ed), *Tropical Savannas. Ecosystems of the World 13*. pp. 605-616. Elsevier Scientific Publishing Company.

Huntley, B.J and Walker, B.H. (eds) (1982). *Ecology of Tropical Savannas*. Springer-Verlag, New York.

Isbell, R.F. (1996). *The Australian Soil Classification.* CSIRO Publishing, Collingwood, Victoria.

Jacobs, S.W.L. (1992). 'New species of *Triodia* and *Plectrachne* (Poaceae) from the Kimberley'. *Nuytsia* **8(2)**: 219-223.

Johnston, R.D. and Lacey, C.J. (1984). A proposal for the classification of tree-dominated vegetation in Australia'. *Australian Journal of Botany* **32**: 529-549.

Jones, R. (1969).'Fire-stick farming'. *Australian Natural History* **16**: 224-228.

Jutson, J.T. (1914). An outline of the physiographical geology (physiography) of Western Australia: Bulletin No. 61. Geological Survey of Western Australia, Perth.

Kemp, E.M. (1981). 'Pre-Quaternary fire in Australia'. In: Gill, A.M., Groves, R.H. and Noble, I.R. (eds), *Fire and the Australian Biota.* Australian Academy of Science, Canberra.

Kenneally, K.F., Keighery, G.J and Hyland, B.P.M. (1991). 'Floristics and phytogeography of Kimberley rainforests, Western Australia'. In: N.L. McKenzie, R.B. Johnston and Kendrick. P.G. (eds), *Kimberley Rainforests*, pp.93-131. Surrey Beatty and Sons, Chipping Norton.

King, P.P. (1827). *Narrative of a Survey of the Intertropical and Western Coasts Performed between the Years 1818 and 1822.* **Vol. 2.** John Murray, London.

Kirkpatrick, J.B. and Dickinson, K.J.M. (1986). Achievements, concepts and conflicts in Australian small-scale vegetation mapping. *Australian Geographical Studies* **24**: 222-234.

Kitchin, M. and Barson, M.M. (1998). *Monitoring Landcover Change: Specifications for the Remote Sensing of Agricultural Landcover Change Project 1990-1995, Version 4.0*. Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry, Canberra. [Online] Available HTML: http://www.brs.gov.au/land&water/landcov/specs.pdf

Küchler, A.W. (1947). 'A geographic system of vegetation'. *Geographical Review* **37**: 233-240.

Küchler, A.W. (1949). 'A physiognomic classification of vegetation'. *Annals of the Association of American Geographers* **39**: 201-210.

Küchler, A.W. (1956). 'Classification and purpose in vegetation maps'. *The Geographical Review* **56**: 155-167.

Küchler, A.W. (1967). *Vegetation Mapping*. The Ronald Press Company, New York.

Kutzbach, J.E. and Ziegler, A.M. (1994). 'Simulation of Late Permian climate and biomes with an atmosphere-ocean model'. In*:* J.R.L. Allen *et al*. (eds), *Palaeoclimates and Their Modelling.* pp. 119-132. Chapman and Hall, London.

Lacey, C.J., Walker, J. and Noble, I.R. (1982). 'Fire in Australian Tropical Savannas'. In*:* B.J. Huntley and B.J. Walker (eds), *Ecology of Tropical Savannas,* pp. 246-272. Springer-Verlag, Berlin.

Lonsdale, W.M. and Braithwaite, R.W. (1991). 'Assessing the effects of fire on vegetation in tropical savannas'. *Australian Journal of Ecology* **16**: 363-374.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (eds) (1990). *Australian Soil and Land Survey Field Handbook.* 2nd Edition. Inkata Press, Melbourne.

McDonald, W.J.F. (1981). Vegetation map. 1:1 000 000 scale. Western Arid Region Land Use Study - Part V. Queensland Department of Primary Industries, Brisbane.

McDonald, W.J.F. and Dillewaard, H.A. (1994). CORVEG (Version 2.0) Vegetation and Flora Database for Queensland. Queensland Department of Environment and Heritage, Brisbane.

McIntosh, R.P. (1967). 'The continuum concept of vegetation'. *Botanical Review* **33**: 130-187.

McKenzie, N.L, Johnston, R.B., Kendrick, P.G. (eds) (1991). *Kimberley Rainforests*. Surrey Beatty and Sons, Chipping Norton.

Milson, J. (2000a). *Trees and Shrubs of north-west Queensland*, Department of Primary Industries, Queensland.

Milson, J. (2000b). *Pasture Plants of north-west Queensland*, Department of Primary Industries, Queensland.

Moore, C. and Betche, E. (1893). *Handbook of the Flora of New South Wales*. Government

Printer, Sydney.
Morgan, G. (1999a) 'Chapter 2 Gulf Plains'. In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.
Morgan, G. (1999b) 'Chapter 10 Desert Uplands'. In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.
Morgan, G. (1999c). 'Chapter 1 Northwest Highlands'. In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.
Mueller, F.J.H. von (1858-1882). *Fragmenta Phytographiae Australiae*, Volumes 1-7, Government Printer, Melbourne.
National Land and Water Resources Audit (2000). *Australian Vegetation Attributes Version 5.0.* Audit, Canberra.
National Vegetation Information System (1999). Vegetation Attributes Version 5. National Land and Water Resources Audit Theme 3 vegetation, condition, cover and use. URL: http://www.nlwra.gov.au/full/20_products/05_by_subject/15_land_resources_and_mgt/40_NVIS/veg_attribute.html
Neldner, V. J. (1999) 'Chapter 3. Cape York Peninsula' In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.
Neldner, V. J. and Clarkson, J. R. (1995). *Vegetation Survey and Mapping of Cape York Peninsula*. (Cape York Peninsula Land Use Strategy, Office of the Co-ordinator General of Queensland, Brisbane, Department of the Environment, Sport and Territories, Canberra and Queensland Department of Environment and Heritage, Brisbane.)
Neldner, V.J. (1984). *South Central Queensland. Vegetation Survey of Queensland.* Queensland Department of Primary Industries Botany Bulletin No. 3.
Neldner, V.J. (1991). *Central Western Queensland. Vegetation Survey of Queensland.* Queensland Department of Primary Industries Botany Bulletin No. 9
Neldner, V.J. (1993). *Vegetation Survey and Mapping in Queensland*. Queensland Botany Bulletin No. 12. Queensland Herbarium, Brisbane.
Neldner, V.J. (1996). *Improving vegetation survey: Integrating the use of geographic information systems and species modelling techniques in vegetation survey. A case study of the eucalypt dominated communities of Cape York Peninsula*. Unpublished PhD thesis, Canberra: Australian National University.
Neldner, V.J. and Clarkson, J.R. (*in prep.*). *Vegetation of Cape York Peninsula*, Queensland Herbarium, Environmental Protection Agency, Brisbane.
Neldner, V.J., Fensham, R.J., Clarkson, J.R. and Stanton, J.P. (1997) The natural grasslands of Cape York Peninsula, Australia. Description, distribution and conservation status*. Biological Conservation* **81**:121-136.
Neldner, V.J., Thompson, E.J., Bean, A.R. and Dillewaard, H.A. (1999). *Methodology for Survey and Mapping of Vegetation Communities and Regional Ecosystems in Queensland*. Queensland Herbarium, Environmental Protection Agency, Brisbane.
Nelson, E.C. (1981). 'Phytogeography of southern Australia'. In: A. Keast (ed), *Ecological Biogeography of Australia,* pp. 734-759. W. Junk, The Hague.
Nicholson, P.H. (1981) Fire and the Australian Aborigine – an enigma. In: Gill, A.M., Groves, R.H. and Noble, I.R. (eds), *Fire and the Australian Biota.* Australian Academy of Science, Canberra.
Nicolle, D. (2000). 'Three new taxa of *Eucalyptus* subgenus *Eudesmia* (Myrtaceae) from Queensland and Western Australia'. *Nuytsia* **13(2)**: 317-329.
Noble, J.C. (1997). *The delicate and noxious scrub: CSIRO studies on native tree and shrub proliferation in the semi-arid woodlands of Eastern Australia*. CSIRO, Canberra
Northcote, K. H., Beckman, G. G., Bettenay, E., Churchward, H. M., van Dijk, D. C., Dimmock, G. M., Hubble, G. D., Isbell, R. F., McArthur, W. M., Murtha, G. G., Nicolls, K. D., Paton, T. R., Thompson, C. H., Webb, A. A., Wright, M. J. (1960-68). *Atlas of Australian Soils (1:2,000,000) Sheets 1 to 10, with explanatory data'.* CSIRO and Melbourne University Press, Melbourne.
NTGS - Northern Territory Geological Survey. (2000). 'Geological Overview', Department of Minerals and Energy Northern Territory. [Online] Available HTML: http://www.dme.nt.gov.au/ntgs/geo_overview/geo_over.html
Omerick, J.M. (1995). Ecoregion: A framework for managing ecosystems. *George Wright Society*

Forum **12 (1)**: 35-50.
Osborne, T.G.B. and Gardner, C.A. (1939). 'Dampier's Australian Plants. *Proceedings of the Linnean Society of London* Session 151, pt.**2**: 44-50.
Patton, R.T. (1933). 'Ecological studies in Victoria. Part II. The Fern Tree Gully'. *Proceedings of the Royal Society of Victoria* **46**: 117-129.
Patton, R.T. (1934). 'Ecological studies in Victoria. Part III. Coastal sand dunes'. *Proceedings of the Royal Society of Victoria* **47**:135-157.
Patton, R.T. (1936). 'Ecological studies in Victoria. Part IV. Basalt plains association'. *Proceedings of the Royal Society of Victoria* **48**: 172-190.
Pedley, L. (1967). Vegetation of the Nogoa-Belyando Area. In: R.H. Gunn, R.W. Galloway, L. Pedley, L. and E.A. Fitzpatrick (eds), *Lands of the Nogoa-Belyando Area, Queensland*. Land Research Series No. 18. CSIRO, Melbourne.
Pedley, L. and Isbell, R.F. (1971). 'Plant Communities of Cape York Peninsula'. *Proceedings of the Royal Society of Queensland.* **82(5)**. University of Queensland Press, Brisbane.
Perry, R.A., (1964). 'Part 1. 'Introduction to the Leichhardt-Gilbert Area'. In: R.A. Perry, J.R. Sleeman, C.R. Twidale, C.E. Pritchard, R.O. Slatyer, M. Lazarides and F.H. Collins (eds), *General Report on the Lands of the Leichhardt-Gilbert Area, Queensland, 1953-54*, Land Research Series No. 11. CSIRO, Melbourne.
Perry, R.A., Sleeman, J.R., Twidale, C.R., Pritchard, C.E., Slatyer, R.O., Lazarides, M. and Collins, F.H. (1964). *General Report on the Lands of the Leichhardt-Gilbert Area, Queensland, 1953-54*, Land Research Series No. 11, CSIRO, Melbourne.
Powell, J.M. (1967). 'Victoria's woodland cover in 1869'. *New Zealand Geographer* **23**: 106-116.
Prescott, J.A. (1931). *The Soils of Australia in Relation to Vegetation and Climate.* Bulletin No. 52. Council of Scientific and Industrial Research, Australia.
Purdie, R.W. (1990). Vegetation (Maps included). In: *Western Arid Region Land Use Study - Part VI,* Technical Bulletin No.28, pp. 49-92. Division of Land Utilisation, Department of Primary Industries, Brisbane.
Purdie, R.W. and McDonald, W.J.F. (1990). Vegetation. (Maps included). In: *Western Arid Region Land Use Study - Part III*, Technical Bulletin No. 29. pp. 69-103. Division of Land Utilisation, Queensland Department of Primary Industries, Brisbane,.
Queensland Herbarium (2001). *Queensland Herbarium Plant Collection Database (HERBRECS).* Queensland Herbarium, Environmental Protection Agency.
Rodway, L. (1903). *The Tasmanian Flora*. Government Printer, Hobart.
Russell-Smith, J. (1991). 'Classification, species richness, and environmental relations of monsoon rain forest in northern Australia'. *Journal of Vegetation Science* **2**: 259-278
Russell-Smith, J. (ed) (1996). *Developing a coordinated approach to fire management and monitoring issues across northern Australia: common issues, opportunities.* Report of the North Australian Rural Fire Manager's Technical Workshop, Darwin, for the Land and Water Resources Research and Development Corporation.
Russell-Smith, J. and Bowman, D.M.J.S. (1992). 'Conservation of monsoon rainforest isolates in the Northern Territory, Australia'. *Biological Conservation* **59**: 51-63
Russell-Smith, J., Allan, G.E., Thackway, R., Rosling, T. and Smith R. (*in press*) Fire management and savanna landscapes in northern Australia. ACIAR Workshop Proceedings.
Sarmiento, G. (1984). *The ecology of neotropical savannas.* Harvard University Press, Cambridge.
Sattler, P.S. (1999). 'Introduction' In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.
Sattler, P.S. and Williams, R.D. (eds) (1999). *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.
Schimper, A.F.W. (1903). *Plant Geography Upon A Physiological Basis*. Oxford University and Clarendon Press, London.
Schodde, R. (1989). 'Origins, radiations and sifting in the Australasian biota – changing concepts from new data and old'. *Australian Systematic Botany Society Newsletter* **60**: 2-11.
Scott, J.M., Davis, F., Csuti, B., Noss, R., Butterfield, B. Caicco, S., Grooves, C., Ulliman, J. Anderson, H. and Wright, R.G. (1993). 'Gap analysis: A geographic approach to protection of biological diversity'. *Wildlife Monographs* **123**: 1-41.
Singh, G., Kershaw, A.P. and Clark, R. (1981). 'Quaternary vegetation and fire history in Australia'. In: A.M. Gill, R.H. Groves and I.R. Noble (eds), *Fire and the Australian Biota*, pp. 23-55. Australian Academy of Science, Canberra.
Solbrig, O.T. (1993). 'Ecological Constraints to Savanna Land Use'. In: O.T. Solbrig and M.D.

Young (eds), *The World's Savannas*, Man and the Biosphere Series Vol. 12, pp. 21-47. United Nations Educational, Scientific and Cultural Organisation, Paris.

Solbrig, O.T. and Young, M.D (1993) 'Economic and Ecological Driving Forces Affecting Tropical Savannas'. In: O.T. Solbrig and M.D. Young (eds), *The World's Savannas*, Man and the Biosphere Series Vol. 12, pp. 3-20. United Nations Educational, Scientific and Cultural Organisation, Paris.

Specht, R.L. (1957). 'Dark Island heath (Ninety-Mile Plains, South Australia). V. The water relationships in heath vegetation and pastures on the Makin sand'. *Australian Journal of Botany* **5**: 151-172.

Specht, R.L. (1958). 'The History of Botanical exploration in the Arnhem Land Aboriginal Reserve. In: R.L. Specht and C.P. Mountford (eds) *Records of the American-Australian Scientific Expedition to Arnhem Land* Vol.3. *Botany and Plant Ecology* pp. 333-414. Melbourne University Press

Specht, R.L. (1963). Dark Island heath (Ninety-mile Plain, South Australia). VII. The effect of fertilisers on composition and growth, 1950-1960. *Australian Journal of Botany* **11**: 67-94.

Specht, R.L. (1970). 'Vegetation'. In: G.W. Leeper (ed), *The Australian Environment* 4th Edition. pp. 44-67. CSIRO and Melbourne University Press.

Specht, R.L. (1981). 'Foliage projective cover and standing biomass'. In: A.N. Gillison and D.J. Anderson (eds), *Vegetation Classification In Australia.* pp. 10-21. CSIRO and Australian National University Press, Canberra,

Specht, R.L., Roe, E.M. and Boughton, V.H. (eds) (1974). *Conservation of Major Plant Communities of Australia and Papua New Guinea.* Morgan, G. (1999). 'Chapter 1 Northwest Highlands'. In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane. Australian Journal of Botany*,* Supplement No.7.

Speck, N.H., Wright, R.L., Sweeney, F.C., Perry, R.A., Fitzpatrick, E.A., Nix, H.A., Gunn, R.H. and Wilson I.B. (1968). *Lands of the Dawson-Fitzroy Area, Queensland.* Land Research Series No. 21, CSIRO, Melbourne.

Stanton, J.P. and Morgan, M.G. (1977). *Project RAKES – The Rapid Selection and Appraisal of Key and Endangered Sites: The Queensland Case Study.* A report to the Department of Environment Housing and Community Development. University of New England, Armidale.

Stephens, C.G. (1977). 'Soils'. In: *Australia, a Geography*. (ed) Jeans, D.N., Sydney University Press, Sydney.

Stewart, W.N. and Rothwell, G.W. (1993). *Palaeobotany and the Evolution of Plants.* 2nd Edition*.* Cambridge University Press.

Stocker, G.C. and Mott, J.J. (1981). 'Fire in the Tropical Forests'. In: A.M. Gill, R.H. Groves and I.R. Noble (eds), *Fire and the Australian Biota*, pp. 427-442. Australian Academy of Science, Canberra

Sun, D., Hnattiuk, R.J. and Neldner, V.J. (1996). *Vegetation Classification and Mapping Systems for Australian Forest Management.* Bureau of Resource Sciences, Canberra.

Sun, D., Hnattiuk, R.J. and Neldner, V.J. (1997). Review of vegetation classification and mapping systems undertaken by major forested land management agencies in Australia. *Australian Journal of Botany* **45**:929-948.

Thackway R. and Cresswell I.D. (eds) (1995). *An Interim Biogeographic Regionalisation for Australia: a framework for setting priorities in the National Reserves System Cooperative Program*. Reserve System Unit, Australian Nature Conservation Agency, Canberra.

Thompson, E.J. and Turpin, G.P. (*in draft*). *Vegetation descriptions for the Desert Uplands bioregion*. Queensland Herbarium, Environmental Protection Agency, Brisbane.

Tracey, J.G. and Webb, L.J. (1975). *Vegetation of the Humid Tropical Region of North Queensland.* (1:100 000 scale maps). CSIRO Division of Plant Industry, Indooroopilly.

TS-CRC - Cooperative Research Centre for the Sustainable Development of Tropical Savannas. (1998). *Tropical Savannas CRC Project Guide 1998-99*, TS-CRC, Darwin.

TS-CRC - Cooperative Research Centre for the Sustainable Development of Tropical Savannas. (1999). *Tropical Savannas CRC Annual Report 1998-99*, TS-CRC, Darwin.

Turner, E.J., McDonald, W.J.F., Ahern, C.R. and Thomas, M.B. (1993). *Western Arid Region Land Use Study. Part V*. Queensland Department of Primary Industries Technical Bulletin No. 30, Brisbane.

Walker, J. and Gillison, A.N. (1982). 'Australian Savannas'. In: B.J. Huntley and B.H. Walker (eds), *Ecology of Tropical Savannas.* Springer-Verlag, Berlin.

Walker, J. and Hopkins, M.S. (1984). 'Vegetation'. In: R.C. McDonald, R.F. Isbell, J.G. Speight, J. Walker and M.S. Hopkins (eds), *Australian Soil and Land Survey Field Handbook,* pp. 44-

67. Inkata Press, Melbourne.
Walker, J. and Hopkins, M.S. (1990). 'Vegetation'. In: R.C. McDonald, R.F. Isbell, J.G. Speight, J. Walker and M.S. Hopkins (eds), *Australian Soil and Land Survey Field Handbook* 2nd Edition. pp. 58-86. Inkata Press, Melbourne.
Warming, E. (1909). *Oecology of Plants.* Clarendon Press, Oxford.

Webb, A.A., Beeston, G.R. and Hall, T.J. (1974). *The Soils and Vegetation of Part of the Mayvale Land System in the Gulf of Carpentaria Region: Agricultural Chemistry Branch Technical Report No 5*. Queensland Department of Primary Industries, Brisbane.
Webb, L.J. (1959). 'A physiognomic classification of Australian rainforests. *Journal of Ecology* **47**:551-570.
Webb, L.J. (1968). Environmental relationships and the structural types of Australian rainforest vegetation. *Ecology* **49**: 296-311.
Webb, L.J. (1978). A general classification of the Australian rainforests. *Australian Plants* **9**:349-363.
Webb, L.J. and Tracey, J.G. (1981). 'Australian rainforests: patterns and change'. In: A. Keast (ed), *Ecological Biogeography of Australia.* Junk, The Hague, pp. 605-694.
Wegener, A. (1915). *Die Enstehung der Kontinente und Ozeane*. Sammlung Vieweg, Brunswick.
Werren, G.L., Goosem, S., Tracey, J.G. and Stanton, J.P. (1995). 'The Australian Wet Tropics Centre of Plant Diversity'. In: *World Centres of Plant Diversity, Volume 2*. pp. 500-506. (eds) S.D. Davies, V.H. Heywood and A.C. Hamilton, WWF/IUCN, Oxford Information Press.
Western Australian Herbarium (1998). FloraBase - Information on the Western Australian flora. Department of Conservation and Land Management. http://www.calm.wa.gov.au/science/florabase.html
Wheeler, J.R. Rye, B.L., Koch, B.L. and Wilson, A.J.G. (eds), (1992). *The Flora of the Kimberley Region*. Department of Conservation and Land Management, Perth.
Whittaker, R.H. (1967). 'Gradient analysis of vegetation'. *Biological Review* **42**:207
Williams, C.H. and Raupach, M. (1983). 'Plant nutrients in Australian soils'. In: *Soils – an Australian Viewpoint*, pp. 777-794. CSIRO and Melbourne University Press, Melbourne.
Williams, R.J. (1955). 'Vegetation regions'. In: *Atlas of Australian Resources*. Department of National Development, Canberra.
Willis, J.H. (1981). 'The History of Botanical Investigation in Central Australia'. In: J. Jessop (ed), *Flora of Central Australia.* pp. 13-20. A.H. and A.W. Reed, Sydney.
Wilson, B.A. (1999) 'Chapter 4 Mitchell Grass Downs'. In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.
Wilson, B.A. and Bowman, D.J.S. (1987). 'Fire, storm, flood and drought: the vegetative ecology of Howard's Peninsula, Northern Territory'. *Australian Journal of Ecology* **12**: 165-174.
Wilson, B.A., Brocklehurst, P.S., Clark, M.J. and Dickinson, K.J.M. (1990). *Vegetation Survey of the Northern Territory - Technical Report No. 49*, Conservation Commission of the Northern Territory, Darwin.
Wood, J.G. (1936). 'Regeneration of the vegetation on the Koonamore Vegetation Reserve' 1926-1936'. *Transactions of the Royal Society of South Australia* **60:** 96-111.
Wood, J.G. (1937). *The Vegetation of South Australia*. Government Printer, Adelaide.
Wood, J.G. (1939). 'Ecological concepts and nomenclature'. *Transactions of the Royal Society of South Australia* **63**: 215-223.
Wood, J.G. and Williams, R.J. (1960). 'Vegetation of Australia'. In: G.W. Leeper (ed), *The Australian Environment* (revised edition), pp. 67-84. CSIRO and Melbourne University Press, Melbourne.
Young, P.A.R. (1999).'Chapter 8 Central Queensland Coast'. In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.
Young, P.A.R., Wilson, B.A. McCosker, J.C., Fensham, R.J. Morgan, G. and Taylor, P.M. (1999). 'Chapter 11 Brigalow Belt'. In: P.S. Sattler and R.D. Williams (eds), *The Conservation Status of Queensland's Bioregional Ecosystems.* Environmental Protection Agency, Brisbane.

7. Appendices

Appendix 1.1 Land Zones recognised in the mapping of the vegetation of the Australian Tropical Savannas.

Map Unit Prefix	Land zone (Queensland equivalent)	Description
A	1	Quaternary marine deposits, subject to periodic inundation by saline or brackish marine waters. Includes mangroves, saltpans and offshore tidal flats. Soils are predominantly saline muds or solonchaks
B	2	Quaternary coastal dunes and beaches. Includes associated degraded dunes, sandplains, swales, dune lakes and swamps, as well as coral and sand cays. Soils are predominantly calcareous sands, podzols or peats.
C	3/4	Cainozoic alluvial plains and piedmont fans. Includes terraces, levées, swamps, and channels of Quaternary alluvium and palaeo-estuarine deposits, and older floodplain complexes and piedmont fans with palaeo-stream channels. Also includes inland freshwater lakes and associated dune systems. Does not include talus slopes. Soils include deep cracking clays, loams, earths, and poorly developed alluvial soils (LZ 3). Cainozoic clay deposits, usually forming gently undulating plains with poorly developed drainage systems. Deep cracking clays of moderate to high fertility, often with gilgai microrelief, and texture contrast soils. Excludes clays plains and downs formed on older bedrock (LZ 4).
D	5	Cainozoic sand deposits, usually forming extensive uniform, near-level or gently undulating plains. Includes slightly dissected surfaces and small remnants of these surfaces. Soils are usually sands, earths or texture contrast and often overlie laterite profiles. Includes extensive sand plains of uncertain origin overlying weathered or unweathered bedrock. Excludes alluvial deposits (C), exposed duricrust (F), and shallow soils derived from underlying bedrock.
n/a	6	Cainozoic inland dune fields, interdune areas and degraded dunefields. Excludes alluvial systems that may traverse this zone. Soils are predominantly sands and earths, with clay soils in some interdune areas.
E	7	Cainozoic duricrusts formed on a variety of rock types. Includes exposed ferruginous, siliceous and mottled horizons and associated talus and colluvium. Usually low mesa and scarps, or low stony rises on downs. Soils are usually skeletal, with shallow texture contrast soils on the adjacent colluvial fans, and shallow red earths on plateaux margins and on larger mesas.
F	8	Cainozoic igneous rocks, including extrusive and intrusive types. Predominantly basalt flows forming extensive plains and occasional low scarps, but including hills, cones and plugs on trachytes and rhyolites, and minor interbedded sediments. These igneous rocks have diverse origins such as flows, pyroclastics, plugs and dikes. Associated soils included black earths, krasnozems, shallow clays and lithosols of generally moderate to high fertility. Excludes alluvial soils derived from these rocks, as well as springs (C) but includes associated talus.
G	9	Cainozoic to Proterozoic consolidated, fine-grained sediments with little or no deformation. Siltstones, mudstones, shales, calcareous sediments and lithic sandstones are typical rock types although minor interbedded volcanics may occur. Usually undulating landscapes with fine textured soils of moderate to high fertility. Excludes areas of duricrust (E).
H	10	Cainozoic to Proterozoic consolidated, medium- to coarse-grained sediments with little or no deformation. Includes siliceous sandstones and conglomerates forming ranges, plateaux and scarps with shallow soils of low fertility. Minor interbedded volcanics may occur. Excludes overlying Cainozoic sand deposits (D), but includes *in situ* earths and texture contrast soils. Also includes springs associated with these sediments.
J	11	Mesozoic to Proterozoic moderately to strongly deformed and metamorphosed sediments and interbedded volcanics. Ranges, hills and lowlands with lithosols and shallow texture contrast soils of low to moderate fertility. Includes low- to high-grade metamorphics such as shales, slates, gneisses of indeterminate origin, and minor areas of serpentinite.
K	12	Mesozoic to Proterozoic igneous rocks. Predominantly granitoids and intermediate to acid volcanics, forming ranges, hills, and lowlands with lithosols and texture contrast soils of low fertility. Includes granites, granodiorites, andesites and rhyolites, and minor areas of interbedded sediments and basic rocks such as gabbros. Excludes serpentinites (J).

adapted from Sattler and Williams (1999).

Appendix 2.1 Geological Time Scale used in this study. Age in millions of years (Ma)., adapted from Stewart and Rothwell 1993.

EON	ERA	PERIOD	EPOCH	major events	Age (Ma)
Phanerozoic	Cainozoic	Quaternary	Holocene	Tasmania and New Guinea isolated from Australian mainland, Europeans arrive in Australia.	0.01
			Pleistocene	serial glaciation, redistrinbution of floras, megafauna dominant, appearance of *Homo.*	1.8
		Tertiary	Pliocene	uplift of Andes and general uplift of continents and changing climates, spread ofgrasslands, restriction or extinction of some fauna.	5.3
			Miocene	worldwide continetal uplifts, rise of European Alps, cooling phase restricts broad-leaf flora, rise of grazing animals and apes.	23.5
			Oligocene	Australia and Antarctica finally separate, widespread distribution of relict taxa, e.g. *Metasequoia, Ginkgo.*	36.7
			Eocene	subtropical climate supports dense forests, coal deposits, modern angiosperms and mamma present.	58.0
			Palaeocene	continents near present positions, trend to seasonal subtropical climates, angiosperms diversify, first lemurs, modern birds.	66.4
	K-T Boundary Extinction Event				
	Mesozoic	Cretaceous	Upper	Africa and South America separate from Australia, formation of Lord Howe Rise and Tasman Sea, first angiopseerms, modern insect insects, first pouched and placental mammals, extinction of great reptiles.	144
			Lower		
		Jurassic	Upper	Gondwana starts to rift, extensive river systemswith sediemntation in lowlands, rich fern and gymnsoperm-dominated flora, rise of higher insects and birds, dinosaurs abundant.	213
			Middle		
			Lower		
		Triassic	Upper	rise of *Ginkgo* and Cycadophytes, diversification of ferns and conifers, decline of Glossopteris Flora, first mammals, rise of dinosaurs.	248
			Middle		
			Lower		
	Palaeozoic	Permian	Upper	uplift and vulcanism in eastern Australia, diversification of reptiles and Glossopteris Flora, extinction of arborescent lycopods.	286
			Lower		
		Carboniferous	Pennsylvanian	accretion of Pangaea, epicontinental seas, vulcanism in east Australia, primitive ferns, seed ferns, lycopods and cordaites, spread of amphibians, sharks, bony fishes and flying insects.	354
			Mississipian		
		Devonian	Upper	fluctuating sea levels, continental uplifting, coral reefs, dicversification of fish and vascular plants, origin of amphibians.	408
			Middle		
			Lower		
		Silurian	Upper	low-lying continents, uplift and vulcanism in east Australia, first vascular plants, first air-breathing animals.	434
			Lower		
		Ordovician	Upper	uplift in the southeast, extensive warm seas, first vertebrates and a great variety of marine invertebrates.	505
			Lower		
		Cambrian	Upper	accretion of Gondwana, marine transgression and extensive erosion in NW Australia, warm epicontinental seas support alage and invertebrate species, first trlobites.	590
			Middle		
			Lower		
Precambrian	Proterozoic			accretion of super-continent, extensive glaciation at end of the period, origins of photosynthesis, eukaryote cell organisation and multicellular life.	1500
	Archaen			extensive vulcanism, high radiation levels, low 0_2 levels, no ozone layer, prokaryotic life forms, H_2S metabolic substrate.	4700

Appendix 2.2 Approximate correlation of Australian Soil Classification and the Great Soil Groups (after Isbell 1996).

Order	Great Soil Group
Calcarosols	Solonized brown soils, grey-brown and red calcareous soils
Chromosols	Non-calcic brown soils, some red-brown earths and a range of podzolic soils
Dermosols	Prairie soils, chocolate soils, some red and yellow podzolic soils
Ferrosols	Krasnozems, euchrozems, chocolate soils
Hydrosols	Humic gleys, gleyed podzolic soils, solonchaks and some alluvial soils
Kandosols	Red, yellow and grey earths, calcareous red earths
Kurosols	many podzolic soils and soloths
Organosols	neutral to alkaline, and acid peats
Podosols	Podzols, humus podzols, peaty podzols
Rudosols	Lithosols, alluvial soils, calcareous and siliceous sands, some solonchaks
Sodosols	Solodized solonetz and solodic soils, some soloths and red-brown earths, desert loams
Tenosols	Lithosols, siliceous and earthy sands, alpine humus soils and some alluvial soils
Vertosols	Black earths, grey, brown and red clays.

Appendix 3.1 Queensland Herbarium, Environmental Protection Agency vegetation data for central and eastern Queensland.

MAP SHEET NAME (1:250 000 SHEET)	VERSION YEAR	AUTHOR
Atherton	2000	S.L. Thompson and M.R. Newton
Ayr	2000	G.W. Wilson
Baralaba	1999	M. Schmeider
Bowen	2000	G.W. Wilson
Buchanan	2001	E.J. Thompson and G.P. Turpin
Charters Towers	2001	E.J. Thompson and G.P. Turpin
Clermont (north)	1999	D.C. Johnson
Clermont (south)	1999	L.P. Bailey
Duaringa	1999	T.S. Ryan
Einasleigh	2000	E.P. Addicott
Emerald (north)	1999	H. Cartan
Emerald (south)	1999	T.S. Ryan
Galilee	2001	E.J. Thompson and G.P. Turpin
Hughenden	2001	E.J. Thompson and G.P. Turpin
Jericho	2001	E.J. Thompson and G.P. Turpin
Longreach (part)	2001	E.J. Thompson and G.P. Turpin
Mackay (part)	1999	S.L. Thompson and I.D. Fox
Mount Coolon	1999	S.L. Thompson and I.D. Fox
Muttaburra (part)	2001	E.J. Thompson and G.P. Turpin
Port Clinton	2000	L.P. Bailey
Rockhampton	1999	T.S. Ryan
Springsure (Mantuan Downs 1:100 000)	1999	D.W. Butler
Springsure (Nandowrie 1:100 000)	1999	K.M. Stephens
Springsure (Springsure 1:100 000)	1999	A.R. Bean and K.M. Stephens
St Lawrence (part)	1999	S.L. Thompson and I.D. Fox
Tambo (part)	2001	E.J. Thompson and G.P. Turpin
Tangorin (part)	2001	E.J. Thompson and G.P. Turpin
Townsville	2000	R.J. Cumming

Appendix 3.1a Queensland Herbarium, Environmental Protection Agency vegetation data for Mitchell Grass Downs.

MAP SHEET NAME (1:250 000 SHEET)	**VERSION YEAR**	**AUTHOR**
Blackall	1999	H. Cartan
Longreach (part)	2000	H. Cartan
Muttaburra (part)	2000	H. Cartan
Tambo (part)	2000	B.A. Wilson
Tangorin (part)	2000	H. Cartan

Appendix 3.2 LANDSAT scenes used for mapping northwest Queensland

PROJECT: NORTHERN AUSTRALIA VEGETATION MAPPING PROJECT
SUB-PROJECT: NORTH-WEST QUEENSLAND
ORGANIZATION: QUEENSLAND HERBARIUM
(Queensland Environmental Protection Agency)

TITLE: Description of SLATS Landsat TM imagery
deployed by Queensland Herbarium (May 1999)

AUTHOR: Jack Kelley -- Senior Computer Support Officer (GIS)
Queensland Herbarium (Queensland Environmental Protection Agency)
Brisbane Botanic Gardens Mt Coot-tha, Mt Coot-tha Road, TOOWONG
Queensland, Australia 4066

TABLE 1. 1:250,000 SHEETS FOR NORTH-WEST QUEENSLAND

CODE	TOPO-250K	NAME	ABBR	HECTARES(AMG)
SE54-01	e5401	MORNINGTON	MORN	1773436
SE54-02	e5402	CAPE VAN DIEMEN	DIEM	1771188
SE54-03	e5403	GALBRAITH	GALB	1771188
SE54-04	e5404	WALSH	WALS	1773436
SE54-05	e5405	WESTMORELAND	WEST	1764201
SE54-06	e5406	BURKETOWN	BURK	1761988
SE54-07	e5407	NORMANTON	NORM	1761988
SE54-08	e5408	RED RIVER	RED!	1764201
SE54-09	e5409	LAWN HILL	LAWN	1754436
SE54-10	e5410	DONORS HILL	DONO	1752261
SE54-11	e5411	CROYDON	CROY	1752261
SE54-12	e5412	GEORGETOWN	GEOR	1754436
SE54-13	e5413	CAMOOWEAL	CAMO	1744144
SE54-14	e5414	DOBBYN	DOBB	1742008
SE54-15	e5415	MILLUNGERA	MILL	1742008
SE54-16	e5416	GILBERTON	GILB	1744144
SF54-01	f5401	MOUNT ISA	ISA!	1733329
SF54-02	f5402	CLONCURRY	CLON	1731232
SF54-03	f5403	JULIA CREEK	JULI	1731232
SF54-04	f5404	RICHMOND	RICH	1733329

Note: SE54-02 (CAPE VAN DIEMEN) is basically just sea,
except for part of Mornington Island.

TABLE 2. IMAGERY MOSAICED FOR EACH 1:250,000 MAP SHEET

The figures are only approximate, and come from
an 'intersection' of two coverages, namely
(1) 1:250,000 sheets (exact)
(2) SLATS scenes (approximate only).

CODE	NAME	IMAGE	YYMM	HECTARES(AMG)
SE54-01	MORNINGTON	morn97jy_e0p4	97jy	1228251
SE54-02	CAPE VAN DIEMEN	-		1591523
SE54-02	CAPE VAN DIEMEN	morn97jy_e0p4	97jy	77394

(Appendix 3.2 cont'd)

SE54-03	GALBRAITH		2258
SE54-03	GALBRAITH	-	230657
SE54-03	GALBRAITH	delt97se_e0p4 97se	1538273
SE54-04	WALSH	-	268
SE54-04	WALSH	buli97oc_e0p4 97oc	1496995
SE54-04	WALSH	delt97se_e0p4 97se	276173
SE54-05	WESTMORELAND	-	920
SE54-05	WESTMORELAND	burk97au_e0p4 97au	92980
SE54-05	WESTMORELAND	doom97jy_e0p4 97jy	353137
SE54-05	WESTMORELAND	morn97jy_e0p4 97jy	1317163
SE54-06	BURKETOWN	-	635642
SE54-06	BURKETOWN	burk97au_e0p4 97au	1071403
SE54-06	BURKETOWN	morn97jy_e0p4 97jy	3716
SE54-06	BURKETOWN	norm97se_e0p4 97se	51228
SE54-07	NORMANTON	-	18994
SE54-07	NORMANTON	delt97se_e0p4 97se	614088
SE54-07	NORMANTON	geor95au_l3s4 95au	30353
SE54-07	NORMANTON	norm97se_e0p4 97se	1098553
SE54-08	RED RIVER	buli97oc_e0p4 97oc	592960
SE54-08	RED RIVER	delt97se_e0p4 97se	36801
SE54-08	RED RIVER	geor95au_l3s4 95au	1123146
SE54-08	RED RIVER	mtga94ju_l3s5 94ju	10848
SE54-08	RED RIVER	norm97se_e0p4 97se	445
SE54-09	LAWN HILL	burk97au_e0p4 97au	235949
SE54-09	LAWN HILL	doom97jy_e0p4 97jy	1394254
SE54-09	LAWN HILL	gunp97au_e0p4 97au	124234
SE54-10	DONORS HILL	ariz95au_l3s4 95au	105736
SE54-10	DONORS HILL	burk97au_e0p4 97au	1247185
SE54-10	DONORS HILL	gunp97au_e0p4 97au	207559
SE54-10	DONORS HILL	norm97se_e0p4 97se	191780
SE54-11	CROYDON	ariz95au_l3s4 95au	214250
SE54-11	CROYDON	bell95au_l3s4 95au	98934
SE54-11	CROYDON	geor95au_l3s4 95au	163816
SE54-11	CROYDON	norm97se_e0p4 97se	1275261
SE54-12	GEORGETOWN	bell95au_l3s4 95au	222981
SE54-12	GEORGETOWN	geor95au_l3s4 95au	1322216
SE54-12	GEORGETOWN	mtga94ju_l3s5 94ju	155664
SE54-12	GEORGETOWN	oakv95ju_l3s5 95ju	53575
SE54-13	CAMOOWEAL	camo97jy_e0p4 97jy	806513
SE54-13	CAMOOWEAL	doom97jy_e0p4 97jy	307337
SE54-13	CAMOOWEAL	gunp97au_e0p4 97au	630294
SE54-14	DOBBYN	ariz95au_l3s4 95au	562858
SE54-14	DOBBYN	gunp97au_e0p4 97au	1179150
SE54-15	MILLUNGERA	ariz95au_l3s4 95au	1209569
SE54-15	MILLUNGERA	bell95au_l3s4 95au	532439
SE54-16	GILBERTON	bell95au_l3s4 95au	1268380
SE54-16	GILBERTON	oakv95ju_l3s5 95ju	475764
SF54-01	MOUNT ISA	camo97jy_e0p4 97jy	641589
SF54-01	MOUNT ISA	gunp97au_e0p4 97au	163578
SF54-01	MOUNT ISA	mtis97au_e0p4 97au	736886
SF54-01	MOUNT ISA	uran97jy_e0p4 97jy	191276
SF54-02	CLONCURRY	ariz95au_l3s4 95au	154754
SF54-02	CLONCURRY	clon97se_e0p4 97se	673456

Appendix 3.2 (cont'd)

SF54-02 CLONCURRY	gunp97au_e0p4	97au	323422
SF54-02 CLONCURRY	mtis97au_e0p4	97au	579601
SF54-03 JULIA CREEK	ariz95au_l3s4	95au	333566
SF54-03 JULIA CREEK	bell95au_l3s4	95au	146420
SF54-03 JULIA CREEK	clon97se_e0p4	97se	595592
SF54-03 JULIA CREEK	kynu97oc_e0p4	97oc	655654
SF54-04 RICHMOND	bell95au_l3s4	95au	357324
SF54-04 RICHMOND	hugh95ju_l3s4	95ju	534404
SF54-04 RICHMOND	kynu97oc_e0p4	97oc	633840
SF54-04 RICHMOND	oakv95ju_l3s5	95ju	207760

Notes...
(1) No image was prepared for SE54-02 (CAPE VAN DIEMEN).
The SE54-02 part of Mornington Island was included in
the image for SE54-01 (MORNINGTON).
(2) SLATS file naming conventions...
Two examples: gunp97au_e0p4, bell95au_l3s4

gunp	97au	_	e0
bell	95au	_	l3
Unique_Scene_ID	Scene_Date	Underscore	Scene_Processing_Stage

p4
s4
Scene_Coordinate_Information

Remarks: "97au" is preferable to "95au"; "l3s4" is preferable to "e0p4".

For complete definitions, consult the SLATS team,
Queensland Department of Natural Resources.

TABLE 3. SLATS SCENES USED
Like Table 2, the figures are only approximate.

ID	NAME	YYMM	HECTARES(AMG)
ariz	Arizona	95au	2580733
bell	Bellfield	95au	2626479
buli	Bulimba	97oc	2089955
burk	Burketown	97au	2647517
camo	Camooweal	97jy	1448102
clon	Cloncurry	97se	1269049
delt	Delta_Downs	97se	2465334
doom	Doomadgee	97jy	2054727
geor	Georgetown	95au	2639530
gunp	Gunpowder	97au	2628237
hugh	Hughenden	95ju	534404
kynu	Kynuna	97oc	1289494
morn	Mornington_Island	97jy	2626524
mtga	Mt_Garnet	94ju	166513
mtis	Mount_Isa	97au	1316486
norm	Normanton	97se	2617267
oakv	Oak_Valley	95ju	737099
uran	Urandangi	97jy	191276

Appendix 3.3 Northern Territory map units from Wilson *et al.* (1990).

(Note: The units presented here were taken directly from the database lookup tables accompanying the map of the Northern Territory (Wilson *et al.* 1990). Nomenclature has not been updated and scientific names have not been italicised)

VEG UNIT1	DESCRIPTION
N1	Mixed species closed-forest (Monsoon vine-thicket).
N10	E. tetrodonta (Stringybark) woodland with Plectrachne pungens (Curly Spinifex) open-grassland understorey.
N101	Seasonal grassland with Muehlenbeckia cunninghamii (Lignum) low sparse-shrubland overstorey.
N102	Coastal dune complex.
N103	Vetiveria elongata grassland.
N104	Xerochloa (Rice Grass) grassland.
N105	Mangal low closed-forest (Mangroves).
N106	Saline tidal flats with scattered chenopod low shrubland (Samphire).
N107	Chenopodium auricomum (Bluebush) low open-shrubland with ephemeral grassland understorey.
N11	E. miniata (Darwin Woolly Butt) woodland with grassland understorey.
N111	Halosarcia (Samphire) low open-shrubland fringing bare salt pans.
N113	Senna artemisioides subsp. helmsii +/- Senna artemesioides subsp. Oligophylla +/- Acacia georginae +/- Acacia spp.
N12	E. miniata (Darwin Woolly Butt), E. tetrodonta (Stringybark) woodland with Plectrachne pungens (Curly Spinifex) grassland understorey.
N13	E. tetrodonta (Stringybark), E. miniata (Darwin Woolly Butt), E. dichromophloia (Variable-barked bloodwood) woodland with Plechtrachne pungens (Curly Spinifex), Chrysogogon fallax (Golden Beard Grass) grassland understorey.
N14	E. tetrodonta (Stringybark), E. tectifica, (Northern Box) woodland with Sorghum grassland understorey.
N15	E. tectifica (Northern Box), E. latifolia (Round-leaved Bloodwood) woodland with Sorghum grassland understorey.
N16	E. tectifica (Northern Box), E. terminalis (Bloodwood) woodland with Sehima nervosum (White Grass), Chrysopogon fallax (Golden Beard Grass) grassla
N17	E. dichromophloia (Variable-barked Bloodwood), E. tetrodonta (Stringybark) woodland with grassland understorey.
N18	E. papuana, (Ghost Gum), E. polycarpa (Long-fruited Bloodwood) woodland with grassland understorey.
N19	E. terminalis (Bloodwood), E. patellaris (Weeping Box) woodland with grassland understorey.
N2	Allosyncarpia ternata (Anbinik) closed-forest.
N20	E. dichromophloia (Variable-barked Bloodwood) low woodland with Chrysopogon fallax (Golden Beard Grass), Plectrachne pungens (Curly Spinifex) grass
N21	E. tintinnans (Salmon Gum) low woodland with Sorghum grassland understorey.
N22	E. terminalis (Bloodwood), E. chlorophylla (Box) low woodland with Sehima nervosum (White Grass), Chrysopogon fallax (Golden Beard Grass) grassland
N23	E. pruinosa (Silver Box) low woodland with Eulalia aurea (Silky Browntop), Sehima nervosum (White Grass) grassland understorey.
N24	E. microtheca (Coolibah), Excoecaria parvifolia (Gutta-percha) low woodland with Chrysopogon fallax (Golden Beard Grass), Dichanthium (Bluegrass) grassland understorey.
N25	E. microtheca (Coolibah) low open-woodland with Eulalia aurea (Silky Browntop), Dichanthium (Bluegrass) grassland understorey.
N26	E. microtheca (Coolibah) low-open woodland with Eulalia aurea (Silky Browntop), Astrebla (Mitchell Grass) grassland understorey.
N27	E. microtheca (Coolibah) low open-woodland with open-grassland understorey.
N28	E. microtheca (Coolibah) low open-woodland with Chenopodium auricomum (Bluebush) sparse-shrubland understorey.
N29	E. phoenicea (Scarlet Gum) low woodland with Plectrachne pungens (Curly Spinifex) hummock grassland understorey.
N3	E. miniata (Darwin Woolly Butt), E. tetrodonta (Stringybark), E. nesophila (Melville Island Bloodwood) open-forest with Sorghum grassland understorey
N31	E. dichromophloia (Variable-barked Bloodwood), E. tetrodonta (Stringybark) low open-woodland with Plectrachne pungens (Curly Spinifex) open-hummock grassland understorey.
N32	E. dichromophloia (Variable-barked Bloodwood), E. miniata (Darwin Woolly Butt) low open-woodland with Plectrachne pungens (Curly Spinifex) open-hummock grassland understorey.
N33	E. dichromophloia (Variable-barked Bloodwood) low open-woodland with Plectrachne pungens (Curly Spinifex) open-hummock grassland understorey.
N34	E. dichromophloia (Variable-barked Bloodwood) low open-woodland with Triodia pungens (Soft Spinifex) hummock grassland understorey.
N35	E. leucophloia (Snappy Gum) low open-woodland with Plectrachne pungens (Curly Spinifex) hummock grassland understorey.
N36	E. leucophloia (Snappy Gum) low open-woodland with Triodia pungens (Soft Spinifex), Plectrachne pungens (Curly Spinifex) open-hummock grassland und
N37	E. brevifolia (Snappy Gum) low open-woodland with Plectrachne pungens (Curly Spinifex) hummock grassland understorey.
N38	E. brevifolia (Snappy Gum) low open-woodland with Triodia pungens (Soft Spinifex) hummock grassland understorey.
N39	E. pruinosa (Silver Box), Lysiphyllum cunninghamii (Bauhinia) low open-woodland with hummock/tussock grassland understorey.
N4	E. miniata (Darwin Woolly Butt), E. tetrodonta (Stringybark) open-forest with Sorghum grassland understorey.
N40	E. ferruginea (Rusty Bloodwood) low open-woodland or Jacksonia odontocarpa open-shrubland with Plectrachne pungens (Curly Spinifex) open-hummock grassland.

VEG UNIT1	DESCRIPTION
N41	E. opaca (Bloodwood) low open-woodland with Plectrachne pungens (Curly Spinifex) hummock grassland understorey.
N42	E. opaca (Bloodwood) low open-woodland with Triodia pungens (Soft Spinifex) hummock grassland understorey.
N44	Terminalia arostrata (Nutwood) low open-woodland with Chrysopogon fallax (Golden Beard Grass), Dichanthium (Bluegrass) grassland understorey.
N45	Lysiphyllum cunninghamii (Bauhinia), E. pruinosa (Silver Box) low open-woodland with Eulalia aurea (Silky Browntop), Sehima nervosum (White Grass)
N46	Lysiphyllum cunninghamii (Bauhinia), mixed species low open-woodland with Sehima nervosum (White Grass), Chrysopogon fallax (Golden Beard Grass) op
N47	Acacia open-shrubland with Sorghum grassland understorey.
N48	Livistona humilis (Fan Palm) tall open-shrubland with Sorghum grassland understorey.
N49	Melaleuca citrolens (Paperbark) low woodland with Chrysopogon fallax (Golden Beard Grass) open-grassland understorey
N5	E. miniata (Darwin Woolly Butt), E. nesophila (Melville Island Bloodwood), Callitris intratropica (Cypress Pine) open-forest with open-shrubland understorey.
N50	Melaleuca minutifolia (Paperbark) low woodland with Sorghum grassland understorey.
N51	Melaleuca viridiflora (Broad Leaved Paperbark), Eucalyptus low open-woodland with Chrysopogon fallax (Goldern Beard Grass) grassland understorey.
N53	Melaleuca forest (Paperbark Swamp)
N54	Mixed closed-grassland/sedgeland (Seasonal Floodplain).
N55	A. shirleyi (Lancewood) open-forest with open-grassland understorey.
N56	Complex of A. shirleyi (Lancewood) low-woodland mixed with Eucalyptus low open-woodland.
N57	Macropteranthes kekwickii (Bullwaddy) tall shrubland with open-grassland understorey.
N6	E. tetrodonta (Stringybark), Callitris intratropica (Cypress Pine) woodland with Plectrachne pungens (Curly Spinifex) open-grassland understorey.
N62	A. georginae (Giddier) low open-woodland with Astrebla pectinata (Bull Mitchell Grass) open-grassland understorey.
N63	A. georginae (Gidyea) low open-woodland with open-grassland understorey.
N7	E. tetrodonta (Stringybark), Callitris intratropica (Cypress Pine) woodland with grassland understorey.
N70	A. aneura (Mulga) tall sparse-shrubland with Cassia, Eremophila (Fuchsia) low sparse-shrubland understorey.
N71	A. aneura (Mulga) tall sparse-shrubland with grassland understorey.
N76	Triodia pungens (Soft Spinifex), Plectrachne schinzii (Curly Spinifex) hummock grassland with Acacia tall sparse-shrubland overstorey.
N76A	Triodia pungens (Soft spinifex) open-hummock grassland with Acacia tall sparse-shrubland overstorey.
N77	Triodia pungens (Soft Spinifex), Plectrachne schinzii (Curly Spinifex), hummock grassland with Acacia tall sparse-shrubland overstorey between dune
N8	E. tetrodonta (Stringybark), E. miniata (Darwin Woolly Butt), E. ferruginea (Rusty Bloodwood) woodland with Sorghum grassland understorey.
N88	Triodia (Spinifex) hummock grassland.
N9	E. tetrodonta (Stringybark), E. miniata (Darwin Woolly Butt), E. bleeseri (Smooth-stemmed Bloodwood) woodland with Sorghum grassland understorey.
N91	Triodia wiseana (Limestone Spinifex) hummock grassland with Terminalia arostrata (Nutwood) low open-woodland overstorey.
N96	Astrebla pectinata (Barley Mitchell grass) grassland.
N97	Astrebla (Mitchell Grass), mixed species grassland with scattered trees and shrubs
N98	Chrysopogon fallax (Golden Beard Grass), Dichanthium fecundum (Bluegrass) grassland.
N99	Enneapogon purpurascens (Nine Awn Grass) grassland.

Appendix 3.4 Queensland map units (Qcodes).

(Note: The units presented here were taken directly from the database lookup table used by the authors to develop a 1:1 000 000 scale map of the vegetation of north Queensland. Scientific names have not been italicised)

VEGUNIT	DESCRIPTION
Q1	Mangrove species closed forest to low closed forest
Q10	Melaleuca spp. + Lophostemon suaveolens + Dillenia alata open forest
Q100	Eucalyptus camaldulensis and/or E. microtheca +/- Melaleuca argentea +/- M. leucadendra +/- Corymbia spp. +/- Acacia spp. +/- Eucalyptus spp.+/- Lysiphyllum spp. +/- Excoecaria parvifolia woodland to open woodland along river channels and levees
Q101	Acacia cambagei and/or A. tephrina +/- Acacia spp. +/- Cassia spp. & sparse understorey of tussock grasses (e.g. Sporobolus actinocladus) or Triodia spp.
Q102	Ephemeral lakes with Eucalyptus microtheca +/- E. camaldulensis (or claypans with sparse herblands) and/or open succulent shrubland
Q102A	Ephemeral saline lake
Q103	Acacia peuce low open woodland and/or sparse ground layer of Atriplex and Sclerolaena spp. +/- Astrebla spp. +/- short grasses +/- scattered trees & shrubs.
Q104	Dichanthium spp., Eulalia aurea +/- Astrebla spp. +/- Aristida latifolia tussock grassland, sometimes sparsely wooded with low trees of Eucalyptus microtheca
Q105	Acacia aneura low woodland to tall open shrubland and/or Archidendropsis basaltica +/- Corymbia spp. +/- Acacia spp. +/- Eremophila latrobei
Q106	Atalaya hemiglauca +/- Grevillea striata +/- Lysiphyllum spp. +/- Ventilago viminalis +/- Acacia spp. +/- Eucalyptus spp. +/- Corymbia spp. sparse low open woodland with sparse understorey of Aristida and Enneapogon spp. OR Aristida spp. open tussock grassland wooded with low trees or shrubs of Atalaya hemiglauca +/- Grevillea striata +/- Lysiphyllum spp. +/- Ventilago viminalis +/- Acacia spp. +/- Eucalyptus spp. +/- Corymbia spp.
Q107	Eucalyptus leucophylla +/- Corymbia terminalis +/- C. appareriinja +/- Eucalyptus leucophloia +/- Acacia cambagei +/- Atalaya hemiglauca +/- Grevillea striata low open woodland with understorey of bare soil and sparse tussock grasses or Triodia spp.
Q108	Corymbia terminalis +/- Acacia spp.+/- Atalaya hemiglauca +/- Eucalyptus spp. low open woodland with understorey of Triodia pungens +/- tussock grasses OR Triodia pungens hummock grassland +/- tussock grasses wooded with scattered low trees of Corymbia terminalis +/- Acacia spp. +/- Atalaya hemiglauca +/- Eucalyptus spp.
Q108A	Corymbia dallachiana and/or C. tessellaris and/or C. terminalis +/- C. plena open woodland with tussock grass understorey sometimes dominated by Aristida ingrata
Q109	Acacia chisolmii +/- A. dictyophleba shrubland +/- low trees of Eucalyptus leucophloia, Corymbia terminalis, and E. pruinosa
Q11	Melaleuca citrolens and/or M. saligna and/or Thryptomene oligandra +/- Melaleuca viridiflora low open woodland to tall shrubland
Q110	Acacia shirleyi low woodland to low open woodland with sparse understorey of short grasses and/or Trioda spp.
Q111	Eucalyptus persistens or E. thozetiana or E. normantonensis +/- Eucalyptus spp. +/- Corymbia spp. open woodland to low open woodland, sometimes with a shrubby layer and with sparse hummock grass understorey of Triodia spp., often with bare soil
Q111s	Acacia shirleyi and/or Acacia catenulata open-forest
Q112	Acacia georginae tall open shrubland to low open woodland +/- Cassia spp. +/- Eucalyptus microtheca +/- Eucalyptus spp. +/- Eremophila spp. +/- Lysiphyllum spp. with understorey of Astrebla pectinata and/or Eragrostis spp. and/or Sporobolus actinocladus
Q113	Senna artemisioides subsp. helmsii +/- Senna artemisioides subsp. oligophylla +/- Acacia georginae +/- Acacia spp. +/- Eremophila spp. shrubland
Q114	Astrebla lappacea +/- Astrebla spp. +/- Aristida latifolia +/- Eulalia aurea +/- Dichanthium spp. +/- Panicum decompositum +/- Iseilema spp. closed tussock grassand to tussock grassland
Q115	Fluctuating climax of Astrebla pectinata, Aristida spp. +/- short grass tossock grassland to open tussock grassland and a seasonally dependent community of Atriplex spp., Sclerolaena spp., and species of Family Asteraceae
Q116	Astrebla spp. closed tussock grassland to tussock grassland sparsely wooded with low trees of Acacia cambagei and/or A. tephrina and/or Atalaya hemiglauca and/or A. sutherlandii and/or A. victoriae
Q117	Eucalyptus leucophloia low open woodland with hummock grass understorey of Triodia molesta and/or Triodia spp. OR Triodia molesta and/or other Triodia spp. hummock grassland sparsely wooded with low trees of Eucalyptus leucophloia +/- Corymbia capricornia +/- Acacia spp.
Q117A	Eucalyptus leucophloia low open woodland with hummock grass understorey of Triodia bitextura

VEGUNIT	DESCRIPTION
Q118	Triodia longiceps +/- Triodia spp. hummock grassland sparsely wooded with low trees of Eucalyptus leucophylla +/- E. leucophloia +/- Corymbia terminalis +/- Acacia spp.
Q12	Melaleuca spp. +/- Lophostemon suaveolens +/- Asteromyrtus symphyocarpa open forest to woodland
Q13	Melaleuca viridiflora + Petalostigma spp low woodland to open woodland +/- emergent Corymbia clarksoniana
Q14	Lakes and lagoons +/- fringing woodlands
Q15	Closed tussock grassland/closed sedgeland +/- emergent Pandanus spp
Q16	Sorghum and/or Fimbristylis spp. and/or Themeda arguens +/- Sporobolus virginicus closed tussock grassland +/- emergent Corypha utan
Q17	Baloskion tetraphyllum subsp. meiostachyum + Dapsilanthus spathaceus + Nepenthes mirabilis + Gahnia sieberiana closed sedge grassland to open sedge grassland
Q18	Imperata cylindrica + Mnesithea rottboellioides + Arundinella setosa closed tussock grassland
Q19	Asteromyrtus lysicephala + Thryptomene oligandra +/- Neofabricia myrtifolia +/- Jacksonia thesioides open herbland +/- emergent Melaleuca arcana
Q2	Sporobolus virginicus closed tussock grassland
Q20	Deciduous or semi-deciduous vine thicket species low closed forest to closed shrubland +/- emergent Lagerstroemia archeriana +/- emergent Melaleuca spp
Q200	Acacia spp. or Lawrencia buchanansis or Alectryon oleifolius or Callistemon viminalis low open woodland to shrubland with tussock grass understorey of Eragrostis speciosa and Sporobolus spp. and Leptochloa fusca OR tussock grassland of Eragrostis speciosa and Sporobolus spp. and Leptochloa fusca wooded with low trees of Acacia spp. or Lawrencia buchanansis or Alectryon oleifolius or Callistemon viminalis
Q201	Acacia agyrodendron open woodland with sparse tussock grass understorey.
Q201A	Acacia argyrodendron open woodland to woodland with sparse tussock grass understorey
Q202	Acacia harpophylla +/- Eucalyptus cambageana +/-softwood scrub spp. open forest to low woodland with sparse tussock grass understorey
Q202A	Acacia harpophylla and/or A. cambagei +/- Eucalyptus cambageana +/- softwood scrub low woodland to open forest with sparse grassy understorey
Q203	Mosaic of Acacia harpophylla (groved) or A. cambagei (groved) +/- A. agyrodendron woodland to low open woodland with sparse tussock grass understorey.
Q203A	Eucalyptus thozetiana or softwood species low open woodland to woodland with sparse hummock grass or tussock grass understorey
Q204	Eucalyptus melanophloia or Eucalyptus sp. (Mt.Hope Homestead Eucalyptus J. Thompson+ BUC175) +/- Corymbia peltata open woodland to low open woodland with Triodia pumgens and/or sparse tussock grass understorey.
Q204A	Eucalyptus melanophloia open woodland with grassy understorey
Q205	Corymbia leichhardtii or Eucalyptus similis or C. lamprophylla and/or C. peltata and/or E. chartaboma +/- Corymbia. spp. +/- Eucalyptus spp woodland to open woodland +/- shrub layer of Acacia spp. with sparse understorey of Triodia spp. or tussock grasses.
Q205s	Corymbia leichhardtii or Corymbia trachyphloia open-woodland
Q206	Corymbia setosa and/or Eucalyptus similis +/- E. chartaboma +/- E. ammophila +/- Lysicarpus angustifolius +/- Corymbia spp. open woodland to low open woodland +/- shrub layer of Grevillea pteridifolia, Melaleuca nervosa, Acacia spp. and sparse hummock grass understorey of Triodia pungens.
Q207	Eucalyptus crebra or E. xanthoclada or E. exilipes or E. quadricostata +/- Corymbia erythrophloia +/- Corymbia spp. open woodland to low open woodland +/- shrub layer of Acacia spp., softwood spp. and sparse understorey of Triodia spp. or tussock grasses.
Q207A	Eucalyptus crebra or E. xanthoclada +/- Brachychiton populneus open woodland with sparse tussock grass understorey
Q207B	Eucalyptus crebra or E. xanthoclada +/- E. exserta +/- Corymbia erythrophloia open woodland with sparse tussock grass understorey +/- Triodia mitchellii
Q208	Eucalyptus tetrodonta and/or E. miniata open woodland with sparse understorey of Triodia pungens and/or tussock grasses.
Q209	Eucalyptus whitei woodland to open woodland with sparse understorey of Triodia pungens.
Q209B	Eucalyptus whitei woodland to open woodland with understorey of tussock grasses
Q21	Eucalyptus microtheca or E. acroleuca and/or Acacia ditricha woodland to low open woodland
Q210	Eucalyptus brownii or E. populnea or E. melanophloia +/- Callitris glaucophylla woodland to open woodland with understorey of tussock grasses.
Q210A	Eucalyptus populnea or E. brownii open woodland with tussock grass understorey

VEGUNIT	DESCRIPTION
Q211	Eucalyptus populnea or E. melanophloia +/- Callitris glaucophylla +/- Casuarina cristata +/- Acacia harpophylla woodland to open woodland with understorey of tussock grasses and/or Triodia pungens.
Q212	Eucalyptus cambageana woodland to open woodland +/- shrub layer of Acacia harpophylla or A. agyrodendron and a sparse understorey of tussock grasses.
Q213	Eucalyptus orgadophila open woodland with understorey of tussock grasses
Q214	Eucalyptus cloeziana or E. decorticans open woodland with sparse understorey of Triodia mitchellii or tussock grasses.
Q215	Eucalyptus shirleyi +/- Corymbia peltata +/- Melaleuca nervosa low open woodland with sparse understorey of tussock grasses
Q216	Low woodland to low open woodland of semi-evergreen vine thicket spp. or microphyll vine forest spp.
Q216A	Microphyll vine thicket species low open woodland to low woodland
Q217	Dichanthium or Bothriochloa spp. or Themeda triandra or Ophiuros exaltatus +/- Panicum spp. +/- Astrebla spp. +/- Eulalia aurea tussock grassland to open tussock grassland sometimes wooded with Acacia farnesiana* +/- Eucalyptus tereticornis +/- E. coolabah +/- E. leptophleba
Q218	Casuarina cristata woodland with sparse understorey tussock grasses
Q219	Callitris glaucophylla and/or Angophora leiocarpa +/- Corymbia plena open woodland with very sparse understorey of tussock grasses.
Q22	Eucalyptus chlorophylla +/- Corymbia clarksoniana +/- Terminalia platyptera woodland to low open woodland +/- subcanopy of Melaleuca spp
Q220	Archidendropsis basaltica low open woodland in groves with understorey of tussock grasses
Q221	Melaleuca nervosa forma nervosa low woodland to low open woodland with sparse understorey of Triodia pungens or tussock grasses.
Q222	Melaleuca tamariscina and/or M. uncinata and/or Acacia leptostachya and/or Thryptomene parviflora +/- Acacia acradenia +/- Acacia spp. low open woodland to open shrubland with sparse understorey of Triodia pungens or T. mitchellii
Q222A	Micromyrtus capricornia +/- Acacia spp. +/- Calytrix tetragona shrubland +/- emergent Eucalyptus spp.
Q222B	Shrubland of Acacia aprepta with sparse grassy understorey and frequent rock outcropping.
Q222C	Acacia leptostachya shrubland
Q222D	Montane heath
Q222E	vine thickets with Cochlospermum gillivraei and Lophostemon grandiflorus
Q23	Corymbia clarksoniana/polycarpa +/- Eucalyptus leptophleba +/- Erythrophleum chlorostachys +/- Eucalyptus spp. +/- Melaleuca spp. woodland to open woodland
Q24	Eucalyptus leptophleba +/- Corymbia polycarpa/clarksoniana +/- C. tessellaris +/- E. acroleuca +/- C. dallachiana open forest to woodland
Q25	Corymbia tessellaris and/or C. clarksoniana and/or Eucalyptus tetrodonta +/- C. novoguinensis open forest to woodland
Q26	Eucalyptus platyphylla +/- Corymbia clarksoniana open forest to woodland
Q26A	Eucalyptus platyphylla, Corymbia dallachiana, C.tessellaris, E. drepanophylla/crebra woodland
Q27	Eucalyptus tetrodonta + Erythropyhleum chlorostachys +/- Corymbia hylandii subsp. peninsularis +/- C. nesophila tall woodland
Q28	Eucalyptus tetrodonta + Corymbia nesophila + C. clarksoniana +/- Erythrophleum chlorostachys woodland +/- shrub layer
Q29	Eucalyptus tetrodonta and/or Corymbia nesophila +/- Erythrophleum chlorostachys +/- C. clarksoniana +/- E. leptophleba +/- C. confertiflora woodland
Q3	Bare saline tidal flats +/- Chenopod short herbland
Q30	Semi-deciduous notophyll vine forest
Q300	Eucalyptus chartaboma and/or E. crebra (sens. lat.) and/or Corymbia erythrophloia +/- E. tetrodonta +/- C. dallachiana and/or C. clarksoniana woodland to open woodland +/- shrub layer of Petalostigma banksii, Terminalia aridicola, Erythrophleum chlorostachys and understorey of sparse tussock grasses
Q301	Eucalytpus microneura and/or E. persistens +/- E. leptophleba +/- E. crebra (sensu lato) +/- E. cullenii +/- Corymbia confertiflora +/- C. dallachiana woodland +/- shrub layer of Eremophila mitchellii, Carissa lanceolata, Terminalia sp., Gardenia vilhelmii, Melaleuca citrolens/acacioides and a sparse tussock grass understorey.
Q302	Eucalyptus tereticornis and/or Corymbia intermedia and/or C. tessellaris and/or Lophostemon suaveolens +/- Allocasuarina torulosa +/- E. granitica tall open forest to woodland +/- shrub layer of Lophostemon suaveolens, Acacia flavescens and Allocasuarina torulosa, with an understorey of tussock grasses +/- Lomandra sp.

VEGUNIT	DESCRIPTION
Q303	Waterholes, lakes, lagoons, swamps +/- Eucalyptus camaldulensis +/- E. microtheca +/- E. moluccana fringing woodland
Q304	Eucalyptus microneura +/- E. persistens +/- E. crebra (sens. lat.) or E. cullenii woodland to low open woodland +/- patchy shrub layer of Petalostigma pubescens +/- Carissa lanceolata +/- Atalaya hemiglauca +/- Melaleuca acacioides/citrolens +/- Gardenia vilhelmii with understorey of tussock grasses
Q305	Eucalyptus crebra (sensu lato) or E. cullenii or E. setosa +/- Corymbia clarksoniana +/- Callitris intratropica +/- Corymbia erythrophloia +/- C. dallachiana +/- C. confertiflora +/- C. portuensis open forest to low woodland +/- shrub layer of Acacia spp. +/- Petalostigma pubescens +/- Alphitonia excelsa +/- Melaleuca spp. with understorey of Heteropogon contortus +/- mixed species tussock grasses
Q305A	Eucalyptus crebra and/or E. tenuipes, Corymbia clarksoniana and C. dallachiana +/- Eucalyptus spp. woodland +/- shrub layer with tussock grass understorey
Q306	Corymbia citriodora and/or Eucalyptus crebra (sensu lato) and/or C. clarksoniana +/- E. tereticornis +/- E. portuensis +/- E. moluccana open forest to open woodland +/- shrub layer of Acacia spp. and/or Melaleuca nervosa and/or Grevillea parallela and/or Lophostemon suaveolens with understorey of tussock grasses
Q306A	Eucalyptus moluccana woodland to open forest +/- shrub layer of Acacia rhodoxylon, Melaleuca viridiflora and grassy understorey of Heteropogon contortus
Q307	Eucalyptus crebra (sensu lato) or E. cullenii +/- Acacia rhodoxylon +/- Corymbia erythrophloia +/- C. dallachiana +/- C. clarksoniana +/- E. tereticornis +/- open shrub layer of Grevillea mimosoides and G. glauca, and softwood species, with dense understorey of tussock grasses dominated by Heteropogon contortus
Q307A	Eucalyptus crebra or E. tholiformis open woodland +/- shrub layers of Acacia spp. and sparse understorey of Triodia mitchellii
Q307B	Eucalyptus crebra and/or E. melanophloia +/- E. populnea +/- Corymbia spp. woodland to open forest with sparse shrub layer
Q308	Vine thickets with species including Strychnos lucida, Antidesma parvifolium, Canarium australianum, Diospyros humilis and patches of Eucalyptus tereticornis and Lophostemon suaveolens low closed forest to low woodland, with a distinct shrub layer and a bare to sparse understorey +/- forbs +/- tussock grasses
Q309	Excoecaria parvifolia tall shrubland to low woodland with sparse understorey of tussock grasses
Q31	Eucalyptus phoenicia + E. tetrodonta + Corymbia hylandii subsp. peninsularis +/- Erythrophleum chlorostachys +/- C. clarksoniana woodland
Q310	Dichanthium and/or Iseilema spp. closed tussock grassland wooded with low trees of Corymbia dallachiana and/or C. terminalis and/or Eucalyptus orgadophila
Q311	Eucalyptus microneura and/or E. leptophleba and/or E. crebra (sens. lat.) +/- Corymbia confertiflora +/- C. dallachiana woodland +/- shrub layer of Eremophila mitchellii, Carissa lanceolata and understorey of tussock grasses OR tussock grassland sparsely wooded with low trees of Eucalyptus microneura and/or E. leptophleba and/or E. crebra (sens. lat.) +/- Corymbia confertiflora +/- C. dallachiana
Q312	Cochlospermum gillivraei, Erythrophleum chlorostachys, Terminalia aridicola +/- Acacia leptostachya +/- Corymbia spp. deciduous low open woodland and a sparse shrub layer of Petalostigma and Acacia spp. with an understorey of sparse tussock grasses
Q313	Vine thickets
Q314	Eucalyptus crebra (sens. lat.) and/or E. microneura +/- E. leptophleba +/- Corymbia spp. woodland to low open woodland +/- clumped shrub layer of Erythrophleum chlorostachys, Petalostigma pubescens and Eremophila mitchellii, and understorey of tussock grasses
Q315	Eucalyptus melanophloia and/or E. shirleyi and/or E. similis +/- Corymbia peltata low open woodland with patchy shrub layer of Petalostigma banksii, Gardenia vilhelmii, Terminalia aridicola subsp. chillagoensis, Callitris intratropica and sparse understorey of tussock grasses
Q316	Eucalyptus crebra (sens. lat.), Corymbia citriodora +/- C. clarksoniana +/- E. portuensis +/- E. cloeziana +/- Eucalyptus spp. +/- softwood species +/- Corymbia spp. open forest to woodland with mixed shrubs of Acacia flavescens, Grevillea glauca, Petalostigma pubescens, Bursaria incana and tussock grass understorey
Q317	Macroptheranthes sp. and Corymbia dallachiana low open woodland
Q318	Complex notophyll vine forest including Toona ciliata, and Melia azedarach
Q319	Eucalyptus cullenii +/- Corymbia erythrophloia +/- C. citriodora +/- C. confertiflora +/- Erythrophleum chlorostachys +/- Terminalia platyptera woodland to open woodland with understorey of Themeda triandra
Q32	Melaleuca viridiflora +/- Melaleuca stenostachya +/- Asteromyrtus spp. +/- Neofabricia myrtifolia woodland to low open woodland
Q320	Eucalyptus persistens and/or E. shirleyi +/- Corymbia setosa +/- E. tetrodonta open woodland to shrubland with shrub layer of Melaleuca acacioides/citrolens, Gardenia vilhelmii, Acacia shirleyi, Petalostigma banksii and sparse understorey of tussock grasses
Q321	Eucalyptus leptophleba, Corymbia clarksoniana, E. cullenii or E. granitica +/- Eucalyptus tereticornis with distinct shrub layer and understorey of tussock grasses
Q322	Eucalyptus drepanophylla +/- Eucalyptus spp. +/- Corymbia spp woodland to open woodland with vine thicket species shrub layer

VEGUNIT	DESCRIPTION
Q323	Eucalyptus drepanophylla +/- Eucalyptus spp. +/- Corymbia spp woodland +/- shrub layer of Acacia, Melaleuca and Grevillea spp.
Q324	Eucalyptus drepanophylla +/- vine thicket spp. woodland
Q325	Woodland with Eucalyptus portuensis +/- E. drepanophylla, +/- E. platyphylla. Midstratum with Petalostigma pubescens, Acacia flavescens +/- Xylomelum scottianum
Q32B	Melaleuca viridiflora woodland +/- emergent Eucalyptus platyphylla, Corymbia clarksoniana, C. dallachiana with tussock grass understorey of Bothriochloa pertusa and Eremochloa spp.
Q33	Acacia shirleyi open forest
Q34	Eucalyptus spp. +/- Melaleuca stenostachya +/- Corymbia hylandii var. hylandii +/- Corymbia spp. +/- Acacia leptostachya woodland to low open woodland +/- shrub layer
Q35	Vine forest
Q35A	Asteromyrtus lysicephala and/or Neofabricia myrtifolia +/- Acacia calyculata +/- Jacksonia thesioides +/- Choriceras tricorne and/or Schizachyrium spp tall open shrubland to open herbland
Q36	Eucalyptus leptophleba and/or Corymbia erythrophloia +/- C. dallachiana +/- C. clarksoniana +/- E. cullenii woodland to open woodland
Q37	Eucalyptus leptophleba + Corymbia papuana + C. clarksoniana open woodland
Q38	Heteropogn triticeus, Themeda arguens, Sorghum plumosum closed tussock grassland +/- open woodland to tall open shrubland of Terminalia aridicola subsp. chillagoensis + T. platyphylla and/or Piliostigma malabaricum
Q39	Simple evergreen notophyll vine forest +/- emergent Eucalyptus pellita +/- emergent Callitris intratropica
Q39A	Deciduous vine thicket +/- emergent Gyrocarpus americanus +/- emergent Bombax ceiba
Q3A	Melaleuca acacioides or Melaleuca saligna +/- Hakea pedunculata +/- Melaleuca spp open forest to tall shrubland
Q4	Syzygium spp. +/- Acacia crassicarpa +/- Terminalia spp. +/- Manilkara kauki closed vine forest +/- Araucaria cunninghamii emergents
Q40	Eucalyptus tetrodonta + Corymbia nesophila +/- C. hylandii var. hylandii +/- Eucalyptus cullenii (or E. crebra) +/- Asteromyrtus brassii woodland to open woodland +/- heath understorey
Q400	Eucalyptus fibrosa subsp. (Glen Geddes) and Corymbia xanthope woodland
Q41	Allocasuarina littoralis and/or Asteromyrtus brassii +/- Neofabricia myrtifolia +/- Lophostemon suaveolens +/- Callitris intratropica low open forest to low woodland
Q42	Eucalyptus tetrodonta +/- Corymbia hylandii var. hylandii and/or E. similis +/- Erythrophleum chlorostachys +/- Eucalyptus cullenii (Sandstone plateaux)
Q43	Vine forest +/- Agathis robusta +/- emergent Acacia aulacocarpa +/- emergent Eucalyptus tereticornis
Q44	Corymbia intermedia +/- Eucalyptus crebra +/- C. nesophila +/- E. cloeziana +/- E. portuensis +/- E. pellita +/- E. reducta +/- E. portuensis open forest to woodland
Q45	Eucalyptus platyphylla and/or E. leptophleba +/- Erythrophleum chlorostachys +/- Eucalyptus cullenii +/- Corymbia clarksoniana open forest to woodland
Q46	Eucalyptus cullenii or E. crebra +/- Eucalyptus spp. +/- Corymbia spp. +/- Melaleuca stenostachya woodland to open woodland
Q47	Eucalyptus persistens subsp. tardecidens + Melaleuca stenostachya low woodland
Q48	Notophyll vine forest or microphyll vine fern thicket +/- emergent Araucaria cunninghamii +/- emergent Palms
Q49	Deciduous vine thicket dominated by Cochlospermum gillivraei +/- Canarium australianum +/- Acacia aulacocarpa +/- Wodyetia bifurcata
Q5	Coastal dune complex (Northern Territory)
Q50	Lophostemon suaveolens and/or Corymbia clarksoniana and/or Welchiodendron longivalve +/- Eucalyptus spp. +/- Corymbia spp. +/- Allocasuarina littoralis open forest to low open forest +/- rainforest species
Q500	Corymbia polycarpa and/or C.grandifolia and/or Eucalyptus tectifica +/- Terminalia canescens, +/- E.pruinosa, +/- C.ferruginea, +/- Erythrophleum chlorostachys, +/- C.confertiflora, +/- E.chlorophylla low woodland to low open woodland with a shrub layer of Melaleuca citrolens, M.viridiflora, Petalostigma and Acacia spp., and a ground layer of Triodia sp. and tussock grasses
Q501	Corymbia polycarpa +/- C. grandifolia +/- Eucalyptus microtheca or C. polycarpa, E. miniata +/- E. microneura +/_ E. tetrodonta; +/- Erythrophleum chlorostachys +/- Terminalia spp. +/- Eucalyptus spp. +/- Corymbia spp. +/- shrubs of Melaleuca and Acacia spp woodland to low woodland with sparse understorey of Chrysopogon, Aristida, Schizachyrium and Eriachne spp.
Q502	Eucalyptus chlorophylla and/or E. tectifica +/- Lysiphyllum cunninghamii +/- Corymbia spp. OR E. tectifica +/- E.chlorophylla, E.leucophloia with Corymbia grandifolia, C.bella (on sand ridges), woodland to low open woodland +/- shrub layer of Melaleuca, Acacia and/or Terminalia spp., and an understorey of Heteropogon contortus, Chrysopogon spp. and Sehima nervosum.

VEGUNIT	DESCRIPTION
Q503	Eucalyptus pruinosa +/- Eucalyptus spp. +/- Corymbia spp. low woodland to low open woodland +/- sparse shrubs of Acacia chisholmii or Melaleuca spp. or Atalaya hemiglauca and understorey of hard tussock grasses +/- Triodia spp.
Q504	Melaleuca viridiflora +/- E. tetrodonta +/- Erythrophleum chlorostachys +/- Corymbia spp. OR E. tetrodonta, C. ferruginea, E. chlorostachys open forest to woodland, low open woodland or tall open shrubland with sparse understorey of Triodia bitextura
Q505	Lysiphyllum sp. +/- Grevillea striata +/- Atalaya hemiglauca +/- Corymbia spp. +/- Eucalptus pruinosa woodland to low woodland often with emergent C. polycarpa and sparse understorey of Aristida ingrata, Aristida spp., and Heteropogon contortus on sandy plains
Q506	Melaleuca citrolens +/- M. acacioides +/- Melaleuca spp. OR Melaleuca acaciodes/citrolens, M. nervosa, M. viridiflora +/- Terminalia platyptera +/- Lysiphyllum sp., low woodland to low open woodland +/- Grevillea spp. +/- Petalostigma banksii mixed shrub layer and an understorey of Aristida spp. and Chrysopogon fallax
Q508	Melaleuca viridiflora and Melaleuca spp. +/- Eucalyptus persistens +/- Terminalia spp. +/- emergent Corymbia polycarpa OR Melaleuca viridiflora +/- E. persistens +/- C. clarksoniana +/- Erythrophleum chlorostachys, low woodland to low open woodland +/- shrub layer of Petalostigma banksii with a sparse understorey of tussock grasses
Q509	Eucalyptus leucophylla +/- E. pruinosa +/- Corymbia terminalis low woodland to low open woodland +/- shrub layer of Acacia and Senna spp. with understorey of Triodia spp. +/- tussock grasses
Q51	Rock pavements and/or granite boulders +/- scattered trees and shrubs +/- Blue green algae
Q510	Terminalia and Lysiphyllum spp., +/- Dendrolobium umbellatum +/- E. chlorophylla +/- Atalaya hemiglauca patchy deciduous low open woodland, sometimes treeless, with understorey of Heteropogon triticeus and H. contortus, Themeda triandra, Dichanthium spp. and Sorghum plumosum
Q511	Corymbia capricornia, Eucalyptus miniata +/- C. aspera +/- E. tetrodonta +/- Terminalia aridicola woodland to low open woodland +/- shrub layer of Calytrix brownii, Gardenia pyriformis, Acacia spp.with an understorey of Triodia spp. +/- tussock grasses
Q512	Eucalyptus cullenii/granitica +/- C. erythrophloia +/- C. confertiflora +/- Terminalia spp. woodland to open woodland with scattered shrubs of Melaleuca viridiflora, Callitris intratropica and a grassy understorey
Q52	Eucalyptus tetrodonta and/or Melaleuca spp. +/- Corymbia hylandii +/- C. nesophila +/- E. brassiana woodland
Q6	Leucopogon spp. and/or Asteromyrtus spp. and/or Acacia humifusa +/- Neofabricia myrtifolia closed shrubland to open herbland
Q7	Melaleuca spp. open forest to low open forest +/- sedgeland
Q8	Corymbia clarksoniana or C. nesophila and/or Eucalyptus tetrodonta +/- C. novoguinensis +/- E. phoenicea open forest to woodland
Q9	Semi-deciduous or evergreen vine forest +/- Melaleuca leucadendra +/- Lophostemon suaveolens +/- Archontophoenix alexandrae

Appendix 3.5 Western Australian (Kimberley) vegetation units adapted by Hopkins *et al*. (1999) from Beard and Webb (1974) and Beard (1979).

(Note: The units presented here were taken directly from the database lookup table attached to the newly digitised version of the Kimberley vegetation map (Beard and Webb 1974, Beard 1979). Nomenclature has not been updated and scientific names have not been italicised. Beard_code is the original physiognomic code used by J.S. Beard to describe the vegetation. Refer to Beard (1979) for the key to the classification.)

VEGUNIT	**BEARD_CODE** (Beard 1979, Beard and Webb 1974)	**DESCRIPTION**
W101	a5Sr t1Hi	Acacia pachycarpa open shrubland with Triodia pungens hummock grass understorey
W104	g;hSrt1Hi	Grevillea spp.; Hakea suberea open shrubland with Triodia pungens tussock grass understorey
W1121	e17Lr xHGi	Eucalyptus gymnoteles low open woodland with hummock grass and tussock grass mixed species understorey
W116	xLb t3Hr	Triodia wiseana sparse hummock grassland sparsely wooded with Adansonia gregorii and other mixed species low trees on limestone.
W117	t1Hi	Triodia epactia (coastal) or Triodia pungens (inland) hummock grassland
W12	e48;49Mi	Eucalyptus tetrodonta; Eucalyptus miniata woodland
W125	n/a	waterbodies
W126	n/a	Lake Argyle
W127	n/a	mudflats
W1271	salt	Saltpans
W133	xHGi	Mixed species grassland of hummock grasses and tussock grasses
W134	e23Lr pHi/anSr tpHi	Eucalyptus chippendalei low open woodland with Plectrachne spp. hummock grass understorey
W151	eLr xGc	Eucalyptus spp. low open woodland with mixed species tussock grass understorey
W1520	e24;48Mc ps2Gc/e50;62Li ps2Gc	Eucalyptus dichromophloia; Eucalyptus tetrodonta woodland with Plectrachne sp.; Sorghum spp; grassy understorey
W155	eLr t/pHi	Eucalyptus spp. low open woodland with Triodia spp.; Plectrachne spp. hummock grass understorey
W157	t3Hi	Triodia wiseana hummock grassland
W175	xGc	Mixed species tussock grassland
W1765	e24;53Lra28;29Sc.ct11Gi/eL1	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia eriopoda; Acacia tumida shrub layer and a Chrysopogon spp.; Triodia bitextura grass layer
W1893	e17Li xGc	Eucalyptus gymnoteles low woodland with mixed species tussock grass understorey
W217	cMi t1Hi	Casuarina decaisneana woodland with Triodia pungens hummock grass understorey
W2175	xGc	Mixed species tussock grassland
W218	h1anSr t1Hi	Hakea spp.; Acacia spp. open shrubland with Triodia pungens hummock grass understorey
W2736	e16;58Lr p3Gc	Eucalyptus brevifolia and Eucalyptus perfoliata low open woodland with Triodia bitextura grassy understorey
W32	xLr a Sc t tpHi	Mixed species low open woodland with Acacia spp. open scrub and Triodia spp. and Plectrachne spp. hummock grass understorey
W37	mSc	Melaleuca spp. shrubland
W41	mSi	Melaleuca spp. open shrubland
W43	mangrove	Mangrove species low closed forest to tall open shrubland
W52	e24;48Mi ps2Gc	Eucalyptus dichromophloia; Eucalyptus tetrodonta; Eucalyptus miniata woodland with Plectrachne spp. and Sorghum spp. tussock grass understorey
W53	e48;49Mi ps2Gc	Eucalyptus tetrodonta; Eucalyptus miniata woodland with Plectrachne spp.; Sorghum spp. tussock grass understorey
W565	e24Lr t1Hi	Eucalyptus dichromophloia low open woodland with Triodia pungens hummock grass understorey

VEGUNIT	**BEARD_CODE** (Beard 1979, Beard and Webb 1974)	**DESCRIPTION**
W569	e24Lr t1;3Hi	Eucalyptus dichromophloia low open woodland with Triodia pungens; Triodia wiseana hummock grass understorey
W589	xGc/t1Hi	Mixed species tussock grassland
W59	be17Lb ads2Gc	Astrebla spp.; Dichanthium fecundum; Sorghum spp. tussock grassland sparsely wooded withLysiphyllum cunninghamii; Eucalyptus gymnoteles low trees
W60	e50;51Mi cGc	Eucalyptus tectifica; Eucalyptus grandifolia woodland with Chrysopogon spp. tussock grass understorey
W61	e17Mr cGc	Eucalyptus gymnoteles open woodland with Chrysopogon spp. tussock grass understorey
W64	b3Lr cGc	Adansonia gregorii; Lysiphyllum cunninghamii; Grevillea striata low open woodland with Chrysopogon spp. tussock grass understorey
W65	tLb a1Gc	Astrebla pectinata; Astrebla spp. tussock grassland sparsely wooded with Terminalia spp. low trees
W67	mLr cGc	Melaleuca spp. low open woodland with Chrysopogon spp. tussock grass understorey
W676	Ci	Open chenopod shrubland (seasonal)
W699	e24;53Lr a28Sc t1;11Hi	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia eriopoda open scrub and Triodia pungens; Triodia bitextura hummock grass understorey
W700	e24;53Lr a28Sc t1;11Hi	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia eriopoda open scrub and Triodia pungens; Triodia bitextura hummock grass understorey
W7001	e24;53Lr a28;29Sc ct11Gi	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia eriopoda; Acacia tumida shrub layer and a Chrysopogon spp.; Triodia bitextura open grass layer
W701	a5g1Sr t1;4Hi	Acacia pachycarpa; Grevillea refracta open shrubland with Triodia pungens; Triodia intermedia hummock grass understorey
W702	t4Hi	Triodia intermedia hummock grassland
W703	e16Lr t4Hi	Eucalyptus brevifolia low open woodland with Triodia intermedia hummock grass understorey
W704	bLr a28;30Sp a2Gc	Lysiphyllum cunninghamii sparse low open woodland and Acacia eriopoda; Acacia impressa shrubs in patches with Aristida pruinosa tussock grassland
W705	e24;53Lb t1;4Hi	Triodia pungens; Triodia intermedia hummock grassland sparsely wooded with Eucalyptus dichromophloia; Eucalyptus setosa low trees
W706	a1Gc/cdGc	Astrebla pectinata closed tussock grassland
W707	be17Lb cdGc	Chrysopogon spp.; Dichanthium fecundum tussock grassland sparsely wooded with Lysiphyllum cunninghamii; Eucalyptus gymnoteles low trees
W709	a30Sr t4Hi	Acacia impressa open shrubland with Triodia intermedia hummock grass understorey
W710	b3Lr t1;11cGc	Adansonia gregorii; Lysiphyllum cunninghamii; Grevillea striata low open woodland with ground layer of Triodia pungens; Triodia bitextura; Chrysopogon spp.
W712	e24;53Lr a28Sc t1;11Hi/b3L	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia eriopoda open scrub layer and Triodia pungens; Triodia bitextura hummock grass understorey
W716	b3LrcGc/eLrt1;4Hi	Adansonia gregorii; Lysiphyllum cunnighamii; Grevillea striata low open woodland with Chrysopogon spp. tussock grass understorey
W717	xLc	Mixed species low woodland
W718	e52;17Mr cGc	Eucalyptus papuana; Eucalyptus gymnoteles open woodland with Chrysopogon spp. tussock grass understorey
W72	eGc	Enneapogon spp. tussock grassland
W720	aGc / adGc	Astrebla/Aristida? tussock grassland
W721	ebLb t4Hi	Triodia intermedia hummock grassland sparsely wooded with Eucalyptus spp.; Lysiphyllum cunninghamii low trees
W722	be24Lb a5;28Sc t11Hi	Acacia pachycarpa; Acacia eriopoda open scrub and sparse low trees of Lysiphyllum cunninghamii; Eucalyptus dichromophloia with Triodia bitextura hummock grass understorey

VEGUNIT	BEARD_CODE (Beard 1979, Beard and Webb 1974)	DESCRIPTION
W724	a5;30Sr t4Hi	Acacia pachycarpa; Acacia impressa open shrubland with Triodia intermedia hummock grass understorey
W725	a5;29Sr t1Hi	Acacia pachycarpa; Acacia tumida open shrubland with Triodia pungens hummock grass understorey
W726	bLr aGc/cdGc	Lysiphyllum cunninghamii low open woodland with Astrebla spp. tussock grass understorey
W727	e24Lr a2Sr t1Hi	Eucalyptus dichromophloia low open woodland and Acacia pyrifolia open shrub layer with Triodia pungens hummock grass understorey
W728	bLr a24;30Sc agi	Lysiphyllum cunninghamii low open woodland and Acacia sp. (24); Acacia impressa open scrub with Aristida pruinosa tussock grass understorey
W729	bg2Lr t1Hi	Low open woodland of Lysiphyllum cunninghamii; Grevillea striata with Triodia pungens hummock grass understorey
W73	s3gc	Sporobolus virginicus short tussock grassland
W730	bgLr a5;28Sc t1;4Hi	Acacia pachycarpa; Acacia eriopoda open scrub and sparse low trees of Lysiphyllum cunninghamii; Grevillea spp. with Triodia pungens; Triodia intermedia hummock grass understorey
W731	e16Lr t1;4Hi	Eucalyptus brevifolia low open woodland with Triodia pungens; Triodia intermedia hummock grass understorey
W733	e60Sr t1Hi	Eucalyptus pruinosa open shrubland with Triodia pungens hummock grass understorey
W735	aMb t3Hr	Triodia wiseana open hummock grassland sparsely wooded trees of Adansonia gregorii
W736	e16;58Lr p3Gc/aLbp4Gi	Eucalyptus brevifolia; Eucalyptus perfoliata low open woodland with Triodia bitextura curly spinifex understorey
W737	e24;53Lr a29Sc t11Gi	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia tumida open scrub and Triodia bitextura tussock grass understorey
W738	e16;24Lr t11Gc	Eucalyptus brevifolia; Eucalyptus dichromophloia low open woodland with Triodia bitextura tussock grass understorey
W739	e50;51Mi s1;2Gc	Eucalyptus tectifica; Eucalyptus grandifolia woodland with Sehima nervosum; Sorghum spp. tussock grass understorey
W739 - delete?	e50;51Mi s1;2Gc	Eucalyptus tectifica; Eucalyptus grandifolia woodland with Sehima nervosum; Sorghum spp. tussock grass understorey
W740	e16;24Mi t11Gc	Eucalyptus brevifolia; Eucalyptus dichromophloia woodland with Triodia bitextura hummock grass understorey
W741	e50;51Mi cdGc	Eucalyptus tectifica; Eucalyptus grandifolia woodland with Chrysopogon spp.; Dichanthium fecundum tussock grass understorey
W742	e18tMi	Eucalyptus camaldulensis and Terminalia spp. woodland
W743	a27bLb cdGc	Chrysopogon spp. and Dichanthium fecundum tussock grassland sparsely wooded with Acacia suberosa; Lysiphyllum cunninghamii low trees
W744	a27bLb a1Gc/cdGc	Astrebla pectinata closed tussock grassland sparsely wooded with Acacia suberosa; Lysiphyllum cunninghamii low trees
W746	e24Lr t3Hi	Eucalyptus dichromophloia low open woodland with Triodia wiseana hummock grass understorey
W75	e55;56Li p3Gc	Eucalyptus phoenicea; Eucalyptus ferruginea low woodland with Triodia bitextura curly spinifex understorey
W750	e50;51Mi a29Sc ct11Gi	Eucalyptus tectifica; Eucalyptus grandifolia woodland with Acacia tumida open scrub and Chrysopogon spp.; Triodia bitextura grass layer
W751	e59Lr a28;29Sc t11Gi	Eucalyptus confertiflora low open woodland with Acacia eriopoda; Acacia tumida open scrub and Triodia bitextura hummock grass understorey
W752	a29Si t4Hi	Shrubland of Acacia tumida with Triodia pungens; Triodia intermedia hummock grass understorey
W754	e49;51Mi a29Sc ct11Gi	Eucalyptus miniata; Eucalyptus grandifolia woodland with Acacia tumida open scrub and Chrysopogon spp.; Triodia bitextura open grass layer

VEGUNIT	BEARD_CODE (Beard 1979, Beard and Webb 1974)	DESCRIPTION
W755	e24;53Lr a29;30Sc t11Gi	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia tumida; Acacia impressa open scrub and Triodia bitextura open grass layer
W756	e18tMi/e17;52Mi	Eucalyptus camaldulensis and Terminalia spp. woodland
W757	e24;58Lr a29;30Sc t11Gi	Eucalyptus dichromophloia; Eucalyptus perfoliata low open woodland with Acacia tumida; Acacia impressa open scrub and a Triodia bitextura open grass layer
W759	e17Mr cdGc	Eucalyptus gymnoteles open woodland with Chrysopogon spp.; Dichanthium fecundum tussock grass understorey
W760	e24;53Lr a29Sc ct11Gi	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia tumida open scrub and Chrysopogon spp.; Triodia bitextura open grass layer
W761	a28;29Si t1;4Hi	Acacia eriopoda; Acacia tumida shrubland with Triodia pungens; Triodia intermedia hummock grass understorey
W762	a29Si t4Hi	Acacia eriopoda low woodland with Triodia intermedia hummock grass understorey
W764	e24;53Lr a28;29Sc ct11Gi	Eucalyptus dichromophloia; Eucalyptus setosa low open woodland with Acacia eriopoda; Acacia tumida shrub layer and a Chrysopogon spp.; Triodia bitextura open grass layer
W767	gSr t1Hi	Grevillea spp. open shrubland with Triodia pungens hummock grass understorey
W77	e16Lr et11Gc	Eucalyptus brevifolia low open woodland with Enneapogon spp. tussock grass understorey and patchy Triodia bitextura.
W770	acSc	Acacia spp.; Casuarina decaisneana shrubland.
W771	e52;57Mi a29Sc pGi	Eucalyptus papuana; Eucalyptus setosa woodland with Acacia tumida open scrub and Plectrachne spp. open grass understorey
W773	e24;50Lr s1;2Gc	Eucalyptus dichromophloia; Eucalyptus tectifica low open woodland with Sehima nervosum; Sorghum spp. tussock grass understorey
W774	a27Lb aGc	Astrebla petinata and Aristida spp. closed tussock grassland sparsely wooded with Acacia suberosa; Lysiphyllum cunninghamii low trees
W78	eLr t1Hi	Eucalyptus spp. low open woodland with Triodia pungens hummock grass understorey
W80	oLr t1Hi	Owenia reticulata low open woodland with Triodia pungens open hummock grass understorey
W8001	e24;49Lr pGc	Eucalyptus dichromophloia; Eucalyptus miniata with Plectrachne spp. curly spinifex understorey
W8002	e24;49Mips2Gc/t1;4Hi	E. dichromophloia; E.miniata open woodland with Plectrachne sp.; Sorghum spp. grassy understorey
W8003	bg2Lr a28;30Sc.a2cgit1Hi	Acacia eriopoda; Acacia impressa shrubland and scattered low trees of Lysiphyllum cunninghamii; Grevillea striata with Aristida pruinosa; Chrysopogon spp. tussock grass understorey and patches of Triodia pungens hummock grasses.
W8005	new	Coastal dune complex
W8006	new	Vine thicket/rainforest
W8007	be17Lb cdGc	Chrysopogon spp., Dichanthium fecundum tussock grassland sparsely wooded with Lysiphyllum cunninghamii, Acacia bidwillii, and Eucalyptus microtheca low trees
W804	e51;62Lit11Gc	Eucalyptus grandifolia; Eucalyptus foelscheana low open woodland with Triodia bitextura grassy understorey
W805	e24Mi t11Gc	Eucalyptus dichromophloia woodland with Triodia bitextura grassy understorey
W806	e16;54Lr t1;11Hi	Eucalyptus brevifolia; Eucalyptus argillacea low open woodland with Triodia pungens; Triodia bitextura open hummock grass understorey
W807	aLr xGc	Acacia spp. low open woodland with mixed species tussock grass understorey
W808	e16Lr t11Gc	Eucalyptus brevifolia low open woodland with Triodia bitextura grassy understorey
W809	e57Mr a2Gc	Eucalyptus polycarpa open woodland with Aristida pruinosa tussock grass understorey
W81	e16Lr t1Hi	Eucalyptus brevifolia low open woodland with Triodia pungens hummock grass understorey
W810	e50;62Mi s2t11Gc	Eucalyptus tectifica; Eucalyptus foelscheana woodland with Sorghum spp.; Triodia bitextura grassy understorey
W811	e54;61Lr ks1Gc	Eucalyptus argillacea; Eucalyptus terminalis low open woodland with Triodia spp.; Sehima nervosum short tussock grass understorey

VEGUNIT	**BEARD_CODE** (Beard 1979, Beard and Webb 1974)	**DESCRIPTION**
W812	e24;49Mi s2;t11Gc	Eucalyptus dichromophloia; Eucalyptus miniata woodland with Sorghum spp.; Triodia bitextura grassy understorey
W813	be17Lb ds2Gc	Dichanthium fecundum; Sorghum spp. tussock grassland sparsely wooded with Lysiphyllum cunninghamii; Eucalyptus gymnoteles low trees
W814	me60Li t11Hi	Melaleuca spp.; Eucalyptus spp. low woodland with Triodia bitextura hummock grass understorey
W815	tLb a1dGc	Astrebla pectinata; Dichanthium fecundum tussock grassland sparsely wooded with Terminalia spp. low trees
W816	e54;61Lr eGc	Eucalyptus argillacea; Eucalyptus terminalis low open woodland with Enneapogon spp. short tussock grass understorey
W817	tLr ds2Gc	Terminalia spp. low open woodland with Dichanthium fecundum; Sorghum spp. tussock grass understorey
W818	e16Lb t5Hi	Triodia inutilis hummock grassland sparsely wooded with Eucalyptus brevifolia low trees
W819	e51;60Lr a2cGc	Eucalyptus grandifolia; Eucalyptus pruinosa low open woodland with Aristida pruinosa; Chrysopogon spp. tussock grass understorey
W820	e16Lb s2t11Gc	Sorghum spp. and Triodia bitextura grassland sparsely wooded with low Eucalyptus brevifolia low trees
W825	e51;62Mi s2t11Gc	Eucalyptus grandifolia; Eucalyptus foelscheana woodland with Sorghum spp.; Triodia bitextura grassy understorey
W826	e16Lr t11Hi	Eucalyptus brevifolia low open woodland with Triodia bitextura hummock grass understorey
W827	tLr t3Hi	Terminalia spp. low open woodland with Triodia wiseana hummock grass understorey
W830	e54;61LreGc/e16Lrt3Hi/s2Gc	Eucalyptus argillacea; Eucalyptus terminalis low open woodland with Enneapogon spp. short tussock grass understorey
W831	e16Lb t4;5Hi	Triodia wiseana and Triodia intermedia hummock grassland sparsely wooded with Eucalyptus brevifolia low trees
W833	e16Lb eGc	Enneapogon spp. short tussock grassland sparsely wooded with Eucalyptus brevifolia low trees
W834	a1dGc	Astrebla pectinata; Dichanthium fecundum tussock grassland
W835	e48;49Mi xLSr p;s2Gc	Eucalyptus tetrodonta; Eucalyptus miniata woodland with a mixed species low open tree and shrub layer and Plectrachne spp; Sorghum spp. grassy understorey
W837	e16Lr eGc	Eucalyptus brevifolia low open woodland with Enneapogon spp. short tussock grass understorey
W838	e52;57Mi ts2Gc	Eucalyptus papuana; Eucalyptus polycarpa woodland with Triodia spp.; Sorghum spp. grassy understorey
W840	cdGc	Chrysopogon spp. and Dichanthium fecundum tussock grassland
W842	e54;61Lr.eGc/e16Lr t3;4Hi	Eucalyptus argillacea; Eucalyptus terminalis low open woodland with Enneapogon spp. short tussock grass understorey
W843	t11Hi	Triodia bitextura hummock grassland
W844	mLr s2Gc	Melaleuca spp. low open woodland with Sorghum spp. tussock grass understorey
W846	e16Lb t1;4Hi	Triodia pungens and Triodia intermedia hummock grassland sparsely wooded with Eucalyptus brevifolia low trees
W847	e16;61Lb t1Hi	Triodia pungens hummock grassland sparsely wooded with Eucalyptus brevifolia; Eucalyptus terminalis low trees
W848	eLr t11Hi	Eucalyptus spp. low open woodland with Triodia bitextura hummock grass understorey
W849	e16;24Lr t1Hi	Eucalyptus brevifolia; Eucalyptus dichromophloia low open woodland with Triodia pungens open hummock grass understorey
W850	aGc	Astrebla spp. closed tussock grassland
W851	e16;61Lb t3;4Hi	Triodia wiseana and Triodia intermedia open hummock grassland sparsely wooded with Eucalyptus brevifolia; Eucalyptus terminalis low trees
W852	e16;61Lr eGc	Eucalyptus brevifolia; Eucalyptus terminalis low open woodland with Enneapogon spp. short tussock grass understorey

VEGUNIT	**BEARD_CODE** (Beard 1979, Beard and Webb 1974)	**DESCRIPTION**
W854	b3Lr cdGc	Adansonia gregorii; Lysiphyllum cunninghamii; Grevillea striata low open woodland with Chrysopogon spp.; Dichanthium fecundum tussock grasland understorey
W855	a27Lb a1Gc/cdGc	Astrebla pectinata tussock grassland sparsely wooded with Acacia suberosa low trees
W856	a27Lb a1Gc/cdGc	Astrebla pectinata tussock grassland sparsely wooded with Acacia suberosa low trees
W858	e55;56Li t11Gc/e16Li t11Gc	Eucalyptus phoenicea; Eucalyptus ferruginea low woodland with Triodia bitextura tussock grass understorey
W861	e50;61Lr a2cGc	Eucalyptus tectifica; Eucalyptus pruinosa low open woodland with Aristida pruinosa; Chrysopogon spp. tussock grass understorey
W864	e24Lr cGc	Eucalyptus dichromophloia low open woodland with Chrysopogon spp. tussock grass understorey
W866	be17Lb cGc	Chrysopogon spp. tussock grassland sparsely wooded with Lysiphyllum cunninghamii; Eucalyptus gymnoteles low trees
W867	e50;51Li s1;2Gc	Eucalyptus tectifica; Eucalyptus grandifolia low woodland with Sehima nervosum; Sorghum spp. tussock grass understorey
W868	e16;24Lr et11Gc	Eucalyptus brevifolia; Eucalyptus dichromophloia low open woodland with Enneapogon spp.; Triodia bitextura grassy understorey
W869	be17Lr cGc	Lysiphyllum cunninghamii; Eucalyptus gymnoteles low open woodland with Chrysopogon spp. tussock grass understorey
W870	e16Lr cGc	Eucalyptus brevifolia low open woodland with Chrysopogon spp. tussock grass understorey
W871	e16Lrt11Gc/t4Hi	Eucalyptus brevifolia low open woodland with Triodia bitextura grassy understorey
W875	e16Lr t1Hi/t4Hi	Eucalyptus brevifolia low open woodland with Triodia pungens hummock grass understorey
W876	a5;29Sr t1;4Hi	Acacia pachycarpa; Acacia tumida open shrubland with Triodia pungens; Triodia intermedia hummock grass understorey
W877	e16;24Lr cGc	Eucalyptus brevifolia; Eucalyptus dichromophloia low open woodland with Chrysopogon spp. tussock grass understorey
W878	e16;24Lb t1;4Hi	Triodia pungens; Triodia intermedia open hummock grassland sparsely wooded with Eucalyptus brevifolia; Eucalyptus dichromophloia low trees
W879	bLr a3gc	Lysiphyllum cunninghamii sparse low open woodland with Aristida browniana tussock grass understorey
W882	e16Lb t4Hi	Triodia intermedia hummock grassland wooded with Eucalyptus brevifolia low trees
W883	e24Lr t11Gc	Eucalyptus dichromophloia low open woodland with Triodia bitextura tussock grass understorey
W884	e51;57Lr cdGc	Eucalyptus grandifolia; Eucalyptus polycarpa low open woodland with Chrysopogon spp.; Dichanthium fecundum tussock grass understorey
W887	e50;51Mi xGc/s1;2Gc	Eucalyptus tectifica; Eucalyptus grandifolia woodland with mixed species tussock grass understorey
W888	e50;51Li cGc	Eucalyptus tectifica; Eucalyptus grandifolia low open woodland with Chrysopogon spp. tussock grass understorey
W894	e17;50Li kGc	Eucalyptus gymnoteles and Eucalyptus tectifica low woodland with Themeda australis tussock grass understorey
W897	eLrxGc	Mixed species tussock grassland sparsely wooded with low trees of Eucalyptus spp.
W899	e16Lr eGc/t4Hi	Eucalyptus brevifolia low open woodland with Enneapogon spp. short tussock grass understorey
W904	e48;49Mi ps2Gc	Eucalyptus tetrodonta; Eucalyptus miniata woodland with Plectrachne sp.; Sorghum spp. grassy understorey
W905	e51;52Mi xGc	Eucalyptus grandifolia; Eucalyptus papuana woodland with mixed species tussock grass understorey
W907	e52;57Mi cs2Gc	Eucalyptus papuana; Eucalyptus polycarpa woodland with Chrysopogon spp.; Sorghum spp. tussock grass understorey
W908	tbLr s2Gc	Terminalia spp; Lysiphyllum cunninghamii low open woodland with Sorghum spp. tussock grass understorey

VEGUNIT	BEARD_CODE (Beard 1979, Beard and Webb 1974)	DESCRIPTION
W909	e24;48;49Mi s2t11Gc	Eucalyptus dichromophloia; Eucalyptus tetrodonta; Eucalyptus miniata woodland with Sorghum spp. and Triodia bitextura grassy understorey
W91	e16Lb t1Hi	Triodia pungens hummock grassland sparsely wooded with Eucalyptus brevifolia low trees
W911	e24Mi s2t11Gc	Eucalyptus dichromophloia woodland with Sorghum spp.; Triodia bitextura grassy understorey
W914	e50;62Mi ks1Gc	Eucalyptus tectifica; Eucalyptus foelscheana woodland with Themeda australis; Sehima nervosum tussock grass understorey
W916	e50;59;62Mi ks1;2Gc	Eucalyptus tectifica; Eucalyptus confertiflora; Eucalyptus foelscheana woodland with Themeda australis; Sehima nervosum; Sorghum spp. tussock grass understorey
W922	eLrt pHi	Eucalyptus spp. low open woodland with Triodia spp.; Plectrachne spp. hummock grass understorey
W923	t5Hi	Triodia inutilis hummock grassland
W93	a2Sr t1Hi	Acacia pyrifolia open shrubland with Triodia pungens; Triodia intermedia hummock grass understorey

Appendix 3.6 Index to common names. (* indicates introduced species).

SCIENTIFIC NAME	common names	FAMILY
Abelmoschus ficulneus	native rosella	MALVACEAE
Acacia acradenia		MIMOSACEAE
Acacia ancistrocarpa	Fitzroy wattle	MIMOSACEAE
Acacia aneura	mulga	MIMOSACEAE
Acacia argyrodendron	blackwood	MIMOSACEAE
Acacia aulacocarpa	hickory wattle	MIMOSACEAE
Acacia calcicola	myall	MIMOSACEAE
Acacia cambagei	gidyea, gidgee	MIMOSACEAE
Acacia catenulata	bendee	MIMOSACEAE
Acacia chisholmii	Chisholm's wattle, turpentine	MIMOSACEAE
Acacia coriacea	dogwood	MIMOSACEAE
Acacia eriopoda	pindan wattle	MIMOSACEAE
Acacia estrophiolata	ironwood	MIMOSACEAE
*Acacia farnesiana**	mimosa	MIMOSACEAE
Acacia georginae	Georgina gidyea	MIMOSACEAE
Acacia hammondii	Hammond's wattle	MIMOSACEAE
Acacia harpophylla	brigalow	MIMOSACEAE
Acacia hemignosta	club-leaf wattle	MIMOSACEAE
Acacia hilliana	Hill's tabletop wattle	MIMOSACEAE
Acacia holosericea	soap bush, silver-leaved wattle	MIMOSACEAE
Acacia kempeana	witchetty bush	MIMOSACEAE
Acacia leptostachya	slender wattle, Townsville wattle	MIMOSACEAE
Acacia ligulata	umbrella bush	MIMOSACEAE
Acacia lysiphloia	turpentine wattle	MIMOSACEAE
Acacia monticola	red wattle	MIMOSACEAE
Acacia murrayana	colony wattle	MIMOSACEAE
*Acacia nilotica**	prickly acacia	MIMOSACEAE
Acacia peuce	waddy wood	MIMOSACEAE
Acacia retivenea	net-veined wattle	MIMOSACEAE
Acacia shirleyi	lancewood	MIMOSACEAE
Acacia stowardii	bastard mulga	MIMOSACEAE
Acacia suberosa	corky-bark wattle, corkwood	MIMOSACEAE
Acacia sutherlandii	corkwood wattle	MIMOSACEAE
Acacia tenuissima	narrow-leaved wattle	MIMOSACEAE
Acacia tephrina	boree	MIMOSACEAE
Acacia tetragonophylla	dead finish	MIMOSACEAE
Acacia tumida	pindan wattle	MIMOSACEAE
Acacia victoriae	gundabluie	MIMOSACEAE
Acacia victoriae ssp. *arida*	gundabluie	MIMOSACEAE
Acacia victoriae ssp. *victoriae*	gundabluie	MIMOSACEAE
Acacia wickhamii	Wickham's wattle	MIMOSACEAE
Achyranthes aspera	chaff flower	AMARANTHACEAE
Adansonia gregorii	boab, baobab	BOMBACACEAE
*Aerva javanica**	kapok bush	AMARANTHACEAE
Allocasuarina decaisneana	desert oak	CASUARINACEAE
Allocasuarina littoralis	black sheoak	CASUARINACEAE
Allosyncarpia ternata	allosyncarpia, Anbinik	MYRTACEAE
Araucaria cunninghamii	hoop pine	ARAUCARIACEAE
Archidendropsis basaltica	dead finish	MIMOSACEAE
Aristida calycina var. *calycina*	dark wiregrass	POACEAE

SCIENTIFIC NAME	common names	FAMILY
Aristida contorta	bunched kerosene grass, wind grass	POACEAE
Aristida hygrometrica	northern kerosene grass	POACEAE
Aristida inaequiglumis	unequal threeawn	POACEAE
Aristida ingrata	feathertop three-awn	POACEAE
Aristida latiflolia	feathertop	POACEAE
Aristida pruinosa	gulf wiregrass	POACEAE
Aristida sp.	three-awn grass	POACEAE
Asteromyrtus lysicephala	Kennedy's heath	MYRTACEAE
Asteromyrtus symphyocarpa	paperbark, paper-barked teatree	MYRTACEAE
Astrebla elymoides	hoop Mitchell, weeping Mitchell grass	POACEAE
Astrebla lappacea	curly Mitchell grass	POACEAE
Astrebla pectinata	barley Mitchell grass	POACEAE
Astrebla sp.	Mitchell grass	POACEAE
Astrebla squarrosa	bull Mitchell grass	POACEAE
Atalaya hemiglauca	whitewood	SAPINDACEAE
Atriplex vesicaria	bladder saltbush	CHENOPODIACEAE
Avicennia marina	white mangrove	AVICENNIACEAE
Banksia dentata	mayali	PROTEACEAE
Boronia alulata	boronia	RUTACEAE
Bombax ceiba	kapok tree, silk cotton tree	BOMBACACEAE
Bossiaea bossiaeoides	bossiea	FABACEAE
Bothriochloa ewartiana	forest bluegrass	POACEAE
Brachyachne convergens	native couch	POACEAE
Brachychiton collinus	hill kurrajong	STERCULIACEAE
Brachychiton paradoxus	red-flowered kurrajong	STERCULIACEAE
Bruguiera parviflora	small-leaved orange mangrove	RHIZOPHORACEAE
Buchanania obovata	wild mango, green mango	ANACARDIACEAE
Bulbostylis barbata	dainty sedge	CYPERACEAE
Calandrinia balonensis	broad-leaf parakeelya	PORTULACACEAE
Callitris intratropica	northern cypress pine	CUPRESSACEAE
Calytrix exstipulata	pink fringe myrtle, turkey bush	MYRTACEAE
Capparis lasiantha	nipan, split jack, wait-a-while	CAPPARACEAE
Carissa lanceolata	conkerberry, currant bush	APOCYNACEAE
Carissa ovata	conkerberry, currant bush	APOCYNACEAE
Cassytha filiformis	dodder laurel, spaghetti plant	LAURACEAE
Casuarina cunninghamiana	river she-oak	CASUARINACEAE
*Cenchrus ciliaris**	buffel grass	POACEAE
*Cenchrus echinatus**	Mossman River grass	POACEAE
*Cenchrus pennisetiformis**	Cloncurry buffel	POACEAE
*Cenchrus setiger**	birdwood grass	POACEAE
Ceriops tagal	yellow mangrove, yellow-leaved spurred mangrove	RHIZOPHORACEAE
Chenopodium auricomum	bluebush	CHENOPODIACEAE
Chionachne hubbardiana	summer grass, hairy ribbon grass, barley grass	POACEAE
Chloris divaricata	comb windmill grass	POACEAE
Chloris virgata	feathertop rhodes grass	POACEAE
Choriceras tricorne	Cape choriceras	EUPHORBIACEAE
Chrysopogon fallax	golden beard grass, ribbon grass	POACEAE
Chrysopogon spp.	beard grass	POACEAE
Cleistochloa spp.		POACEAE
Cleome viscosa	tick weed, spider weed	CAPPARACEAE
Clerodendrum floribundum	lolly bush	LAMIACEAE

SCIENTIFIC NAME	common names	FAMILY
Cochlospermum fraseri	kapok tree, cotton tree	BIXACEAE
Cochlospermum gillivraei	kapok, cotton tree	BIXACEAE
Cochlospermum gregorii	kapok, cotton tree	BIXACEAE
Corymbia aspera	rough-leaved ghost gum	MYRTACEAE
Corymbia bella	north-west ghost gum, ghost gum	MYRTACEAE
Corymbia bleeseri	rusty-barked bloodwood, smooth-stemmed bloodwood	MYRTACEAE
Corymbia cadophora	twin-leaved bloodwood, twinleaf bloodwood	MYRTACEAE
Corymbia capricornia	variable-barked bloodwood, small-fruited bloodwood	MYRTACEAE
Corymbia citriodora	lemon-scented gum	MYRTACEAE
Corymbia clarksoniana	Clarkson's bloodwood	MYRTACEAE
Corymbia confertiflora	broad-leaved carbeen, rough-leaved cabbage gum	MYRTACEAE
Corymbia curtipes	broad-leaved bloodwood	MYRTACEAE
Corymbia dampieri	pindan bloodwood	MYRTACEAE
Corymbia dallachiana	ghost gum, Dallachy's gum	MYRTACEAE
Corymbia dichromophloia	variable-barked bloodwood	MYRTACEAE
Corymbia drysdalensis	variable-barked bloodwood	MYRTACEAE
Corymbia erythrophloia	red bloodwood	MYRTACEAE
Corymbia flavescens	wrinkle-leaved ghost gum	MYRTACEAE
Cormbia ferruginea	rusty bloodwood	MYRTACEAE
Corymbia foelscheana	fan-leaved bloodwood, broad-leaved bloodwood	MYRTACEAE
Corymbia grandifolia	large-leaved cabbage gum	MYRTACEAE
Corymbia hylandii	hyland's bloodwood	MYRTACEAE
Corymbia intermedia	pink bloodwood	MYRTACEAE
Corymbia latifolia	round-leaved bloodwood	MYRTACEAE
Corymbia lamprophylla	shiny-leaved bloodwood	MYRTACEAE
Corymbia leichhardtii	yellowjacket, rustyjacket	MYRTACEAE
Cormbia nesophila	Melville Island bloodwood	MYRTACEAE
Corymbia opaca	plains bloodwood	MYRTACEAE
Corymbia papuana	ghost gum	MYRTACEAE
Corymbia peltata	rustyjacket, yellowjacket	MYRTACEAE
Corymbia pocillum	red bloodwood	MYRTACEAE
Corymbia polycarpa	long-fruited bloodwood	MYRTACEAE
Corymbia porrecta	grey bloodwood	MYRTACEAE
Corymbia setosa	rough-leaved bloodwood, hairy gum	MYRTACEAE
Corymbia sp.	bloodwood	MYRTACEAE
Corymbia terminalis	western bloodwood, inland bloodwood, desert bloodwood	MYRTACEAE
Corymbia tessellaris	Moreton Bay ash, carbeen	MYRTACEAE
Corymbia trachyphloia	brown bloodwood, Newcastle Range bloodwood	MYRTACEAE
Corymbia zygophylla	rough-leaved bloodwood	MYRTACEAE
Corypha utan	gebang, fifty-year palm	ARECACEAE
Crotalaria medicaginea	trefoil rattlepod	FABACEAE
Crotalaria novae-hollandiae	New Holland rattlepod	FABACEAE
*Cryptostegia grandiflora**	rubbervine	ASCLEPIADACEAE
Cymbopogon ambiguus	silky heads	POACEAE
Cymbopogon bombycinus	silky oil grass, lemon-scented grass	POACEAE
Cymbopogon obtectus	silky heads	POACEAE
Dactyloctenium radulans	button grass	POACEAE
Dichanthium fecundum	gulf bluegrass, curly bluegrass	POACEAE

SCIENTIFIC NAME	common names	FAMILY
Dichanthium sericeum	Queensland bluegrass	POACEAE
Dichanthium sp.	blue grass	POACEAE
Digitaria brownii	cotton panic	POACEAE
Diospyros humilis	ebony	EBENACEAE
Dodonaea physocarpa	chinese lantern hopbush	SAPINDACEAE
Dolichandrone heterophylla	lemon wood	BIGNONIACEAE
Ehretia saligna	coonta, peachwood	BORAGINACEAE
Enchylaena tomentosa	ruby saltbush	CHENOPODIACEAE
Enneapogon avenaceus	common bottlewashers	POACEAE
Enneapogon cylindricus	jointed nineawn grass	POACEAE
Enneapogon polyphyllus	limestone bottlewashers, leafy nineawn grass	POACEAE
Enneapogon purpurascens	nineawn grass	POACEAE
Enneapogon sp.	nineawn grass	POACEAE
Eragrostis eriopoda	woollybutt	POACEAE
Eragrostis xerophila	neverfail	POACEAE
Eremophila bignoniiflora	creek wilga, gooramurra	MYOPORACEAE
Eremophila freelingii	rock fuchsia bush	MYOPORACEAE
Eremophila gilesii	desert fuchsia	MYOPORACEAE
Eremophila latrobei	native fuchsia	MYOPORACEAE
Eremophila longifolia	berrigan, dogwood	MYOPORACEAE
Eremophila mitchellii	false sandlewood	MYOPORACEAE
Eriachne obtusa	northern wanderrie	POACEAE
Eriachne mucronata	mountain wanderrie	POACEAE
Erythrina vespertilio	batswing coral-tree	FABACEAE
Erythrophleum chlorostachys	ironwood, Cooktown ironwood	CAESALPINIACEAE
Eulalia aurea	silky browntop	POACEAE
Euphorbia tannensis	desert spurge	EUPHORBIACEAE
Eucalyptus brevifolia	snappy gum	MYRTACEAE
Eucalyptus brownii	Reid River box	MYRTACEAE
Eucalyptus camaldulensis	river red gum	MYRTACEAE
Eucalyptus cambageana	Dawson gum, Dawson River blackbutt	MYRTACEAE
Eucalyptus chartaboma	woollybutt	MYRTACEAE
Eucalyptus chlorophylla	glossy-leaved box, shiny-leaved box	MYRTACEAE
Eucalyptus cloeziana	Gympie messmate	MYRTACEAE
Eucalyptus coolabah	coolibah	MYRTACEAE
Eucalyptus crebra	narrow-leaved ironbark	MYRTACEAE
Eucalyptus cullenii	Cullen’s ironbark	MYRTACEAE
Eucalyptus decorticans	gum-topped ironbark	MYRTACEAE
Eucalyptus exserta	Queensland peppermint	MYRTACEAE
Eucalyptus ferruginea	rusty bloodwood	MYRTACEAE
Eucalyptus fibrosa subsp. (Glen Geddes M.I. Brooker 10230)	serpentinite ironbark	MYRTACEAE
Eucalyptus gamophylla	blue mallee	MYRTACEAE
Eucalyptus gongylocarpa	marble gum	MYRTACEAE
Eucalyptus gymnoteles	coolibah	MYRTACEAE
Eucalyptus leptophleba	Molloy red box, Molloy box	MYRTACEAE
Eucalyptus leucophloia	snappy gum	MYRTACEAE
Eucalyptus leucophylla	Cloncurry box	MYRTACEAE
Eucalyptus melanophloia	silver-leaved ironbark	MYRTACEAE
Eucalyptus microneura	Georgetown box	MYRTACEAE
Eucalyptus microtheca	coolibah	MYRTACEAE
Eucalyptus miniata	Darwin woollybutt	MYRTACEAE

SCIENTIFIC NAME	**common names**	**FAMILY**
Eucalyptus moluccana	gum-topped box, grey box	MYRTACEAE
Eucalyptus normantonensis	Normanton box	MYRTACEAE
Eucalyptus oligantha	broad leaf box	MYRTACEAE
Eucalyptus orgadophila	mountain coolibah	MYRTACEAE
Eucalyptus oxymitra	mallee	MYRTACEAE
Eucalyptus patellaris	weeping box	MYRTACEAE
Eucalyptus persistens	knotted box	MYRTACEAE
Eucalyptus phoenicea	scarlet gum	MYRTACEAE
Eucalyptus platyphylla	poplar gum	MYRTACEAE
Eucalyptus populnea	poplar box, bimble box	MYRTACEAE
Eucalyptus pruinosa	silver-leaved box, silver box	MYRTACEAE
Eucalyptus shirleyi	silver-leaved ironbark	MYRTACEAE
Eucalyptus similis	Queensland yellowjacket	MYRTACEAE
Eucalyptus spp.	gum trees	MYRTACEAE
Eucalyptus socialis	red mallee	MYRTACEAE
Eucalyptus tectifica	Darwin box, grey box	MYRTACEAE
Eucalyptus tereticornis	blue gum, forest red gum	MYRTACEAE
Eucalyptus tetrodonta	Darwin stringybark, messmate	MYRTACEAE
Eucalyptus thozetiana	napunyah	MYRTACEAE
Eucalyptus tintinnans	salmon gum, belgium gum	MYRTACEAE
Eucalyptus whitei	White’s ironbark	MYRTACEAE
Eulalia mackinlayi	silky browntop	POACEAE
Evolvulus alsinoides	tropical speedwell	CONVOLVULACEAE
Excoecaria parvifolia	gutta percha	EUPHORBIACEAE
Ficus opposita	sandpaper fig	MORACEAE
Ficus racemosa	cluster fig	MORACEAE
Fimbristylis dichotoma	eight day grass	CYPERACEAE
Flueggea virosa subsp. *melanthesoides*	white currant bush, cattle bush	EUPHORBIACEAE
Gardenia megasperma	gardenia	RUBIACEAE
Gardenia vilhelmii	breadfruit tree	RUBIACEAE
Gastrolobium grandiflorum	heart leaf poison bush	FABACEAE
Glycine tomentella	woolly glycine, rusty glycine	FABACEAE
Gossypium australe	rose cottonbush, native cotton	MALVACEAE
Gossypium sturtianum	Sturt’s desert rose	MALVACEAE
Grevillea dryandri	Dryander’s grevillea	PROTEACEAE
Grevillea glauca	bushman’s clothes pegs	PROTEACEAE
Grevillea juncifolia	desert grevillea	PROTEACEAE
Grevillea parallela	silver oak, silver beefwood	PROTEACEAE
Grevillea pteridifolia	fern grevillea	PROTEACEAE
Grevillea refracta	silverleaf grevillea	PROTEACEAE
Grevillea striata	beefwood	PROTEACEAE
Grevillea wickhamii	holly grevillea	PROTEACEAE
Grewia retusifolia	emu berry, dysentery bush	TILIACEAE
Haemodorum coccineum	blood root	HAEMODORACEAE
Hakea arborescens	tree hakea	PROTEACEAE
Hakea chordophylla	bull hakea	PROTEACEAE
Hakea leucoptera	needlewood	PROTEACEAE
Hakea lorea	corkbark, corkwood	PROTEACEAE
Halosarcia indica	samphire	CHENOPODIACEAE
Bracteantha bracteata	golden everlasting	ASTERACEAE
Rodanthe floribunda	white paper daisy	ASTERACEAE

SCIENTIFIC NAME	common names	FAMILY
Chrysocephalum pterochaetum	perennial sunray	ASTERACEAE
Heliotropium tenuifolium	native heliotrope	BORAGINACEAE
Heteropogon contortus	black spear grass, bunched spear grass	POACEAE
Heteropogon triticeus	spear grass	POACEAE
Hibiscus meraukensis	Merauke hibiscus	MALVACEAE
Hibiscus sturtii	hill hibiscus	MALVACEAE
Hibiscus tiliaceus	northern cottonwood	MALVACEAE
*Hyptis suaveolens**	hyptis	LAMIACEAE
Imperata cylindrica	blady grass	POACEAE
Indigofera hirsuta	hairy indigo	FABACEAE
Indigofera linifolia	round-pod indigo, narrow-leaved indigo	FABACEAE
Indigofera linnaei	Birdsville indigo	FABACEAE
Ipomoea pes-caprae	beach morning glory, goatsfoot trefoil	CONVOLVULACEAE
Iseilema fragile	slender Flinders grass	POACEAE
Iseilema vaginiflorum	red Flinders grass	POACEAE
Jacksonia odontoclada	angled broom bush	FABACEAE
Jacksonia ramosissima	angled broom bush	FABACEAE
*Leucaena leucocephala**	leucaena	MIMOSACEAE
Livistona humilis	fan palm	ARECACEAE
Lophostemon grandiflorus subsp. *riparius*	northern swamp box, freshwater mangrove	MYRTACEAE
Lophostemon suaveolens	swamp mahogany	MYRTACEAE
Lumnitzera racemosa	white-flowered black mangrove	COMBRETACEAE
Lysicarpus angustifolius	budgeroo	MYRTACEAE
Lysiphyllum carronii	bauhinia, bean tree	CAESALPINIACEAE
Lysiphyllum cunninghamii	bauhinia, bean tree	CAESALPINIACEAE
Macropteranthes kekwickii	bullwaddy	COMBRETACEAE
Malvastrum americanum	malvastrum	MALVACEAE
Maireana aphylla	cottonbush	CHENOPODIACEAE
Maireana astrotricha	southern bluebush	CHENOPODIACEAE
Marsilea drummondii	nardoo	MARSILEACEAE
Maytenus cunninghamii	yellowberry bush	CELASTRACEAE
Melaleuca acacioides	coastal paperbark, black teatree	MYRTACEAE
Melaleuca alsophila	coastal paperbark	MYRTACEAE
Melaleuca argentea	silvery weeping river teatree, paperbark	MYRTACEAE
Melaleuca bracteata	river teatree, black teatree	MYRTACEAE
Melaleuca citrolens	narrow-leaved paperbark, scrub teatree, lemon-scented teatree.	MYRTACEAE
Melaleuca fluviatilis	weeping river teatree, paperbark	
Melaleuca glomerata	inland teatree	MYRTACEAE
Melaleuca leucadendra	weeping river teatree, paperbark	MYRTACEAE
Melaleuca minutifolia	black teatree, paperbark	MYRTACEAE
Melaleuca nervosa	fibrebark	MYRTACEAE
Melaleuca stenostachya	teatree	MYRTACEAE
Melaleuca tamariscina	paperbark teatree	MYRTACEAE
Melaleuca uncinata	teatree	MYRTACEAE
Melaleuca viridiflora var. *viridiflora*	broad-leaved paperbark, broad-leaved teatree, myrtle.	MYRTACEAE
Melhania oblongifolia	velvet hibiscus	STERCULIACEAE

SCIENTIFIC NAME	**common names**	**FAMILY**
*Melinis repens***	red Natal grass	POACEAE
Muehlenbeckia florulenta	lignum	POLYGONACEAE
Myoporum deserti	Ellangowan poison bush, turkey bush, pencil bush	MYOPORACEAE
Nauclea orientalis	leichhardt tree	RUBIACEAE
Neofabricia myrtifolia	yellow teatree	MYRTACEAE
Neptunia gracilis	low sensitive plant	MIMOSACEAE
Ophiuros exaltatus	canegrass	POACEAE
Oryza australiensis	Australian wild rice	POACEAE
Owenia acidula	emu apple	MELIACEAE
Owenia reticulata	desert walnut, broad-leaved emu apple	MELIACEAE
Pandanus spiralis	screw palm	PANADANACEAE
Pandanus spp.	screw palm	PANADANACEAE
Panicum decompositum	native millet, stargrass	POACEAE
Parinari nonda	nonda	CHRYSOBALANACEAE
*Parkinsonia aculeata**	parkinsonia	CAESALPINIACEAE
*Parthenium hysterophorus**	parthenium	ASTERACEAE
Perotis rara	comet grass	POACEAE
Petalostigma banksii	smooth-leaved quinine	EUPHORBIACEAE
Petalostigma pubescens	quinine tree	EUPHORBIACEAE
Petalostigma quadriloculare	quinine bush, witchetty bush	EUPHORBIACEAE
Piliostigma malabaricum	bauhinia	CAESALPINACEAE
Planchonia careya	cocky apple	LECYTHIDACEAE
Polycarpaea breviflora		CARYOPHYLLACEAE
Polycarpaea corymbosa		CARYOPHYLLACEAE
Portulaca oleracea	pigweed, munyeroo	PORTULACACEAE
Pterocaulon sphacelatum	fruit salad plant, apple bush	ASTERACEAE
Ptilotus obovatus	silver tail	AMARANTHACEAE
Ptilotus polystachys	red pussytail	AMARANTHACEAE
Ptychosperma elegans	solitaire palm	ARECACEAE
Rhagodia spinescens	spiny saltbush	CHENOPODIACEAE
Rhizophora stylosa	red mangrove	RHIZOPHORACEAE
Salsola kali	prickly saltwort	CHENOPODIACEAE
Santalum lanceolatum	sandalwood	SANTALACEAE
Sarcostemma viminale subsp. *australe*	pencil caustic, caustic vine	ASCLEPIADACEAE
Schizachyrium fragile	fire grass	POACEAE
Schoenus sparteus	sedge	CYPERACEAE
Sclerolaena bicornis	goathead burr	CHENOPODIACEAE
Sclerolaena convexula	tall copper burr	CHENOPODIACEAE
Sclerolaena decurrens	copper burr	CHENOPODIACEAE
Sehima nervosum	white grass	POACEAE
Senna artemisioides subsp. *helmsii*	crinkled cassia, blunt-leaf cassia	CAESALPINIACEAE
Senna artemisioides subsp. *oligophylla*	limestone cassia	CAESALPINIACEAE
Sesbania cannabina	sesbania pea, yellow bush pea	FABACEAE
Sesbania javanica	tall sesbania pea	FABACEAE
Setaria surgens	annual pigeon grass	POACEAE
Sida acuta	spinyhead sida	MALVACEAE
Sida subspicata	spiked sida	MALVACEAE
Sida trichopoda	high sida	MALVACEAE
Solanum ellipticum	potato bush, wild potato	SOLANACEAE

SCIENTIFIC NAME	**common names**	**FAMILY**
Solanum quadriloculatum	tomato bush, wild tomato	SOLANACEAE
Sorghum intrans	annual sorghum	POACEAE
Sorghum plumosum	plume sorghum	POACEAE
Spermacoce stenophylla	blue heads	RUBIACEAE
Sporobolus actinocladus	katoora, ray grass	POACEAE
Sporobolus australasicus	Australian dropseed	POACEAE
Sporobolus caroli	fairy grass, yakka grass	POACEAE
Sporobolus virginicus	marine couch, sand couch, saltwater couch.	POACEAE
*Stylosanthes hamata**	Caribbean stylo – includes cv. amiga and verano	FABACEAE
*Stylosanthes scabra**	shrubby stylo – includes cv. seca	FABACEAE
Terminalia aridicola subsp. *aridicola*	arid peach	COMBRETACEAE
Terminalia aridicola subsp. *chillagoensis*	arid peach	COMBRETACEAE
Terminalia arostrata	nutwood	COMBRETACEAE
Terminalia canescens	winged nut-tree, bendee	COMBRETACEAE
Terminalia fernandiana	billygoat plum	COMBRETACEAE
Terminalia platyphylla	wild plum, durin	COMBRETACEAE
Terminalia platyptera	yellow wood, wing-seed terminalia	COMBRETACEAE
Themeda avenacea	oat kangaroo grass, native oat grass	POACEAE
Themeda arguens	miniature grader grass	POACEAE
*Themeda quadrivalvis**	grader grass	POACEAE
Themeda triandra	kangaroo grass	POACEAE
Thysanotus banksii	fringe lily	ANTHERICACEAE
Trema tomentosa var. *tomentosa*	poison peach	ULMACEAE
Trema tomentosa var. *viridis*	poison peach	ULMACEAE
Trema tomentosa	poison peach	ULMACEAE
Tribulus terrestris	caltrop	ZYGOPHYLLACEAE
Trichodesma zeylanicum	camel bush, cattle bush	BORAGINACEAE
Triodia basedowii	hard spinifex, lobed spinifex	POACEAE
Triodia bitextura	feathertop spinifex	POACEAE
Triodia brizoides	spinifex	POACEAE
Triodia burkensis	spinifex	POACEAE
Triodia bynoei	spinifex	POACEAE
Triodia intermedia	winged spinifex	POACEAE
Triodia irritans	hard spinifex	POACEAE
Triodia longiceps	porcupine spinifex, grey spinifex	POACEAE
Triodia melvillei	spinifex	POACEAE
Triodia mitchellii	buck spinifex	POACEAE
Triodia molesta	pincushion spinifex	POACEAE
Triodia pungens	soft spinifex, gummy spinifex	POACEAE
Triodia schinzii	feathertop spinifex	POACEAE
Triodia spicata	spike flower spinifex	POACEAE
Triodia wiseana	limestone spinifex	POACEAE
Tripogon loliiformis	five-minute grass	POACEAE
Ventilago viminalis	vine tree, supplejack	RHAMNACEAE
Vitex trifolia var. *trifolia*	vitex, monk's pepper	LAMIACEAE
Waltheria indica	waltheria	STERCULIACEAE
Xanthium occidentale	noogoora burr	ASTERACEAE
Xanthostemon paradoxus	bridal tree	MYRTACEAE
Xerochloa imberbis	northern rice grass	POACEAE

SCIENTIFIC NAME	common names	FAMILY
*Ziziphus mauritiana**	chinee apple	RHAMNACEAE
Zygochloa paradoxa	sandhill cane grass	POACEAE

Appendix 3.7 Lookup table for vegetation unit to 1:1 million, 1:2 million and BVGs.

(Note: This lookup table relates the vegetation map units used within this report and on the map of the Vegetation of the Australian Tropical Savanns (Fox *et al.* 2001). UNIT_2M_FINAL is the code for the vegetation map units described in this report. VEG_UNIT is the map unit from each state and territory map used to compile the final map. BVG_2M_final is the broad vegetation group to which each map unit has been assigned. UNIT_1M_final is a map code for the digital 1:1 000 000 map of the Vegetation of the Australian Tropical Savannas. This was made available to researchers in northern Australia and will assist them to access further information about each map unit.)

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
A1	N105	26	A1
A1	Q1	26	A1
A1	W43	26	A1
A2	Q2	26	A2
A3	N106	26	A3
A3	Q3	26	A3
A3	W127	26	A3
A3	W1271	26	A3
B1	Q4	1	B1
B2	Q8	26	B2
B2	Q7	26	B3
B2	N102	26	B4
B2	Q5	26	B4
B2	W8011	26	B4
B2	Q6	26	B5
B2	W770	26	B6
B2	W8004	26	B7
B2	W8005	26	B8
B2	N47	26	D64
C1	Q9	1	C1
C1	Q20	1	C2
C10	N24	3	C21
C10	N26	3	C21
C10	Q21	3	C21
C10	W1893	3	C21
C10	W59	3	C21
C10	W61	3	C21
C10	W759	3	C21
C10	W894	3	C21
C10	N18	3	C22
C10	W718	3	C22

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
C10	W809	3	C22
C10	W907	3	H4
C11	N50	20	C41
C12	Q11	20	C31
C12	W37	20	C31
C12	W41	20	C31
C12	W48	20	C31
C13	Q32B	20	C18
C13	Q13	20	C23
C13	N51	20	C28
C13	W844	20	C28
C14	N48	23	K23
C15	Q19	22	C30
C16	N111	26	C24
C16	Q103	25	C24
C17	N96	23	C32
C17	Q115	23	C32
C17	W706	23	C32
C17	W834	23	C32
C17	W850	23	C32
C18	N44	23	C29
C18	Q104	23	C33
C18	W720	23	C33
C18	W840	23	C38
C18	N98	23	G19
C18	W707	23	G19
C18	W743	23	G19
C18	W8007	23	G19
C18	W807	23	G19
C18	W866	23	G19
C19	Q18	23	C34
C19	N54	23	C35
C19	Q15	23	C35
C19	W175	23	C35
C19	Q16	23	C36
C19	N103	23	C37
C19	N104	23	C37

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
C19	W73	23	C37
C2	Q302	2	C4
C2	Q306A	2	C5
C20	Q200	25	C25
C20	Q17	25	C39
C20	N101	25	C40
C20	N107	25	C40
C20	Q102	25	C40
C20	Q14	25	C40
C20	Q303	25	C40
C20	W125	25	C40
C20	W676	25	C40
C3	N53	19	C6
C3	Q10	19	C6
C3	Q12	19	C6
C4	Q212	16	C14
C4	Q201	16	C19
C4	Q201A	16	C19
C4	Q202	16	C3
C4	Q203	16	C7
C5	Q101	16	C20
C6	Q108A	3	C10
C6	Q23	3	C9
C7	N25	3	C13
C7	N27	3	C13
C7	N28	3	C13
C7	Q100	3	C13
C7	W756	3	C13
C7	W813	3	C13
C7	Q22	3	C15
C7	Q24	3	C17
C8	Q325	3	C11
C8	Q26	3	C16
C9	Q210	12	C12
C9	Q210A	12	J9
CQC	CQC	CQC	CQC
D1	Q30	1	D1

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
D10	N15	4	D10
D10	W914	4	D10
D10	W916	4	D10
D10	W838	4	D12
D11	N16	4	D20
D11	Q502	4	D20
D12	W750	4	D21
D12	W1750	4	D28
D13	N10	5	D23
D13	Q504	5	D23
D13	N7	5	D24
D14	W754	5	D16
D14	N12	5	D17
D14	N13	5	D26
D14	W909	5	D26
D14	Q208	5	D31
D14	W771	5	D7
D15	Q31	5	D18
D15	Q29	5	D22
D15	Q28	5	D25
D15	Q27	5	D6
D16	Q206	13	D30
D17	Q209	12	D27
D18	Q505	21	D35
D19	N49	20	D54
D19	Q506	20	D54
D19	W67	20	D54
D2	Q306	2	D8
D20	Q221	20	D36
D20	Q508	20	D37
D20	Q32	20	D38
D21	W64	21	D39
D21	W710	21	D39
D21	W854	21	D39
D22	Q106	23	D41
D23	W699	6	D42
D23	W700	6	D42

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
D23	W7001	6	D42
D23	W737	6	D42
D23	W755	6	D42
D23	W760	6	D42
D23	W764	6	D42
D23	W751	6	D43
D23	W757	6	D43
D24	W712	6	D44
D25	N19	8	D46
D25	N42	8	D46
D25	Q108	8	D46
D26	W826	7	D47
D26	W848	7	D47
D26	W565	7	D48
D26	W81	7	D48
D26	W849	7	D48
D26	W899	7	D48
D26	W703	7	D49
D26	W731	7	D49
D26	W806	7	D49
D26	W818	7	G14
D27	N36	7	D50
D27	Q109	7	D50
D28	Q107	8	D51
D29	W729	9	C27
D29	N39	9	D33
D29	W733	9	D33
D29	N23	9	D34
D29	Q503	9	D34
D29	W819	9	D34
D29	W861	9	D34
D29	N40	9	D45
D29	W704	9	D53
D29	W728	9	D53
D29	W879	9	D53
D3	Q25	2	D2
D30	Q222	20	D55

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
D31	N71	18	D59
D31	Q105	18	D59
D31	N70	18	J18
D32	W709	18	D57
D32	W724	18	D57
D32	W752	18	D57
D32	W761	18	D57
D32	W876	18	D57
D32	W722	18	D58
D32	W730	18	D58
D32	W8003	18	D58
D32	W701	18	D63
D33	Q35A	22	D60
D33	Q222A	22	D62
D34	W104	21	D65
D34	W767	21	D65
D35	W702	24	D66
D35	W721	24	D66
D35	W882	24	D66
D35	W843	24	D69
D36	N76	24	D68
D36	N77	24	D68
D36	W32	24	D68
D36	W895	24	D68
D4	N4	5	D3
D4	N5	5	D4
D4	N3	5	D5
D5	N20	10	D11
D5	N17	10	D9
D6	Q501	4	D13
D6	Q500	4	D32
D7	Q305	12	D14
D7	Q305A	12	D14
D8	Q211	12	D19
D9	Q301	14	D15
E1	N57	17	D56
E1	N55	17	E1

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
E1	Q110	17	E1
E1	Q33	17	E1
E1	N56	17	E3
E2	Q34	13	E2
E3	W871	7	E4
E4	W117	24	E8
F1	Q35	1	F1
F1	Q216A	1	F2
F1	Q308	1	F3
F1	Q39A	1	F3
F2	Q207A	15	F5
F2	Q307	15	F5
F3	Q36	15	F6
F4	W739	15	F4
F4	W825	15	F4
F4	W887	15	F4
F4	W905	15	F4
F5	Q304	15	F7
F6	Q213	15	F8
F7	N22	8	F9
F7	W811	8	F9
F7	W816	8	F9
F7	W842	8	F9
F8	Q310	23	F13
F8	N97	23	F15
F8	W8010	23	F15
F8	Q217	23	F16
F9	N88	24	F14
F9	W830	24	F14
G1	Q204	14	G23
G10	Q114	23	G17
G10	Q116	23	G18
G10	W65	23	G18
G10	W744	23	G18
G10	W815	23	G18
G10	W855	23	G18
G10	W856	23	G18

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
G11	N99	23	G20
G11	W72	23	G20
G2	Q37	14	G2
G3	Q213s	15	G22
G4	W814	20	G4
G5	N113	16	G13
G5	Q113	16	G13
G5	N63	16	G5
G5	N62	16	G6
G5	Q112	16	G6
G6	N41	8	G8
G7	Q509	8	G3
G8	Q510	21	G10
G8	W817	21	G11
G8	W908	21	G11
G8	Q38	21	G21
G8	N45	21	G9
G8	N46	21	G9
G8	W726	21	G9
G8	W869	21	G9
G9	W116	24	G15
G9	W735	24	G15
G9	N91	24	G16
G9	W157	24	G16
G9	W746	24	G16
G9	W827	24	G16
G9	W716	24	G7
H1	N2	1	H1
H1	Q39	1	H2
H1	W8006	1	H2
H1	N1	1	H2
H10	Q205s	13	H32
H11	Q214	13	H14
H12	Q320	13	H15
H13	N34	10	H20
H13	W155	10	H20
H13	W569	10	H20

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
H13	W727	10	H20
H13	W867	10	H7
H14	W804	11	H24
H14	W884	11	H24
H15	N38	7	H25
H15	W846	7	H25
H15	W875	7	H25
H15	W91	7	H25
H15	W833	7	H26
H15	W837	7	H26
H15	W738	7	H27
H15	W740	7	H27
H15	W870	7	H27
H15	W877	7	H27
H16	N35	7	H28
H16	Q117A	7	H28
H17	W725	18	G12
H17	W762	18	G12
H17	W93	18	G12
H18	W80	24	H29
H18	W705	24	H30
H18	W847	24	H30
H18	W878	24	H30
H2	Q110s	17	H31
H3	Q41	22	H16
H4	Q307A	13	H5
H4	Q319	13	H6
H5	Q40	5	H8
H6	N14	5	H10
H6	N9	5	H12
H6	W12	5	H12
H6	W53	5	H12
H6	W835	5	H12
H6	N8	5	H13
H7	N6	5	H11
H7	Q42	5	H9
H8	N29	11	H18

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
H8	W75	11	H18
H8	W858	11	H18
H9	N33	10	H17
H9	W805	10	H17
H9	W911	10	H17
H9	N21	10	H19
H9	N32	10	H21
H9	W717	10	H21
H9	W8001	10	H21
H9	W8002	10	H21
H9	W883	10	H21
H9	W773	10	H22
H9	W864	10	H22
H9	N31	10	H23
H9	Q511	10	H23
H9	W1520	10	H3
H9	W52	10	H3
H9	W812	10	H3
J1	Q43	1	J1
J1	Q313	1	J2
J10	Q47	14	J13
J10	Q111	14	J17
J11	Q118	24	J19
J12	Q117	24	J16
J13	W831	24	J20
J2	Q44	2	J3
J3	Q205	13	J4
J4	Q45	14	J8
J5	Q311	14	J11
J6	W741	4	J10
J6	W60	4	J22
J7	Q203A	14	J21
J8	Q46	14	J5
J8	Q322	14	J6
J8	Q400	14	J7
J9	W852	7	J14
J9	W8008	7	J15

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
K1	Q216	1	K2
K1	Q49	1	K2
K1	Q48	1	K3
K12a	Q51	21	K27
K2	Q321	2	K10
K2	Q26A	2	K4
K2	Q316	2	K4
K2	Q50	2	K5
K3	Q52	5	K14
K4	N11	5	K12
K4	W904	5	K15
K5	W810	4	K13
K5	W888	4	K22
K6	Q207	4	K16
K6	Q314	14	K6
K6	Q512	14	K7
K6	Q323	14	K8
K6	Q324	14	K9
K7	Q312	21	K17
K7	W2736	21	K24
K7	W736	21	K24
K8	W77	7	K18
K8	W868	7	K18
K8	N37	7	K19
K8	W808	7	K19
K8	W851	7	K25
K8	W820	7	K26
K9	Q315	14	K20
K9	Q215	14	K21
SEQ	SEQ	SEQ	SEQ
WT	WT	WT	WT
	W151		C26
	Q218		C8
	Q219		D29
	Q220		D40
	Q222C		D61
	Q317		E6

UNIT_2M_FINAL	VEG_UNIT	BVG_2M_final	UNIT_1M_final
	Q222B		E7
	Q309		F10
	Q222D	22	F12
	Q222E		K1