BioCondition

A Condition Assessment Framework for Terrestrial Biodiversity in Queensland

Assessment Manual

Queensland Herbarium, Science Delivery

Version 2.2

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Great state. Great opportunity.

Queensland Government

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Introduction

The management of native vegetation to produce services such as food and fibre has meant that an estimated 62 per cent of Australia's native vegetation has been modified by agricultural and grazing enterprises (Thackway and Lesslie 2006). Knowledge of the extent of native vegetation by broad structural and floristic type is therefore considered integral for natural resource planning, management and environmental reporting. Consequently, vegetation mapping programs to describe structural and floristic type have been conducted across the majority of the states and territories of Australia.

Compared with vegetation *extent*, the assessment of vegetation *condition* is considerably less well documented in Queensland, and indeed most of Australia. It has only been relatively recently that policy demands and expectations have conceptualized vegetation condition as a major component of native vegetation management, primarily to assist decision making for developmental approvals, incentive payments and market-based investments (Keith and Gorrod 2006). Regional natural resource management groups are also interested in vegetation condition, given its listing as a national environmental indicator for reporting targets (MEWG 2004). At the property scale, land managers are increasingly becoming aware of the challenge to demonstrate duty of care (Bates 2001; Neldner 2006). A procedure to effectively assess vegetation condition is necessary to support these decision-making and reporting schemes, including the implementation of offsets and biobanking and comprehensive environmental accounts (Hawke 2009). The ability to assess and monitor vegetation condition is also essential for governments to administer legislation relating to the landscapes and biodiversity covered by their jurisdiction.

A simple, rapid assessment approach is highly desirable as compared with a time-consuming and complicated, if thorough, approach as it facilitates uptake of use by resource managers (Andreasen *et al.* 2001). Accordingly, a number of condition assessment tools have utilised key attributes or surrogates of biodiversity values that can be rapidly measured in the field (Gibbons and Freudenberger 2006). These include the 'Habitat Hectares' assessment framework in Victoria (Parkes *et al.* 2003) and 'BioMetric' in New South Wales (Gibbons *et al.* 2008).

Box 1: Definition of Biodiversity

Biodiversity is defined as:

'….the variety of life, its composition, structure and function, at a range of scales' (Freudenberger and Harvey, 2003)

Composition: the variation in species, populations and gene pools

Structure: the physical variation of habitat and ecosystem components, such as tree, shrub and ground layers

Function: "the way it all works together"; hard to see, but includes important processes such as carbon, nutrient and water cycling

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BioCondition is a condition assessment framework for Queensland that provides a measure of how well a terrestrial ecosystem is functioning for biodiversity (Box 1) values. It is a site-based, quantitative and therefore repeatable assessment procedure that can be used in any vegetative

state, and provides a numeric score that can be summarised as a condition rating of 1, 2, 3 or 4, or functional through to dysfunctional condition for biodiversity. In BioCondition, 'condition' refers to the degree to which the attributes of a patch of vegetation differ from the attributes of the same vegetation in its reference state (Box 2).

Box 2: Definition of condition for biodiversity

> **Condition for biodiversity is defined as:**
>
> *The similarity in key features of the regional ecosystem being assessed with those of the same regional ecosystem in its reference state.*
>
> *The reference state refers to the natural variability in attributes of an ecosystem relatively unmodified since the time of European settlement, or the 'best on offer'. Benchmarks for attributes are derived from this state.*

In BioCondition, the reference state refers to the natural variability or range in attributes of an ecosystem that is relatively unmodified since European settlement, or 'best on offer' (BOO). The reference approach has been criticized as being the construct of another Clementsian-based successional model (McCarthy *et al.* 2004), but this will depend on what state is used as the 'desired' state of condition for comparison (Gibbons and Freudenberger 2006). The BioMetric approach (Gibbons *et al.* 2008) aims to avoid this criticism by providing a range of values as the benchmark for vegetation communities, representing the natural alternative states that the community may display as a consequence of environmental variation or natural disturbance. In general, the 'historical' pristine natural state, with absence of post-European human disturbance is usually used as the reference state (e.g. Parkes *et al.* 2003). However, the use of sites in a 'pristine' state is unrealistic, given that impacts from post-European settlement management are widespread. Furthermore, it is extremely unlikely that a given patch of vegetation could be restored to historical states (Hobbs and Norton 1996; Oliver *et al.* 2002). Sites that have been least impacted by local threats should be of increased value for aspects of biodiversity, and thus constitute the best available benchmark representing the desired state (Landsberg and Crowley 2004).

The BioCondition method is designed for use by assessors who have a reasonable working knowledge of regional ecosystem (RE) mapping and vegetation assessment at the site scale. It provides a protocol for vegetation condition assessment at the patch, paddock or property scale. The BioCondition score does not provide an index of habitat *suitability* for fauna*,* as this will depend on many other factors that are not directly surrogates of condition, such as predator risk, and sheltering component of habitat such as rock cover and density of dead, hollow-bearing trees. Furthermore, we need to be cognisant that vegetation states other than the reference state may also be important for biodiversity in some situations.

Describing vegetation as 'poor' or 'dysfunctional' suggests that it is of little service to biodiversity, which is not always the case. For example, regrowth, thickened vegetation, and even swards of exotic grass all represent transitional vegetative states that provide some service to native fauna in the landscape, particularly within heavily modified landscapes (Bowen *et al.* 2007; Eyre *et al.* 2009a,b). Also, for some attributes, we still do not understand the complexities of their response to disturbance events (Eyre 2010). What constitutes a 'natural state' for benchmarking purposes for

some attributes remains questionable? For example, a dense or 'thickened' midstorey is often described as symptomatic of inappropriate land management, but it may be simply reflecting natural ecological dynamism (Fensham 2008). Whichever the case, patches of vegetation in the landscape with a dense midstorey are important refuge areas for diurnal birds (Maron and Kennedy 2007; Eyre *et al.* 2009a). Finally, BioCondition is not intended for use in regional planning or assessment of conservation significance, although outputs can contribute to this. The Biodiversity Planning Assessments (BPAs) have been prepared for these purposes and can be sourced from the Queensland Government website.

Box 3: Components of BioCondition

The primary components of BioCondition include:
1. the assessment unit

2. a suite of vegetation condition attributes that act as surrogates or indicators of biodiversity values

3. benchmarks for each of the attributes for each regional ecosystem

4. an assessment method

5. a scoring system that will provide a final 'condition' score.

1.1 Drivers and Constraints

In Australia, existing frameworks and procedures to assess vegetation condition for biodiversity differ in their approaches, and this is reflective of the various legislative, management and policy objectives, as well as the resources (such as time, expertise and budget) available to conduct the assessments. State-based condition assessment methodologies in Victoria (Habitat Hectares; Parkes *et al.* 2003) and New South Wales (BioMetric; Gibbons *et al.* 2005) have a legislative basis and are therefore more rigidly implemented and resourced relative to other available assessments. However, methods to assess resources for demonstration of sustainable use are usually less rigid in their implementation, and operator expertise is often less specialized (e.g. ABCD land condition assessment by landholders; Chilcott *et al.* 2003). Examples of existing condition assessment methodologies can be aligned relevant to the gradation between available resources and the rigor of the objectives required to conduct the assessments in a broad matrix (Table 1). The most challenging assessment frameworks to develop sit within the compartment of the matrix corresponding with high operational constraints and low regulatory rigor. In this compartment, the conduct of any assessment must provide as reliable an estimate of condition for as little effort as possible, given it is reliant on the self-motivation of a landholder without any financial or technical assistance.

Table 1: Examples of vegetation condition assessments within a matrix of increasing operational constraints and regulatory requirements

		Management or policy objectives		
		Sustainable use	**Protection**	**Regulation**
Operational constraints	**High**	**Self-motivated landholder assessment** e.g. Stocktake (Aisthorpe and Paton 2004) for assessing ABCD land condition (Chilcott *et al.* 2003)	**Incentive programs** e.g. Queensland Government Nature Assist for the establishment of Nature Refuges	**Regulatory-motivated landholder assessment**
	Medium	**Site-based monitoring** e.g. Landscape Function Analysis (Tongway and Hindley 2005)	**Incentive programs employing market-based instruments** e.g Habitat Hectares (Parkes *et al.* 2003) for BushTender auctions (Vic)	**Development applications** e.g. BioMetric (Gibbons *et al.* 2008) for clearing native vegetation (NSW); offsetting
	Low	**Regional long-term monitoring programs** e.g. TRAPS grazed woodland dynamics monitoring (Back *et al.* 1997); NFPP productive forest monitoring (QDPI 1995)	**Formal reservation** e.g. Biodiversity and habitat assessments (Eyre *et al.* 1998) for the South East Queensland Regional Forest Agreement	**Environmental impact assessment** e.g. for assessing impact of mining or petroleum activities under the *Environmental Protection Act 1994*

1.2 Version control

This version (Version 2.2) differs only slightly from the previous version (Version 2.1), including;

- Reformatting into the current Queensland Government template
- Removal and amendment of superfluous webpage links.
- References to retracted or changed Queensland Government policies and strategies have been removed or updated.

NOTE: There is no methodological change between V 2.1 and V 2.2.

2 The assessment: getting started

2.1 Define the objective of the assessment

For any assessment or monitoring program, the development and clear articulation of the objective for the assessment is a critical first step. The objective will clarify if a rapid condition assessment such as BioCondition is the appropriate method to use. The objective will also determine the spatial and temporal scale of the assessment required (i.e. how many assessment sites through space and time are required). It will determine how the assessment unit should best be delineated or if extra attributes may be needed. For example, if the objective is to assess the condition of a grazing paddock for biodiversity, then assessment units would be delineated for remnant and non-remnant vegetation in that paddock, but if the objective was to assess the condition of the remnant vegetation for biodiversity across a property, then the assessment units would be delineated based on remnant vegetation only. Having clear objectives will provide a foundation for assessing the value of the assessment program (Field *et al.* 2007).

2.2 Resources required

Prior to visiting an area to assess vegetation condition using BioCondition, it will be important to collate existing biodiversity and spatial (mapping) information relating to the area. Queensland Government spatial datasets can be downloaded from the Queensland Government's QSpatial website. Digital regional ecosystem mapping (showing remnant vegetation) will be desirable, as will any orthorectified digital imagery or aerial photographs.

Regrowth vegetation, as well as remnant vegetation, is assessable for BioCondition, and therefore mapping showing areas of regrowth will also be required. Regrowth mapping can be downloaded from the QSpatial website as *Vegetation Management Act former high value regrowth vegetation version 2.1*. This dataset maps areas of non-remnant woody vegetation that were used for vegetation management purposes before December 2013. The mapping was derived from the Queensland Government's Remote Sensing Centre 2006 Foliage Projective Cover (FPC) mapping and 1989 to 2007 'Woody Change' product mapping. Mapping and imagery should encompass the entire area to be assessed, including a buffer of at least 2 km.

The following equipment is desirable for completing a BioCondition assessment:

- 100 m transect tape

- 50 m transect tape (optional)

- 1 x 1 m quadrat for measuring ground cover (or some 1 m long sticks)

- compass (to lay out the site)

- star pickets for the 0 m and 50 m point along the transect for relocating the site

- diameter tape or a smaller measuring tape

- this manual (or a copy of Appendix 1) and copies of the BioCondition assessment datasheet (Appendix 2)

- access to the Internet in order to obtain information about the REs that occurs on the property or management area; RE maps (remnant, regrowth and pre-clear) and RE descriptions can also be obtained from the QSpatial website. With descriptions of REs available on the Queensland Government Website (http://www.qld.gov.au/).

- benchmark documents for each of the REs that will be assessed. (Available on the Queensland Government Website (http://www.qld.gov.au/).

- clinometer, hypsometer or ruler for measuring tree heights

- digital or print film camera

- clipboard, pencils and erasers

- flagging tape (not essential)

- plant identification books (not essential)

- Global Positioning System (GPS).

See Appendix 3 for further information on resources.

2.3 Benchmarks

Benchmarks are quantitative values derived from reference sites for each site condition attribute assessed in BioCondition, and are used as a reference value for comparison purposes. They are specific to each RE, and are based on the average or median value from reference or BOO sites. The aim of the benchmarks is to discriminate condition states between assessable sites. Benchmarks have now been developed for a number of REs in Southeast Queensland, New England Tablelands, Brigalow Belt, Mulga Lands, Northwest Highlands, Mitchell Grass Downs, Channel Country and Desert Uplands bioregions, and are currently available on the Queensland Government Website (http://www.qld.gov.au/).

The benchmark documents can be subject to periodic review and will be updated with addition of further reference site data. While every effort has been made to ensure that the information presented in the benchmarks is as reliable as possible, the State of Queensland accepts no liability and gives no assurance in respect of their accuracy and shall not be liable for any loss or damage arising from their use. Benchmarks are based on a combination of quantitative and qualitative information. The benchmarks have been generated from existing standardised floristic and habitat data collected from reference sites, and/or elicited from experts with knowledge on REs. Since there are data gaps for many REs and/or attributes within REs, expert elicitation is essential for the setting of appropriate benchmarks. A method to elicit expert knowledge specifically for the validation and/or development of benchmarks has been designed and tested specifically for BioCondition (Low Choy *et al.* 2009).

The natural variability in structure and floristic composition under a range of climatic and natural disturbance regimes throughout the geographic extent of the RE has tried to be considered during benchmark development. The establishment and assessment of local reference sites may be required to account for this spatial and temporal (seasonal and annual) variability. Assessment of local reference sites will also be required in cases where benchmarks are not yet available for REs, or an assessment needs to be conducted during less than optimal conditions. Quantitative benchmark data can then be generated by locating and setting up a local BOO reference site. Reference site assessment does require reasonable botanical and habitat assessment experience

and skills, and entails detailed measurement and recording of vegetation floristics and structure. A reference site assessment protocol (Eyre *et al.* 2011) is available from the Queensland Government website.

3 The assessment unit and site selection

3.1 Delineation of the assessment unit

As for any assessment relying on a limited number of field sites, the location of these sites is very important for the overall adequacy of the assessment. The delineation of assessment units and the number of sites to assess will depend upon the overall objective of the assessment. Units of assessment are used to determine where and how many sites are needed to adequately assess the condition of the property or area of interest. Assessment units are relatively homogenous units defined by a unique RE and broad condition state (i.e. 'remnant' versus 'regrowth' versus 'non-remnant'). Non-remnant vegetation includes any vegetation that has not been otherwise mapped as remnant or regrowth vegetation by the Queensland Government. The non-remnant vegetation can be further delineated into two separate assessment units if required (e.g. for offsets), i.e. 'young woody regrowth' and 'non-remnant vegetation'. Although not currently mapped, this delineation can be obtained by using the woody cover mapping of SLATS and the pre-clearing RE mapping in areas that are not already mapped as remnant vegetation or high-value regrowth. Definitions of the broad condition states that can be used to delineate assessment units are given in Box 4.

Depending upon the objective of the assessment, there may be a requirement to assess all vegetation, or just components. Assessment units do not need to be continuous tracts, and can occupy two or more discrete areas, but should be larger than 1 ha in area (100 x 100 m) (see Figure 1). Assessments being conducted within discrete management areas, e.g. a cattle grazing property, can also use management units such as paddocks to delineate the assessment units. Ideally, to assess the condition of an area the aim would be to locate sites within each assessment unit, based on each broad condition state and RE. However, the purpose of the assessment and resources available to conduct an assessment of an area will ultimately influence the size and number of units to assess. For example, the purpose of an assessment may be to assist with prioritising ameliorative management practices within remnant and regrowth Endangered REs. Delineation of assessment units would then be restricted to remnant and regrowth Endangered REs, and exclude non-remnant vegetation.

It is best to generate a map of the area to be assessed showing the extent and types of remnant vegetation, the distribution of any mapped regrowth vegetation, the distribution of pre-cleared vegetation (if required), the position of roads, watering points and the location of fence lines so that assessment units can be mapped and area statements derived. This map can then be used in advance of conducting field assessments, to plan the locations of the assessment sites. Free RE maps and regrowth maps are available as downloadable hard copy maps for properties and as digital data from the Regional Ecosystems area of EHP's website www.ehp.qld.gov.au and Queensland government data website (https://data.qld.gov.au/). RE mapping is also available using the Biota Globe in the Queensland Globe using Google Earth (www.dnrm .qld.gov.au/). The hard copy maps and digital data can be used to produce a map specific for the area. The applicability of the RE mapping should be assessed in the field to check if it is relevant at the scale at which the assessment is being conducted. REs are defined at scales which range from 1:50 000

(e.g. South East Queensland) to 1:100 000 (e.g. rangeland bioregions) and a single polygon may contain several mapped REs (heterogeneous polygons).

Box 4: Definition of remnant vegetation and regrowth vegetation for delineating assessment units

Remnant vegetation is defined under the *Vegetation Management Act 1999* as vegetation shown on a regional ecosystem or remnant map.

Where there are no maps available, remnant vegetation is defined as vegetation where the dominant canopy has greater than 70% of the height and greater than 50% of the cover relative to the undisturbed height and cover of that stratum and dominated by species characteristic of the vegetation's undisturbed canopy.

In grassland ecosystems, remnant status is assigned to grasslands that;

    a)   Have not been ploughed in the last 15 years (generally detectable on Landsat imagery) and;
    b)   Contain >20% of the native species normally found in the ecosystem under the same ecological and seasonal conditions (as defined in benchmark documents or REDD) and;
    c)   Have a high ratio of native species to exotic species (>5:1).

High-value regrowth vegetation is defined under the *Vegetation Management Act 1999* as vegetation;

    a)   Located in areas that has not been cleared since 31 December 1989 and that is an endangered, of concern or a least concern regional ecosystem.
    b)   Under the Act, the definition applies to vegetation located on a lease issued under the Land Act 1994 for agriculture or grazing purposes (i.e., not freehold land). However, for the purposes of delineating assessment units for BioCondition, then the above definition can be used.

Non-remnant vegetation is defined as all vegetation that is not mapped as remnant vegetation or regrowth vegetation, as defined above.

Non-remnant vegetation can be further delineated to include;

    a)   young woody regrowth, defined as woody vegetation of any endangered, of concern or least concern regional ecosystem that has been cleared since 31 December 1989. This can be mapped using SLATS woody cover and assigned to the most likely regional ecosystem by referring to the pre-clearing regional ecosystem mapping.
    b)   significantly modified vegetation that fails to meet the structural and/or floristic characteristics of remnant vegetation, and is not mapped as regrowth or cannot be mapped as young woody regrowth. It also includes urban and cropping land, and modified grasslands that do not match the criteria for remnant status.

3.2 Number and location of sites

As a guide it is best to aim for two to five sites per assessment unit, dependant on the area of each unit (i.e. assessment unit <60 ha, aim for at least two sites, assessment unit >500 ha, aim for five sites). Select a site location that is representative of the unit you are assessing, and at least 50 m from any major disturbance, such as a road or a dam. Also aim to locate sites at least 1 km apart. This is particularly important if it is intended to survey fauna at the sites, to ensure independence of the data between sites assessed (Eyre *et al.* 1998).

3.3 When to assess

It is not favourable to sample during the peak of summer or following a period of drought due to a reduction in plant diversity. The best time for assessment is at the end of the summer rainfall growing season, when plant diversity is greatest. For the majority of Queensland, this is often from late March to late May, but is dependent on local seasonal conditions. As a general rule of thumb, site assessment north of the Tropic of Capricorn should generally be conducted after the wet season, ideally between March and May, to ensure adequate sampling of ground cover species (Neldner *et al*. 2004). South of the Tropic of Capricorn, site assessment should be generally conducted in May or June following the wetter summer months. An exception would be sampling in spring following an unseasonably wet winter, when many plant species are flowering.

It is not always possible to assess condition during optimal times, particularly in areas experiencing long-term drought. In these cases, it is recommended that a "local" reference site/s within the RE of interest and representing the desirable condition state (i.e. mature and relatively undisturbed or a BOO site) is located and used to generate interim benchmarks with which the BioCondition assessment site can be compared. The reference site/s should be measured at the same time as the BioCondition sites to account for variation due to seasonal or drought effects, particularly in the attributes i) species richness; ii) tree canopy cover; and iii) perennial grass cover.
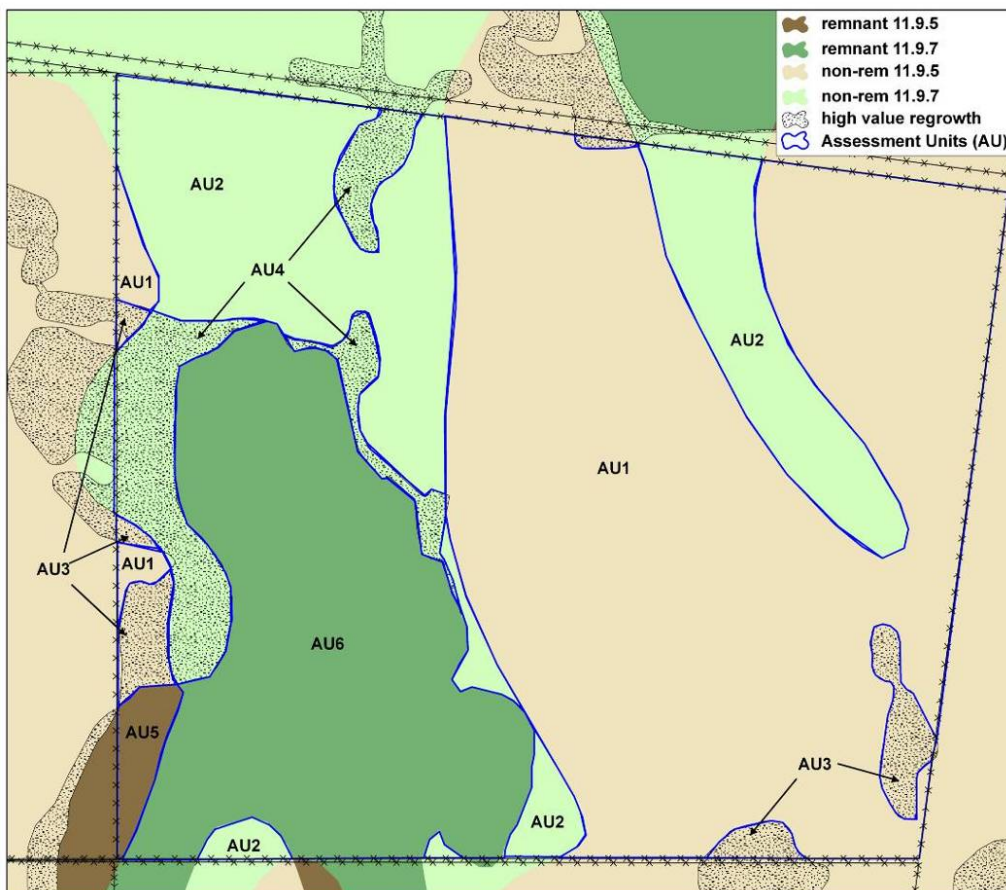
Figure 1: Assignation of the assessment unit

In this example (Figure 1), six assessment units (AU) have been identified for a paddock. AU1 represents an assessment unit delineated by a non-remnant area of brigalow and belah scrub 11.9.5 (mapped using the pre-cleared RE mapping); AU2 is non-remnant poplar box woodland 11.9.7; AU3 is regrowth RE 11.9.5 or; AU4 is regrowth RE 11.9.7; AU5 is remnant RE 11.9.5; and AU6 is remnant RE 11.9.7.

3.4 Setting up the assessment site

Details of the site assessment are presented here. A quick field guide is provided in Appendix 1. The assessment site constitutes a 100 m x 50 m (0.5 ha) area, within which 10 site-based attributes are measured. This correlates to the habitat and BioCondition reference site assessment area used to identify benchmarks for attributes (Eyre *et al.* 2011).

The site should be marked out by laying out a 100 m centre-line transect that follows the contour, i.e. along a slope as opposed to up or down a slope. Mark the 50 m point on the transect with a star picket or tyre on the ground[1]— this point acts as the centre of the assessment site. For REs characterised by a tree layer, marking out 25 m either side of the transect line forms the larger assessment area of 100 x 50 m. A greater need arises for precision when assessing the numbers of large trees within the site (it may require measuring out the distance when trees appear to be 'borderline' within the site). The assessment of the ten site-based attributes is conducted within five assessment areas within the 100 x 50 m site, as shown in Figure 2, and summarised as follows:

1. 100 x 50 m area: assessed for number of large trees, recruitment of canopy species, tree canopy height and native tree species richness. In long, linear assessment units (e.g. riparian areas), it may be necessary to adjust the configuration of the 100 x 50 m plot area so that these attributes are adequately sampled. In these cases, it is recommended that the plot area remains the same, if possible e.g. extend the length of the plot to 200 m, but reduce the width of the plot to 25 m.

2. 100 m transect: assessment of tree canopy cover and native shrub canopy cover.

3. 50 x 10 m sub-plot, centred from the 25 m point to the 75 m point along the centre transect, and encompassing 5 m either side of the transect: assessed for non-native plant cover and native plant species richness of shrubs, grass and non-grass species. This equates to the CORVEG standard plot area used by the Queensland Herbarium (Neldner et al. 2012).

4. 50 x 20 m sub-plot, centred from the 25 m point to the 75 m point along the transect, and encompassing 10 m either side of the transect: assessed for coarse woody debris.

5. Five 1 x 1m quadrats, starting at the 35 m point and located on alternate sides of the centre-line, 10 m apart along the 100 m transect: assessed for native grass cover and organic litter (an average value is derived over the five quadrats).

Photographs are recommended to be taken each time a BioCondition assessment is undertaken (Appendix 4). Spot photos of the 1 x 1 m quadrats can be taken to document change in ground cover over time, while a landscape or series of landscape photos provides a record of the tree and shrub layers and the general condition of the site. At the centre point of the transect it is useful to take four photos north, south, east and west of the 50 m plot centre.

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[1] In more open areas, where there are cattle present, tyres can be preferential due to the tendency of cattle to use star pickets as scratching posts leading to concentrated disturbance around the posts.

The figure shows a 100 × 50 m plot layout with measurements:

100 × 50 m plot
- Large trees
- Tree canopy height
- Recruitment of canopy species
- Native tree species richness

100 m transect
- Tree canopy cover
- Native shrub cover

50 × 20 m plot
- Coarse woody debris

50 × 10 m plot
- Native shrub, grass, and forbs/other species richness
- Non native plant cover

1 × 1 m quadrats
- Native perennial grass cover
- Organic litter cover

Figure 2: BioCondition field site area and layout

4 The assessable attributes and scores

A full species survey or census to quantify the biodiversity values of a patch of vegetation is expensive to conduct and requires high levels of technical expertise. As such, use of indicators of biodiversity, or measurable surrogates of biodiversity, is a relatively reliable and cost effective approach to assess or monitor biodiversity (Noss 1990, Sarkar and Margules 2002, McElhinny *et al.* 2005). At the site scale, biodiversity indicators are either based on key or 'indicator' species or structural aspects of the vegetation that are known to be important for biodiversity values (Lindenmayer *et al.* 2000; Parkes *et al.* 2003; McElhinny *et al.* 2005).

The approach using key indicator species is limited because relationships between species and biodiversity are yet to be established (Lindenmayer and Cunningham 1997; Margules *et al.* 2002), as well as other inherent issues with survey conditions and how these can influence detectability of species (e.g. Wayne *et al.* 2005). Experience and skills in species detection and identification can also limit efficacy of direct assessment of species. However, indicators based on key vegetative structural elements are proving to be a more reliable and cost effective approach for the assessment of biodiversity, and form the basis of assessment of vegetation condition elsewhere in Australia (Parkes *et al.* 2003; Oliver and Parkes 2003; Gibbons *et al.* 2008).

The suite of assessable attributes in BioCondition was selected based on:

- known or perceived surrogacy for biodiversity values and representation of ecological processes relative to composition, structure and function (Table 2)
- ease of measurability in field situations
- known or perceived sensitivity to change
- lack of correlation between each other
- ability to allow discrimination between sites
- value in educating or instructing on biodiversity values.

The dwarf grey skink (*Menetia greyii*) (left) and Burnett's skink (*Carlia foliorum*) both need woody debris and organic litter as habitat.

Table 2: Summary of the functional role of vegetation for biodiversity and indicators of those functions

Vegetation functions	Attributes that act as indicators of the functions
Structural aspects	
Provision of reliable foraging resources for wildlife (e.g. nectar, leaves, seeds)	Large trees Shrub cover Tree canopy cover Native perennial grass Coarse woody debris Organic leaf litter Ground cover
Provision of reliable sheltering resources and or breeding sites for wildlife	Large trees and/or hollow-bearing trees Coarse woody debris Tree canopy cover Shrub cover Organic litter Perennial grass cover
Functional aspects	
Nutrient and water cycling	Tree canopy cover Organic litter cover Coarse woody debris
Maintenance of soil condition	Organic litter cover Native perennial 'decreaser' grass species basal area Native perennial non-grass cover Coarse woody debris
Retention of plant propagules	Organic litter Coarse woody debris
Compositional aspects	
Maintenance of plant species diversity	Native plant species richness Recruitment of canopy species Native perennial 'decreaser' grass species basal area Non-native plant species cover (lack of)

4.1 The assessable attributes

In BioCondition, attributes are weighted to standardise relative 'importance', meaning the degree to which the attribute:

- has a potential impact upon long-term condition (e.g. non-native plants)
- is difficult or takes a long time to replace in a system if lost (e.g. large trees)
- has habitat value based on empirical research.

The attributes of biodiversity that are assessable in BioCondition, and their relative weightings that contribute to the overall condition score, are shown in Table 3.

Attributes collected for the BioCondition assessment represents the minimum that should be collected to make a robust condition assessment. In BioCondition, the assessor will need to distinguish between dominant plant species, although it is not required that they identify what those species are, although they will need to be able to distinguish between native and non-native species[2]. If sufficient expertise exists, assessors are encouraged to collect more comprehensive data, e.g. identify and list species present in each layer as a way of value adding to the information collected at each site.

Table 3: The assessable attributes and weightings for deriving the final BioCondition score

	Attribute	Weighting (%)
Site-based condition attributes	Large trees	15
	Tree canopy height	5
	Recruitment of canopy species	5
	Tree canopy cover (%)	5
	Shrub layer cover (%)	5
	Coarse woody debris	5
	Native plant species richness for four lifeforms	20
	Non-native plant cover	10
	Native perennial grass cover (%)	5
	Litter cover	5
Landscape attributes (fragmented subregions[3])	Size of patch	10
	Context	5
	Connectivity	5
OR Landscape attributes (intact subregions)	Distance to permanent water	20
TOTAL		100

4.2 Assessing regional ecosystems with naturally missing attributes

For treeless or non-woody species dominant REs, e.g. grassland REs (as defined in the glossary), the woody-type site attributes such as tree canopy cover, tree canopy height, large trees etc are not assessable and the final condition score is standardised accordingly. A similar standardisation is made for shrubland REs, which naturally lack large trees and coarse woody debris, and mangrove ecosystems, which naturally occur without native perennial grass cover. In such cases,

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[2] Trials performed by a range of assessors with varying levels of botanical knowledge found that the native species richness counts were within 10% of each other.

[3] See Section 6 for definition and locality map of bioregions and subregions that contain fragmented landscapes, and bioregions and subregions that contain intact landscapes.

the benchmark value will be zero for these attributes, thus the maximum score for the attributes is adjusted to zero. **In general, if the benchmark document gives a zero for an attribute, then the attribute is discounted from the final score.** This has the effect of standardising the scoring for these REs to between 0 and 1 when calculating the total BioCondition score.

A grassland ecosystem, which naturally does not contain trees or shrubs, gets a maximum score of 50, incorporating a total possible score of 30 for the site-based attributes, plus a further possible score of 20 for the landscape scale attributes (Table 4). Similarly, a mangrove ecosystem which does not support grasses or litter means the attributes grass species richness, perennial grass cover and litter cover are not included in the BioCondition assessment or scoring procedure (Table 4). If the total score for an assessment site in grassland is 50, then it's standardised BioCondition score is 1.0, while a total score of 50 in a mangrove ecosystem would give a BioCondition score of 0.59, and in a wooded non-mangrove ecosystem the BioCondition score is 0.5.

Table 4: The assessable attributes and weightings in ecosystems where attributes are naturally absent

Attribute	Wooded ecosystems Weighting (%)	Grassland ecosystems Weighting (%)	Shrubland ecosystems Weighting (%)	Mangrove* ecosystems Weighting (%)
Site-based Large trees	15	0	0	15
Tree canopy height	5	0	0	5
Recruitment of dominant canopy species	5	0	5	5
Tree canopy cover (%)	5	0	0	5
Shrub layer cover (%)	5	0	5	5
Coarse woody debris	5	0	0	5
Native plant species richness - Trees	5	0	0	5
- Shrubs	5	0	5	5
- Grasses	5	5	5	0
- Other	5	5	5	5
Non-native plant cover	10	10	10	10
Native perennial grass cover (%)	5	5	5	0
Litter cover	5	5	5	0
Total site score	**80**	**30**	**45**	**65**
Landscape Size of patch	10	10	10	10
Context	5	5	5	5*
Connectivity	5	5	5	5
OR Distance to artificial water	20	20	20	N/A
Total landscape score	20	20	20	20
TOTAL BioCondition SCORE	100	50	65	85

* ocean may be included as 'remnant'

5 Assessment of site-based attributes

5.1 100 x 50 m plot

5.1.1 Large trees

Large trees are an important resource within forest and woodland ecosystems. They provide greater leaf material, nectar and bark-surface area for foraging purposes, and are more likely to contain hollows and crevices for nesting and sheltering purposes. Large trees are defined as the number of living trees per hectare with a diameter at breast height (DBH) greater than the DBH threshold provided in the benchmark document. Native trees larger than the DBH threshold are counted within the 100 x 50 m assessment area (i.e. 0.5 hectare, this value will need to be doubled to compare with the benchmark value).

In some REs a large tree DBH threshold will be identified for both eucalypt[4] and non-eucalypt tree species due to the natural variation in potential size. For example, a mature mulga tree (*Acacia aneura*) can never reach the size of a mature poplar box (*Eucalyptus populnea*), therefore the large tree DBH threshold is smaller for mulga than for poplar box. Where the benchmark document specifies different diameter thresholds for large eucalypt and non-eucalypt trees, the benchmark number of large trees will be the number of large eucalypts and the number of large non-eucalypts added together to give one per hectare value which is then scored using Table 5. An example of scoring large trees is given in Box 5.

Table 5: Description and scores for the number and habitat value of large trees

Description	Score
No large trees present	0
0 to 50% of benchmark number of large trees	5
≥50% to 100% of benchmark number of large trees	10
≥ benchmark number of large trees	15

Box 5: Example of scoring large trees

Scoring large trees

RE 11.4.12: Benchmark document has a DBH threshold for eucalypts as 58 cm with the 12 large trees per ha. For non-eucalypts the DBH threshold is 26 cm with 16 large trees per ha. The benchmark is 12 + 16 = **28 large trees per ha**.

During the BioCondition assessment 6 large eucalypt trees (>58 cm DBH) were counted (i.e. 12 large eucalypt trees per ha) and 3 large non-eucalypt trees (>26 cm DBH) were counted (i.e. 6 large non-eucalypt trees per ha).

The assessment gives **18 large trees per ha**. This is within 64% of the benchmark value (i.e. 18/28 = 64%), which means the score will be on the third row of Table 10, receiving a score of **10.**

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[4] Eucalypt includes species of genera *Eucalyptus, Corymbia, Angophora, Lophostemon* and *Syncarpia*.

5.1.2 Tree canopy height

Tree height is indicative of stand development and site productivity and is relatively simple to measure. Tree height and cover are used by the Queensland Herbarium in the definition of remnant vegetation in the production of the RE mapping (Neldner *et al.* 2012).

Tree canopy height (measured to the top of the highest leaves) refers to the median canopy height in metres, estimated for the trees in the ecologically dominant layer (EDL) or canopy layer (see Box 6) within the 100 x 50 m assessment area. The median canopy height is the height that has 50% of canopy trees higher and lower than it (Figure 3). This is generally synonymous with average height except when there are some trees that are substantially higher or lower than the median (Neldner *et al.* 2012). Description and scoring categories for assessing tree height are given in Table 6. A reliable method for assessing tree height is provided in Appendix 5. It is recommended that a clinometer or hypsometer be used if available.

For this attribute, if there is a distinct emergent or subcanopy layer in the appropriate RE benchmark, the height of each these layers (EDL, emergent and subcanopy) is measured and scored separately. In these cases, the score for each is then averaged to give one score for tree height. For disturbed/regrowth sites, which frequently only have one diffuse layer, the canopy height of the species present is compared to the values in the appropriate layer in the benchmark.

Box 6: Identifying vegetation layers for BioCondition assessment

In BioCondition, assessment of the **tree height**, **recruitment** and **tree canopy cover** attributes require consideration of the vegetation layers or strata that typify the RE of interest.

Where there is an emergent tree layer identified in the appropriate RE benchmark document, e.g. widely scattered popular box (*Eucalyptus populnea*) trees emerging above a dominant canopy of mulga (*Acacia aneura*), then the emergent layer species are assessed separately from the EDL species for the purposes of these three attributes. Similarly if a subcanopy layer is identified in the appropriate RE benchmark because it contributes a significant amount of biomass to the vegetation, e.g. a conspicuous subcanopy layer of *Allocasuarina littoralis* under a canopy of *Eucalyptus crebra*, then the subcanopy layer is assessed as well as the EDL species for the three attributes. The process for stratifying the vegetation into layers and examples are given in **Appendix 6**.
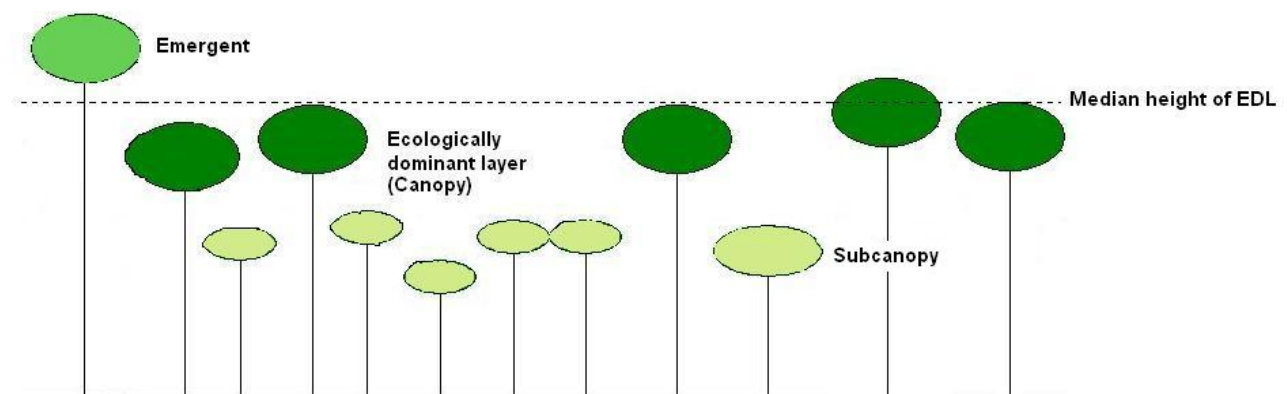
Figure 3: Median height of the ecologically dominant Layer (EDL)

Table 6: Description and scores for tree canopy height

Description	Score
<25% of benchmark height	0
≥25% to 70% of benchmark height	3
≥70% of benchmark height	5

5.1.3 Recruitment of dominant canopy species

Recruitment or regeneration is essential to the sustainability of any ecosystem. Some land management practices, such as burning or grazing, and natural processes such as drought, can affect the processes required for natural regeneration.

The recruitment attribute assesses the presence of regeneration of the dominant canopy species in the 100 x 50 m assessment area. The canopy equates to the EDL for forests and woodlands, plus the emergent and subcanopy layers if they contribute a significant amount of biomass (Box 6 and Appendix 6). Where the EDL is the shrub layer, then the recruitment of the dominant species from this layer and any emergent tree layer are included for this attribute. Due to the seasonal and therefore ephemeral nature of non-woody vegetation, the assessment of recruitment is restricted to woody perennial species only.

Recruitment is assessed as the proportion of dominant species present at a site that are regenerating, i.e. having individuals with a DBH <5 cm. For example, if four dominant canopy species occur at the site, but only two of these species are present as regeneration, then the proportion is 50%. This would be allocated a BioCondition score of 3 (Table 7).

Table 7: Description and scores for the recruitment of canopy species

Description	Score
<20% of dominant canopy* species present as regeneration	0
≥20 – 75% of dominant canopy* species present as regeneration	3
≥75% of dominant canopy* species present as regeneration	5

*canopy species are those species listed in the RE benchmark in the EDL, emergent and subcanopy layers or as identified in the RE description (REDD database) that make up the dominant proportion of the EDL, emergent and subcanopy layers (but does not include those listed as occurring as scattered individuals).

Note: As only the dominant species are assessed for Recruitment, not all of the species counted during the assessment of Native Tree[5] Species Richness (Section 5.1.4) will necessarily be included in the assessment of this attribute.

5.1.4 Native tree species richness

The richness of plants or flora species is recognised as an important attribute to assess in studies related to the assessment of condition for biodiversity. Not only does it reflect a portion of the

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[5] Or shrubs in the case of shrub lands

biodiversity present on site, the number, and abundance of plant species can have a direct relationship on the fauna present and influence a whole range of functional processes reflective of the condition of a stand.

To simplify measurement, native plant species richness, rather than diversity (diversity measures incorporate abundance), is estimated for four life-forms: trees, shrubs, grasses and forbs/other (see Appendix 7 for a list of life-form groups categorised for BioCondition and Appendix 8 for a description of those life-forms). For native tree species richness assessment is based on the number of native tree species observed in the 100 x 50 m plot. For all other life forms (shrubs, grasses, forbs/others) species richness is assessed in the 50 x 10 m plot (see Section 5.4.1). Native tree species richness is scored with the other life-forms as described in Table 11.

5.2 100 m transect

5.2.1 Tree canopy cover

Tree canopy cover can be used to characterise stand productivity and the distribution and abundance of biomass (McElhinny 2002). It refers to the estimation of the percentage canopy cover of the living, native tree layer along the 100 m transect, using the line intercept method (Greig-Smith 1964). For this attribute, only the cover of the species making up the EDL or tree canopy cover is assessed for the majority of REs. Canopy cover equates to crown cover as defined by Walker and Hopkins (1990). The vertical projection of the tree canopy over the 100 m transect is recorded. The total length of the projected canopy of each layer is then divided by the total length of the tape to give an estimate of percentage canopy cover on the site, which then can be compared with the benchmark value. Over-abundance or under-abundance (e.g. thinning) in the tree canopy will result in lower scores (Table 8).

If there is, or should be, a distinct emergent or subcanopy layer (this will be defined by the benchmark document for the assessable RE), then the canopy cover of each of these layers (EDL, emergent and subcanopy) is assessed separately, then averaged to give one score for tree canopy cover. If exotic species are present in the canopy (e.g. camphor laurel *Cinnamomum camphora*, exotic pines *Pinus* spp.) then cover of these can be measured separately and indicated with an asterisk (*) but will not form part of the final scoring for the site. Figure 4 and Box 7 provide an example of tree canopy cover assessment and scoring.

Table 8: Description and scores for tree canopy cover

Percentage of Tree Canopy (EDL) Cover [6] relative to Benchmark	Score
<10% of benchmark	0
≥10% and <50%	2
≥50% or ≤200%	5
>200%	3

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[6] (and Emergent and Subcanopy if these layers are identified in the benchmark document)
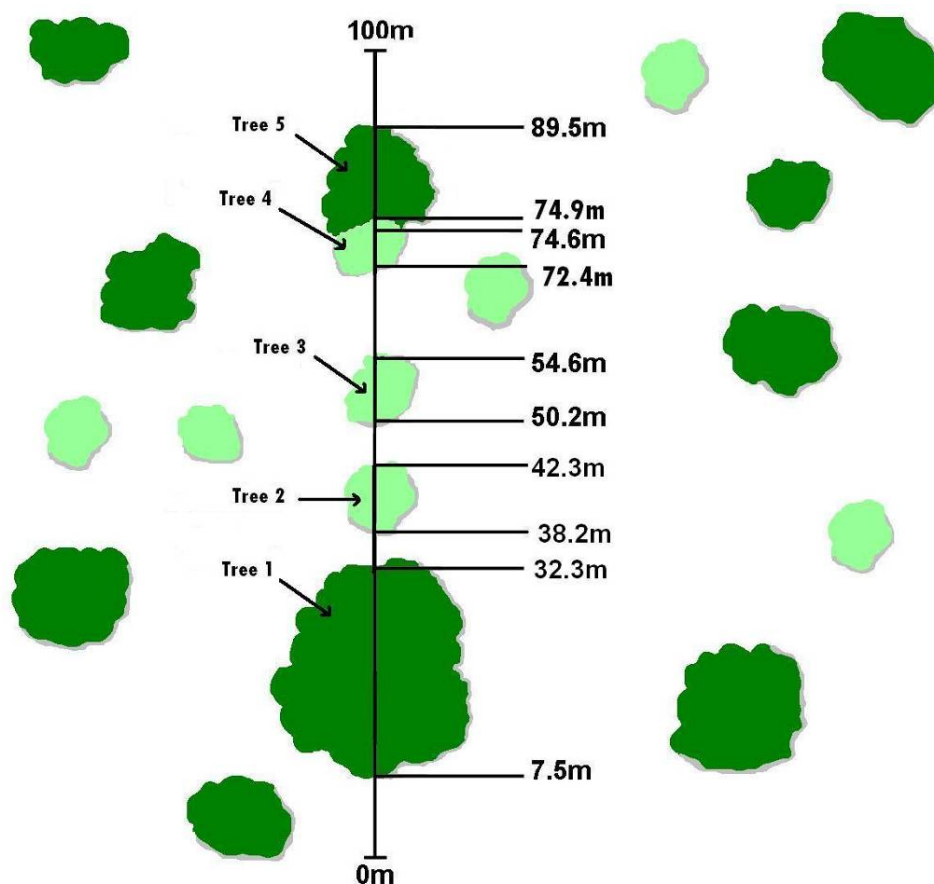
Figure 4: Example of assessing canopy cover percentage

Box 7: Example of scoring tree canopy cover

In Figure 4, this regional ecosystem has a canopy (EDL) and a subcanopy.

The canopy cover (EDL) is **39.7%**, calculated as:

= (canopy cover Tree 1) + (canopy cover Tree 5)

= (32.3–7.5) + (89.5–74.6)   = 24.8 + 14.9   **= 39.7%**.

If the canopy benchmark for this regional ecosystem is **42%**, then the assessment is within **95%** of the benchmark (i.e. **39.7/42 = 94.5%**). This corresponds with the third row of Table 8, with a score of **5**.

The subcanopy cover is 11%, calculated as:

= (cover Tree 2) + (cover Tree 3) + (cover Tree 4)

= (42.3 – 38.2) + (54.6 - 50.2) + (74.9 –72.4)   = 4.1 + 4.4 + 2.5   **= 11%**

This is compared to the subcanopy benchmark of 30%, so the assessment is within 37% of the benchmark (i.e. **11/30 = 36.6%**), which corresponds with the second row of Table 8. Therefore, the assessment would receive a score of **2** for the subcanopy cover layer.

The averaged, final score for tree canopy cover is 3.5 (i.e. 5 [canopy] + 2 [subcanopy] = 7/2)

2

5.2.2 Shrub cover

Shrub canopy cover refers to the estimate of the percentage cover of native shrubs recorded along the 100 m transect (similar to the estimation of tree canopy cover using a vertical projection of shrub crowns downwards over the centre line transect). Management and disturbance can result in shrub cover that is either insufficient, which has been shown to reduce habitat quality for birds in Queensland (Eyre *et al.* 2009a), or excessive, which may not represent a stable state, particularly in the rangelands (Witt *et al.* 2009). Consequently, the score is reduced if shrub cover is either under-abundant or overabundant (>200%) relative to the benchmark (Table 9). This is to account for the issue of woody vegetation thickening, which can arise under particular climatic conditions from the interactions of varying fire and grazing regimes. If non-native shrubs (e.g. *Lantana* spp.) are present along the transect line, these can be measured separately and indicated with an asterisk (*) but will not form part of the scoring of the site.

Table 9: Description and scores for shrub cover

Description	Score
<10% of benchmark shrub cover	0
>/= 10 to <50% or >200% of benchmark shrub cover	3
≥50% or ≤200% of benchmark shrub cover	5

5.3 50 x 20 m plot

5.3.1 Coarse woody debris

Coarse woody debris (CWD) is an important component in many aspects of ecosystem functioning (Woldendorp *et al.* 2002; Mackensen *et al.* 2003). It is primarily measured as a habitat surrogate for ground-dwelling fauna (MacNally and Horrocks 2002), but can also be used as a variable in the estimate of carbon biomass, and as an indicator of management disturbance (Eyre *et al.* 2010).

In BioCondition, coarse woody debris refers to logs or dead timber on the ground that is >10 cm diameter and >0.5 m in length (and more than 80% in contact with the ground). Assessment is conducted by measuring the length of all fallen woody logs and other coarse woody debris (>10 cm diameter and >0.5 m in length) to the boundary of the 50 x 20 m plot (i.e. 0.1 ha). The total measured value is multiplied by 10 for comparison with the benchmark which is a metre per hectare value). Scores are lower for sites where there is an over-abundance of CWD (Table 10), because in some ecosystems, such as silviculturally managed cypress pine, an overabundance of CWD is indicative of disturbance from selective clearing or silvicultural treatment.

Table 10: Description and scores for number of CWD

Description	Score
<10% of benchmark number or total length of CWD	0
>/= 10 to <50% or >200% of benchmark number or total length of CWD	2
≥50% or ≤200% of benchmark number or total length of CWD	5

5.4 50 x 10 m plot

5.4.1 Native plant species richness

To simplify measurement, native plant species richness, rather than diversity (diversity measures incorporate abundance), is estimated for four life-forms: trees, shrubs, grasses and forbs/other (see Appendix 7 for a list of life-form groups categorised for BioCondition and Appendix 8 for a description of those life-forms). For a species that may occur in a number of layers with different lifeforms, for example, *Acacia harpophylla,* which may occur as a tree in the canopy and also as a shrub in the shrub layer, then the species is counted for each layer it occurs in. Where a species has two lifeforms in the same layer, such as *Acacia aneura,* which may have a single stemmed 'tree' lifeform as well as multi-stemmed 'shrub' lifeform in the same layer, then it is classed as the most frequent lifeform in that layer. Assessment is based on the number of native shrub, grass and forb/other species observed in the 50 x 10 m plot for each benchmarked life-form group (Table 11). Native tree species richness is assessed over the 100 x 50 m plot (see Section 5.1.4).

Table 11: Description and scores for native plant species richness for each life form

Description	Score
<25% of benchmark number of species within each life-form	0
≥25% to 90% of benchmark number of species within each life-form	2.5
≥90% of benchmark number of species within each life-form	5

5.4.2 Non-native plant cover

Non-native plants are introduced or exotic plant species that cause major modification to native species richness, abundance and ecosystem function (Humphries *et al.* 1991: Grice 2004). Generally, two types of non-native plant invasion are recognised: introduction of exotic plants and movement of native species into new areas well outside their natural range. In the Australian rangelands, there are limited studies that quantify the effects of non-native plants on fauna, although the few studies available suggest a negative net effect (Grice 2004). The establishment of exotic pastures e.g. buffel grass *Cenchrus ciliaris* has been associated with a loss in native species and alterations in fire regimes (Fensham and Fairfax 2000; Franks 2002; Jackson 2005; Eyre *et al.* 2009b).

Non-native plant cover is the percentage cover of the total vegetation cover that is comprised of exotic and non-indigenous species, assessed within the 50 x 10 m sub-plot. Where there are non-native plants present in more than one layer, such as a grass in the ground layer and shrub in the shrub layer, then the cover in each layer are added together. The benchmark for non-native plant cover for any ecosystem type is zero (Table 12).

Table 12: Description and scores for non-native plant cover

Description	Score
>50% of vegetation cover are non-native plants	0
≥25 – 50% of vegetation cover are non-native plants	3
≥5 – 25% of vegetation cover are non-native plants	5
<5% of vegetation cover are non-native plants	10

5.5 1 x 1 m quadrats

5.5.1 Native perennial grass cover

In earlier versions of BioCondition, three components of the ground layer were scored based on cover: perennial grass species; perennial forb (non-grass) species; and annual grass and forb species. Perennial forb cover and annual species cover are no longer assessable in BioCondition as many assessors are not confident about the identification of annual species (Kelly et al. 2011), and there is high correlation between forb and perennial grass cover and that there is wide inter- and intra-seasonal variation that can occur particularly in the drier parts of Queensland.

Perennial grass cover refers to the average percentage cover of native perennial grasses, assessed within each of the five 1 x 1 m quadrats and averaged to give a value for the site which is then scored against the benchmark value (Table 13). The ground cover is measured by a vertical projection downwards of the living and attached plant material. A stylised guide is provided in Figure 5 to help estimate cover percent. This cover equates to the projected foliage cover in Walker and Hopkins (1990).

Table 13: Description and scores for native perennial grass species cover

Description	Score
<10% of benchmark native perennial (or preferred and intermediate) grass cover	0
≥10 to 50% of benchmark native perennial (or preferred and intermediate) grass cover	1
≥50 – 90% of benchmark native perennial (or preferred and intermediate) grass cover	3
≥90% of benchmark native perennial (or preferred and intermediate) grass cover	5
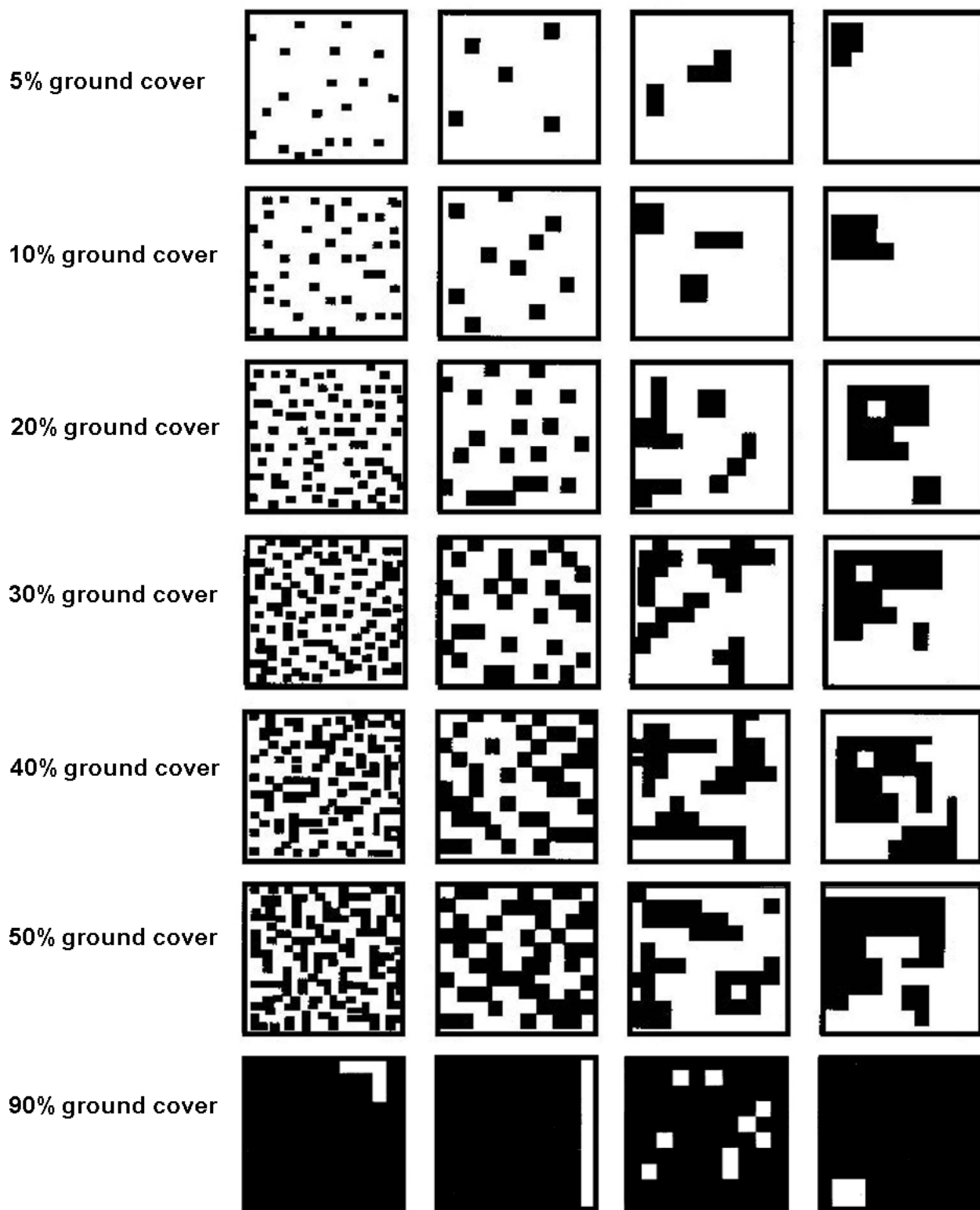
Figure 5: Stylised examples of ground cover proportions.

Various ground cover amounts (%) can be evenly spread across the quadrat or distributed in patches.

5.5.2 Organic litter

Litter is described as a key habitat component for wildlife and woodland functioning (McIntyre *et al.* 2002). Leaf and woody litter protects the soil from erosion and its decomposition provides continual nutrient supply into the ecosystem. It supports a diverse range of invertebrates, which in turn provide a food source for vertebrate species.

Litter is defined as including both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter. Organic litter cover refers to the average percentage cover assessed within each of the five 1 x 1 m quadrats. Note that within a quadrat, the sum of the native ground cover (shrubs, grasses and forbs etc), non-native plant ground cover, organic litter (including any CWD) and bare ground/rock cover should equal 100%.

Sites with over-abundance as well as under-abundance of organic litter cover receive lower scores (Table 14).

Table 14: Description and scores for percentage of organic litter

Description	Score
<10% of benchmark organic litter	0
≥ 10 to <50% or >200% of benchmark organic litter	3
≥50% or ≤200% of benchmark organic litter	5

Litter provides shelter during the day for ground geckos like this foraging thick-tailed gecko *Underwoodisaurus milii.*

6 Assessment of landscape-scale attributes

The context of the landscape surrounding the site is also assessed in BioCondition. This is because landscape context is known to have a significant influence on the long-term viability of the habitat patch for biodiversity values (Andren 1994; Fahrig 1997, 2001).

Landscape context does not only refer to fragmented landscapes with sharp or high contrast edged boundaries (e.g. vegetated versus cleared boundaries), but also intact landscapes where there are gradients of habitat quality or low contrast edges (e.g. increased grazing disturbance with distance from water points). These concepts correlate with 'abrupt' or 'gradual' boundaries used in landscape ecology (McIntyre and Barrett 1992; McAlpine and Eyre 2002).

In BioCondition, landscape context attributes are scored using different attributes depending upon whether the assessment is within a *fragmented landscape* (patch size, connectivity and context), or an *intact landscape* (distance to water). Fragmented landscapes can be defined as areas where the amount of remnant vegetation is less than 65% (McIntyre and Hobbs 2000). This includes subregions in South East Queensland, Brigalow Belt, New England Tableland, Central Queensland Coast and Wet Tropics bioregions. It also includes the West Balonne Plains, Eastern Mulga Plains, Nebine Plains, North Eastern Plains and Langlo Plains subregions in the Mulga Lands bioregion and the Jericho subregion in the Desert Uplands bioregion (Accad *et al.* 2010). Other subregions in the Mulga Lands, and Cape York Peninsula, Einasleigh Uplands, Gulf Plains, Northwest Highlands, Mitchell Grass Downs, Desert Uplands and Channel Country can be defined as intact landscapes (Figure 6).

The landscape context attributes are best calculated using data stored in Geographical Information Systems (GIS). RE mapping (remnant) and regrowth (non-remnant) vegetation mapping can be used to assess landscape context and is available from the Regional Ecosystem Maps section of the Queensland Government QSpatial website (http://qspatial.information.qld.gov.au/IQAtlas/) and the Queensland government data website (https://data.qld.gov.au/). Alternatively, Appendix 9 provides a method for the calculation of area using aerial photographs.
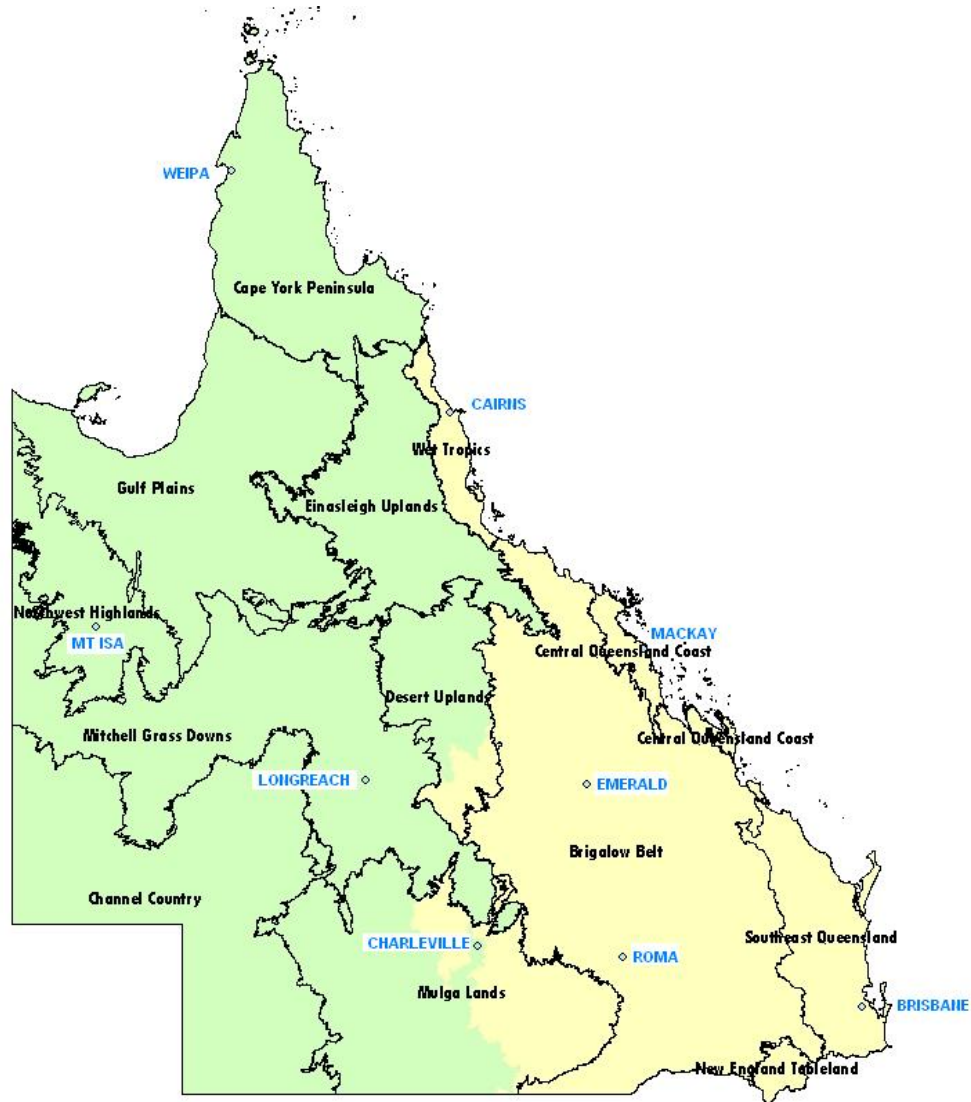
Figure 6: Fragmented (yellow) and intact (green) regions of Queensland

6.1 Fragmented landscapes

6.1.1 Size of patch

This attribute is a measure of the size of the patch of vegetation in which the assessment unit is located. The scoring reflects the importance of large patches in the landscape, and is based on the size of a patch of either remnant vegetation, or regrowth vegetation, or a combination of remnant and regrowth vegetation (Table 15). Larger patches are less susceptible to ecological edge effects and are more likely to sustain viable populations of native flora and fauna than smaller patches (McIntyre *et al.* 2000; Lindenmayer *et al.* 1999). Larger patches are also less susceptible to propagule pressure from exotic pasture species such as buffel grass (Eyre *et al.* 2009b).

The assessment unit may form a component of a patch that includes a range of other units of REs of varied condition states. For BioCondition assessments, an estimate of patch area will include any remnant or regrowth vegetation (i.e. irrespective of RE or tenure) that is contiguous with the assessment unit (Figure 7). In cases where the assessable patch is connected to larger areas of remnant vegetation, but through narrow corridors (<200 m in width) within 1 km radius of the site, then these areas should be treated as a different patch and not included in the calculation of patch size (e.g. Figure 8).

Patch size is assessed for vegetation mapped as either remnant and/or regrowth. Regrowth is included in the assessment of patch size in recognition of its contribution to increasing or maintaining biodiversity values, particularly in highly modified landscapes (Bowen *et al.* 2007).

Table 15: Description and scores for size of patch

Description	Score
<5 ha remnant **AND/OR** regrowth	0
≥5 – 25 ha remnant **AND/OR** regrowth	2
≥25 – 100 ha remnant **OR** ≥25 – 200 ha remnant and regrowth **OR** ≥25 – 200 ha regrowth	5
≥100 – 200 ha remnant **OR** >200 ha remnant and regrowth **OR** >200 ha regrowth	7
≥200 ha remnant	10
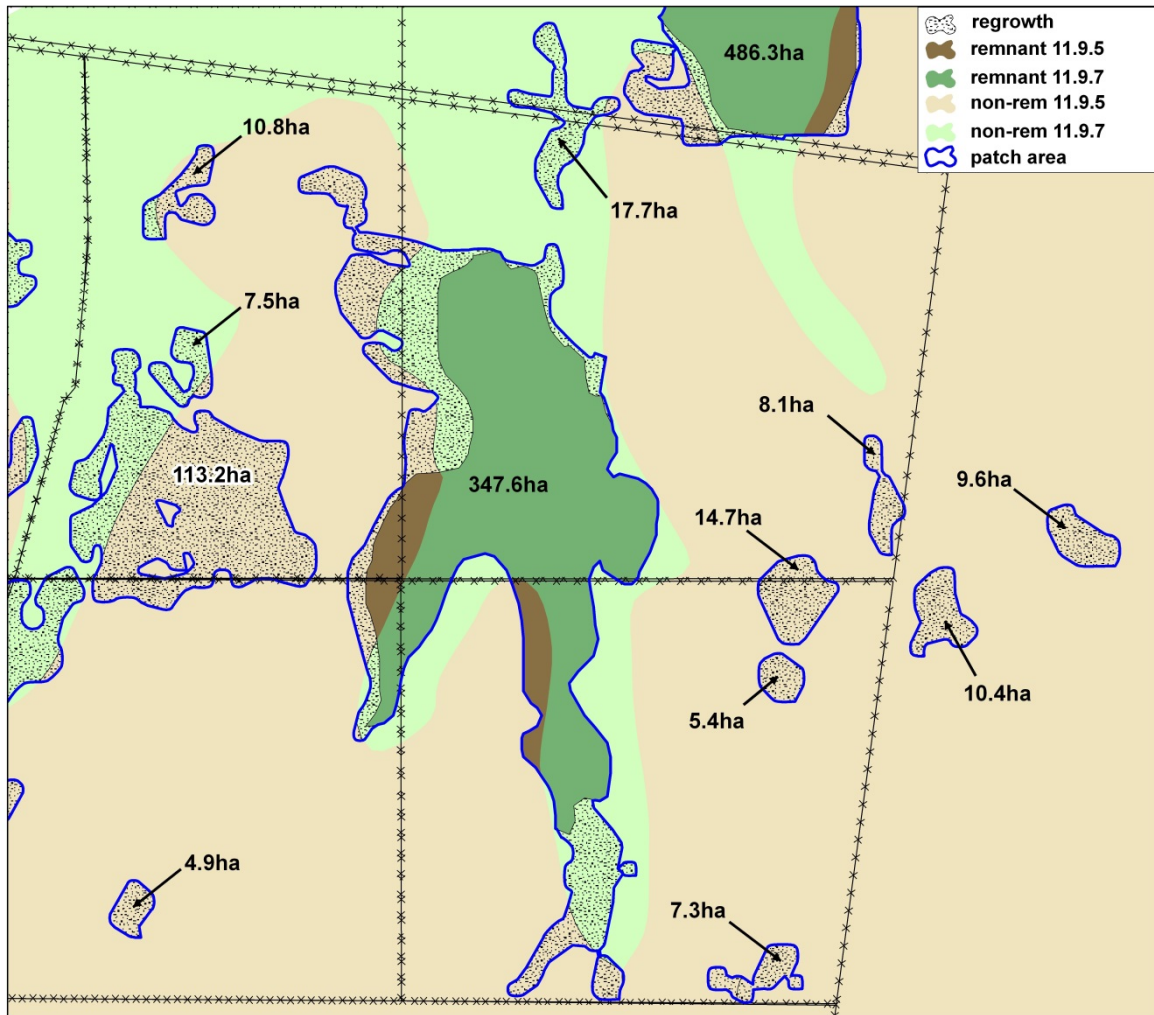
Figure 7: Example of the delineation of the patch area
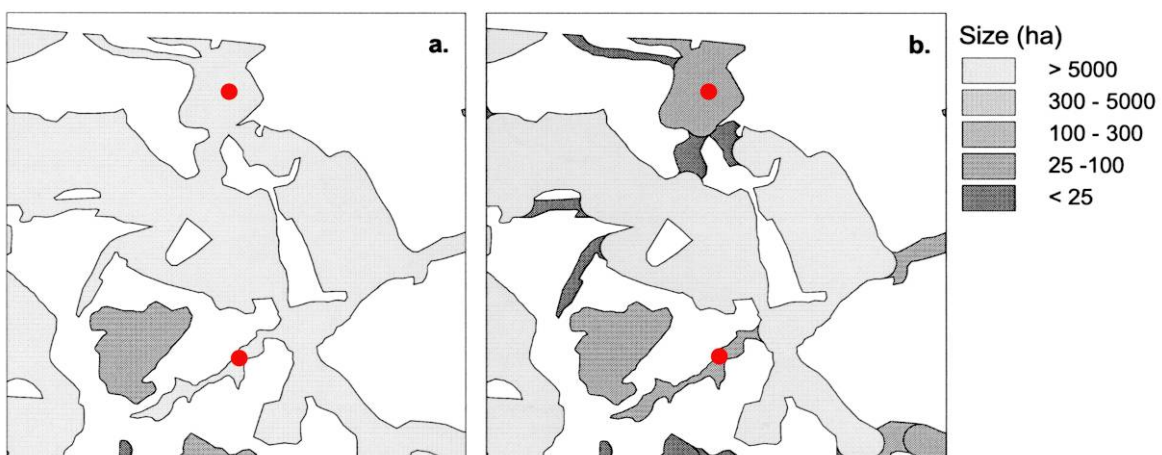
Figure 8: Patch size of remnant vegetation (a) before, and (b) after segmentation of narrow (<200 m) linear landscape elements

For example, before segmentation patch area of Site A >5000 ha, and after segmentation 25 to 100 ha. This site would therefore score 5 in BioCondition.

6.1.2 Connectivity

As a landscape level attribute, connectivity aims to assess the degree to which the assessment unit is connected with adjacent native vegetation. Connectivity relates to the capacity species have to disperse through the landscape between suitable patches of habitat, and therefore has important implications for species persistence (With 2004). A landscape with high connectivity is one in which a particular fauna species can readily move between suitable areas of habitat. A landscape with low connectivity means populations become largely isolated (Bennett *et al.* 2000). Immigration by a species into a single patch of habitat is related to connectivity at the landscape scale. However, other aspects such as the size of the patch (landscape attribute 1) and the amount of habitat in the landscape (landscape attribute 3), as well as the dispersal behaviour of species all contribute to the strength of the relationship (Tischendorf and Fahrig 2000).

In BioCondition there are four broad categories that describe the connectivity of the assessment unit within the landscape (Table 16 and Figure 9). Both remnant and regrowth vegetation are assessed within the connectivity attribute.

Table 16: Description and scores for connectivity in the landscape.

Category	Description	Score
Low	The assessment unit is not connected using any of the below descriptions.	0
Medium	The assessment unit: is connected with adjacent remnant vegetation along >10% to <50% of its perimeter **OR** is connected with adjacent remnant vegetation along <10% of its perimeter **AND** is connected with adjacent regrowth native vegetation > 25% of its perimeter.	2
High	The assessment unit: is connected with adjacent remnant vegetation along 50% to 75% of its perimeter.	4
Very high	The assessment unit: is connected with adjacent remnant vegetation along >75% of its perimeter **OR** includes > 500 ha remnant vegetation	5
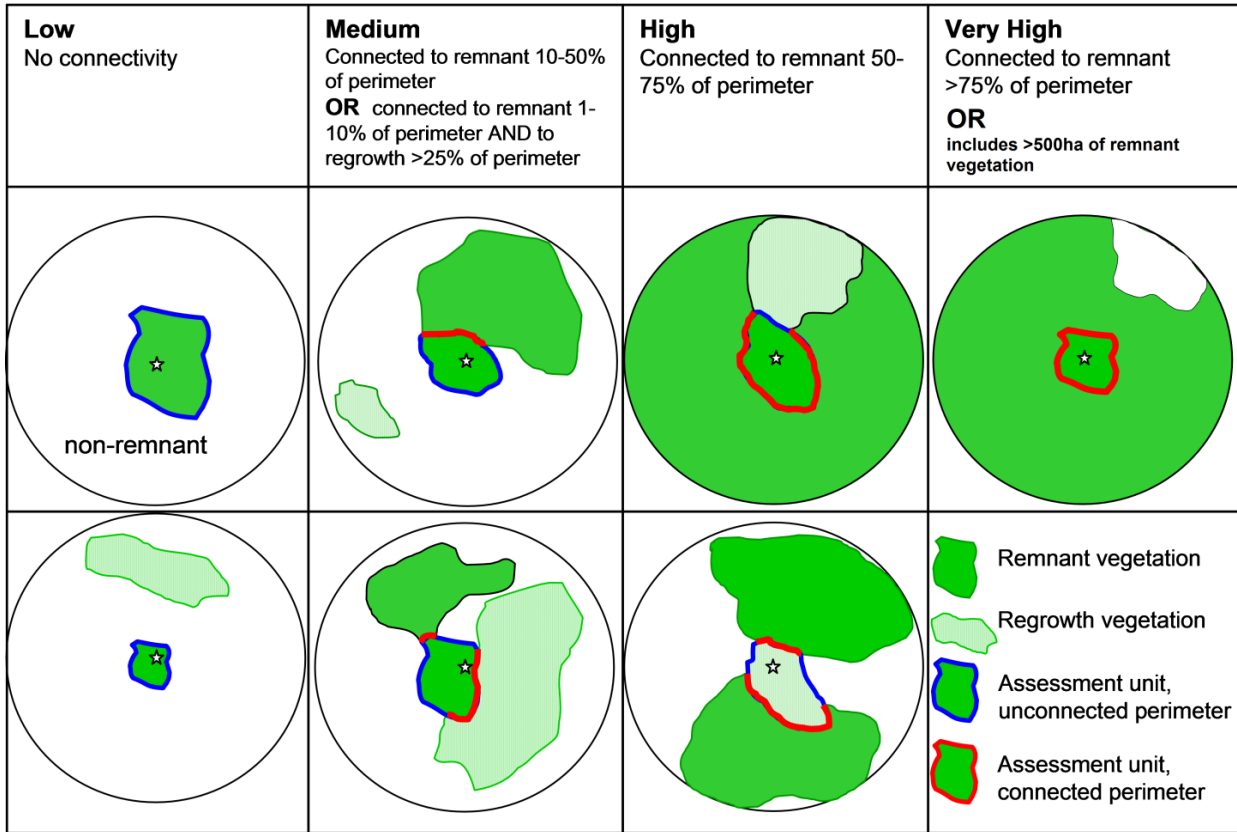
Figure 9: Examples of landscape connectivity scores

6.1.3 Context

The context attribute refers to the amount of native vegetation that is retained in the landscape proximal to the site being assessed. A 1 km radius buffer from the 50 m mark of the BioCondition transect is used to delineate a circular spatial extent. The scoring relates to the proportion of native remnant vegetation and/or regrowth vegetation) is retained within the 1 km radius landscape, and categorised as Low, Medium, High or Very High vegetation cover (Table 17, Figure 10).

The percent thresholds used to categorise the scores have been derived from the literature, which generally demonstrate that there is a 10 to 30% threshold of habitat loss within a landscape below which species will be lost from the ecosystem (Andren 1994; McIntyre *et al.* 2000; Radford *et al.* 2005).

Table 17: Description and scores for landscape context

Category	Description	Score
Low	<10% remnant vegetation AND <30% native non-remnant vegetation (regrowth)	0
Medium	≥10% to 30% remnant vegetation AND <30% regrowth **OR** <10% remnant vegetation AND ≥30% regrowth	2
High	≥30% to 75% remnant vegetation **OR** ≥10% to 30% remnant vegetation AND ≥30% regrowth	4
Very High	>75% remnant vegetation	5
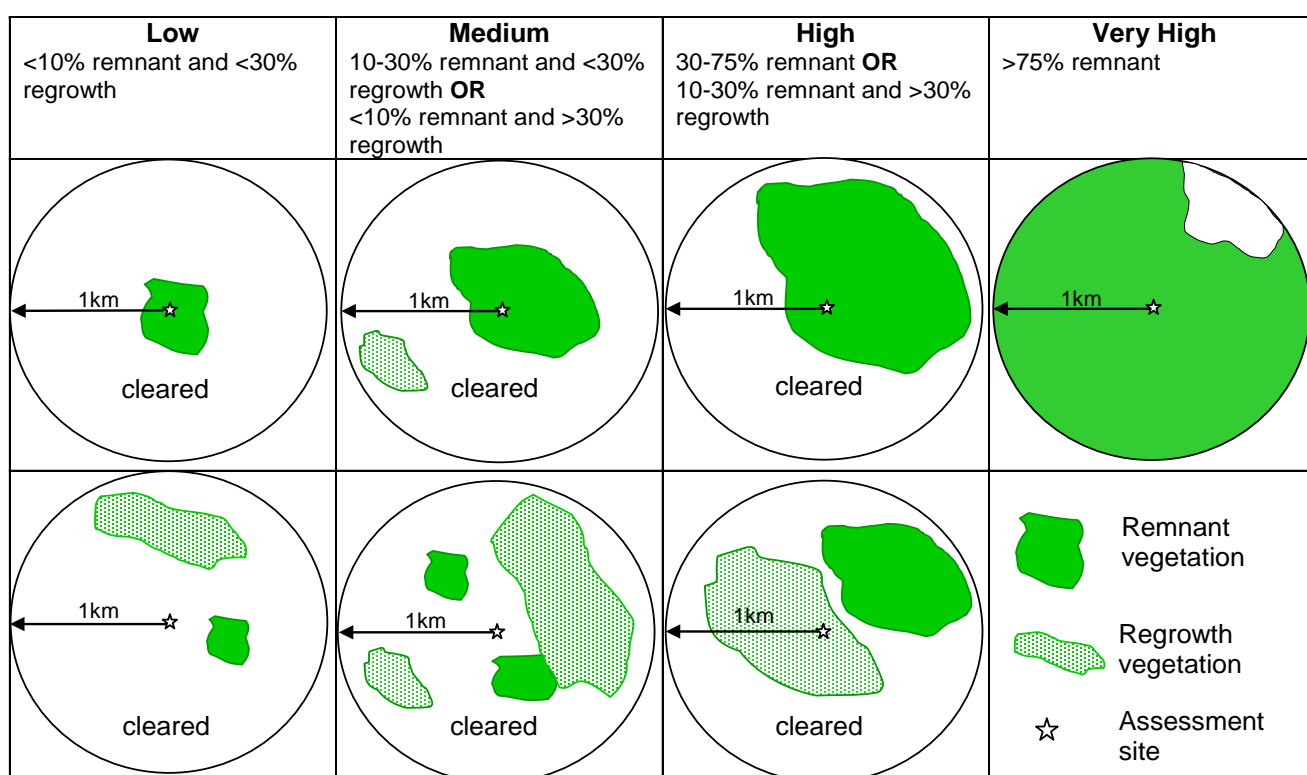
Figure 10: Examples of landscape context scores

6.2 Intact landscapes

6.2.1 Distance from permanent water

The intact landscapes of Queensland's arid and semi-arid rangelands include a diversity of relatively unfragmented ecosystems of tropical savannas, woodlands, shrublands and grasslands (James *et al.* 1999; Woinarski and Fisher 2003). The dominant landuse is grazing by domestic livestock with minimal deliberate landscape modification in terms of vegetation clearing (Freudenberger and Landsberg, 2000). However, natural permanent water is rare in the landscape

and to support the pastoral industry there has been an ongoing program of artificial waterpoint development since the late 1800s (Fensham and Fairfax 2008). This creates a pattern of grazing pressure, from stock as well as feral and native herbivores, that tends to radiate in intensity with distance from permanent water, known as a piosphere (James *et al.* 1999). Consequently, with increased densities of artificial water points in the rangelands, areas of water remoteness for grazing relief are becoming increasingly rare. The issue with piospheres is that species assemblages can change in response to variation in grazing intensities, with the loss of 'decreaser' species, or species sensitive to grazing pressure, closer to water points (Landsberg *et al.* 1999; Pringle and Landsberg 2004).

Distance from permanent water points is therefore a landscape level attribute that is measured and scored in BioCondition for the intact landscapes of the Queensland rangelands. Scoring is based on the shortest distance from the centre of the site to the nearest accessible permanent water point within the one fenced area (Table 18).

Three sources of water are used to provide permanent water for stock in the rangelands (James *et al.* 1999), including:

- unconfined aquifers, where water is pumped to the surface by windmill, solar or diesel pumps
- artesian and sub-artesian aquifers e.g. the Great Artesian Basin, where water is either naturally forced to the surface or pumped
- stored surface runoff, where surface runoff from rain is trapped in dams.

For the BioCondition assessment, permanent water points are typically dams (earth tanks), raised ring tanks and troughs on pipelines, but can include natural permanent water supplies such as rivers and waterholes.

Table 18: Description and scores for distance from permanent water. The description is relevant to the assessment site.

Description	Score
0 to 500 m from water point	0
500 m to 1 km from water point	2
1 km to 3 km from water point	5
3 km to 5 km from water point	10
>5 km from water point	20

Cattle drink from a ring tank in poplar box country, Brigalow Bioregion

7 Calculating and classifying the BioCondition score

The BioCondition (BC) score for the assessment site is determined by adding the scores obtained for each site-based and landscape level attribute (Table 19) and dividing by the maximum possible score for the RE (e.g. 100 for wooded REs, 50 for grassland REs, 65 for shrub land REs, or 85 for mangrove REs). Dividing the summed total by the maximum possible score standardises the total between 0 and 1, which allows equivalence between different ecosystems such as grasslands, for which the benchmark value of some attributes
is zero.

Table 19: Scoring and weighting of the site-based and landscape scale attributes

	Attribute	Weighting (%)
Site-based attributes		
a	Large trees	15
b	Tree canopy height	5
c	Recruitment of canopy species	5
d	Tree canopy cover (%)	5
e	Shrub layer cover (%)	5
f	Coarse woody debris	5
g	Native plant species richness for four life-forms	20
h	Non-native plant cover	10
i	Native perennial grass cover (%)	5
j	Litter cover	5
Landscape attributes		
k	Patch size	10
l	Connectivity	5
m	Context	5
n	Distance to water	20

The BioCondition score (BC) for a site can be calculated as:

Equation 1:

$$BC = \frac{a + b + c + d + e + f + g + h + i + j + \text{either } (k + l + m) \text{ or } (n)}{Y + Z}$$

Where:

a–n   are the attributes a to n (from Table 18 above)

Y   is the maximum site-based score that can be obtained site-based attributes (a–j) that are relevant to the RE being assessed e.g. in a wooded ecosystem $Y = 80$, and in a grassland $Y = 30$.

Z   is the maximum site score that can be obtained for landscape attributes (k–m in fragmented landscapes or n in intact landscapes) ($Z = 20$).

If the site-based scores and landscape-scale scores are required to remain separate and yet still comparable across ecosystems, this can be achieved using the following calculations;

Site-based score (S$_c$)

$$S_c = \frac{a + b + c + d + e + f + g + h + i + j}{Y}$$

Landscape score (Lc)

In fragmented landscapes $Lc = \dfrac{k + l + m}{Z}$ OR   in intact landscapes $Lc = \dfrac{n}{Z}$

A BioCondition score (BC) for an assessment site is:

$$BC = (S_c \times Y/(Y+Z)) + (L_c \times Z/(Y+Z))$$

Note that the above calculation is a re-expression of equation 1, in that it will give the same score if all attributes (site-based and landscape-scale) were simply added together and divided by 100 (or 50 for grassland REs, 65 for shrubland REs, or 85 for mangrove REs).

7.1 To obtain an overall BC score for an area

If an estimation of condition by area is required (as determined by the objective), an area-weighted score can be derived by relating the BC scores to the overall assessment unit. This type of calculation may be required for use in offsets. This is achieved by averaging the BC score for each assessment site within the assessment unit, and then multiplying the average by the area of the assessment unit. This will give a notional score on a per hectare basis.

1.   Obtain the average BC for an assessment unit;

$$BC_{(average)} = \frac{BC_1 + BC_2 + \ldots BC_x}{N}$$

$BC_{(average)}$ Average BC score for an assessment unit

BC_x BC score for assessment site x within the assessment unit

N   Number of assessment sites sampled within the assessment unit

2.   Obtain an area-weighted BC score for the assessment unit.

$Z_y = (BC_{(average)} \times A)$

Z_y Area-weighted site score for assessment unit y

A   Area in hectares of the assessment unit y

If the assessment unit Z_y is disjunct, or made up of discrete, separated units ($Z_{ya}..Z_{yx}$), then an area-weighted BC score is obtained by:

$$Z_y = Z_{ya} + Z_{yb} + ..Z_{yx}$$

Where:

Z_{yx} is the area-weighted score for disjunct unit x of assessment unit y

3.   Obtain the overall area-weighted BC score for the area of interest.

Overall area-weighted score for the area of interest $= Z_A + Z_B + ….Z_X$

Z_A Area-weighted site score for assessment unit A

Z_B Area-weighted site score for assessment unit B

Z_X Area-weighted site score for assessment unit X

An example of the calculation procedure is given in Box 8.

7.2 Categorising the BioCondition score to align with the ABCD framework

To align with grazing land condition the 'ABCD' assessment framework (Chilcott *et al.* 2003; Karfs *et al.* 2009), BioCondition scores can also be categorised as a rating of 1 (for 'functional' biodiversity condition) to 4 (for 'dysfunctional' biodiversity condition). Figure 11 provides an example of various condition states of a Brigalow Belah RE (11.9.5), where BioCondition scores have been categorised into the '1234' classes.

An effective way to categorise the BioCondition score as '1234' is to use summary statistics (mean $\pm$ standard deviation) of all the BioCondition scores generated for the overall assessment (Table 20). However, this does require a range of BioCondition scores, from dysfunctional through to functional condition, and from a reasonably large sample of sites. Therefore, based on BioCondition scores for >190 sites evenly distributed across condition states (Eyre *et al.* unpublished data) the classification provided in Table 21 can be used.

Table 20: Rules used to delineate the BioCondition '1234' classes

BioCondition class	Lower cut-off of site score for classification
1	Mean +1 standard deviation
2	Mean
3	Mean −1 standard deviation
4	All scores > Mean −1 standard deviation

Table 21: Final classification of BioCondition scores into '1234'

BioCondition class	% Value
1	>0.80
2	>0.60 – 0.80
3	0.40 – 0.59
4	<0.40

Box 8: Example of deriving an area-weighted BioCondition score

The objective of the assessment is to obtain an area-weighted score for the total area of remnant and regrowth vegetation

Assessment unit A: RE 11.9.5, Brigalow belah remnant woodland

Assessment unit B: RE 11.3.21, Qld Bluegrass remnant grassland

Assessment unit C: RE 11.9.5, Brigalow belah regrowth woodland
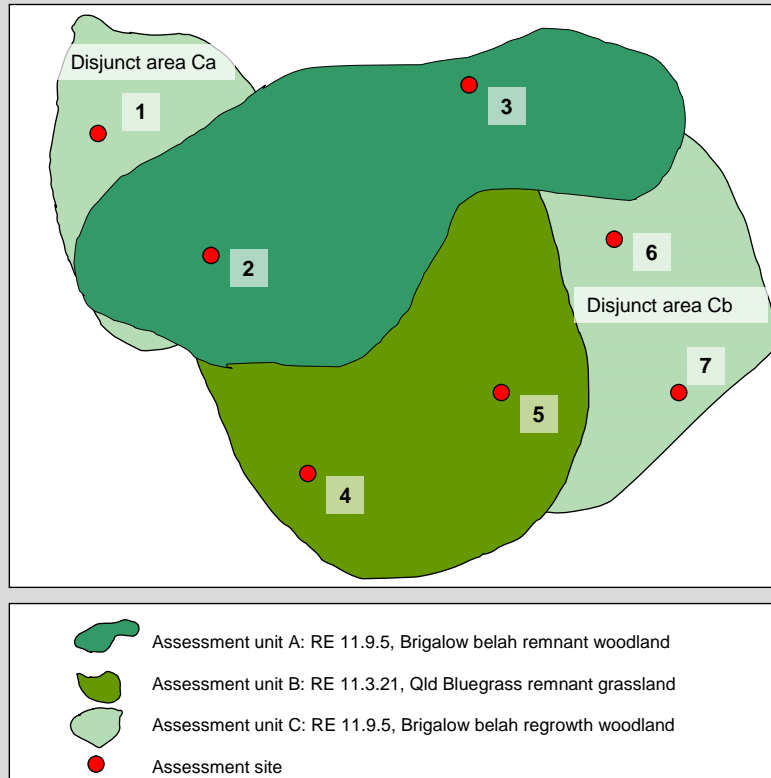
Assessment site

Seven BioCondition assessment sites were located between three assessment units, and each obtained the following scores:

Assessment site	Assessment unit	Ecosystem type	Site score (S_c)	Landscape score (L_c)	Total BC score
1	Ca	Wooded	35/80 = 0.44	13/20 = 0.65	0.48
2	A	Wooded	77/80 = 0.96	14/20 = 0.70	0.91
3	A	Wooded	71/80 = 0.89	12/20 = 0.60	0.83
4	B	Grassland	22/30 = 0.73	13/20 = 0.65	0.70
5	B	Grassland	24/30 = 0.80	14/20 = 0.70	0.76
6	Cb	Wooded	18/80 = 0.23	14/20 = 0.70	0.32
7	Cb	Wooded	20/80 = 0.25	12/20 = 0.60	0.32

AT A GLANCE: *BRIGALOW BELAH SCRUB*

Land type: **BRIGALOW AND BELAH SCRUB**   *Regional Ecosystem:* **11.9.5**

RATING 1:

- 3 or more tree species and high canopy cover (more than 35 %)
- More than 4 shrub species and cover (more than 10 % but not more than 45%)
- More than 11 trees larger than 30 cm DBH* (or 90 cm circumference)#
- More than 6 fallen logs in a 10m radius from a given point
- More than 30 % of the ground covered by native intermediate and preferred grass species
- More than 25 % of the ground covered by litter
- Is well connected with other remnant vegetation
- More than 75 % of the surrounding landscape contains remnant and/or high value regrowth vegetation

RATING 2:

- 2 tree species with medium canopy cover (20-35 %)
- 2-4 shrub species with medium cover (5-10 %)
- 6 to 10 trees larger than 30 cm DBH (or 90 cm circumference)
- 3-5 fallen logs in a 10m radius from a given point
- 16-29 % of the ground covered by native intermediate and preferred grass species
- 10 –25 % of the ground covered by litter
- Well connected with other remnant and/or high value regrowth vegetation
- More than 30 % of the surrounding landscape contains remnant and/or regrowth vegetation

RATING 3:

- 1 tree species and low tree canopy cover (5 –20 %)
- 1 shrub species and low shrub cover (3-5 %)
- 1-5 trees larger than 30 cm DBH (or 90 cm circumference)
- 2 fallen logs in a 10m radius from a given point
- 5 -15% of the ground covered by native or more than 10% non native intermediate and preferred grass species
- 5 -10% of the ground covered by litter
- Not well connected with other remnant vegetation
- 10-30% of the surrounding landscape contains remnant and/or high value regrowth vegetation

RATING 4:

- Very few trees (< 5 % cover), if any, none large.
- Few shrubs of same species (less than 2 % cover) OR an over-abundance of shrubs (more than 45 %)
- None or 1 fallen log in a 10m radius from a given point
- Less than 5 % of the ground covered by native intermediate and preferred grass species
- Less than 5 % of the ground covered by litter
- Less than 10 % of the surrounding landscape contains remnant Or less than 30 % of the surrounding landscape contains remnant and high value regrowth vegetation

*dbi—Diameter at breast height (measured at 1.3m above the ground)   #Count within a 50 x 50m area

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'1234' Biodiversity Condition Framework

mla Queensland Government

Figure 11: Example of '1234' condition states for Brigalow Belah RE 11.9.5

8 Glossary

Annual species	Annual species are short-lived plants, completing their life-cycle within a single vegetative period, which can vary from a few weeks to several months. Annuals usually die within one year. Annual grasses are generally characterized by short growth, not forming large tussocks or root mass, no evidence of previous seasons growth (i.e. remains of last year's tiller bases, and absence of stolons or rhizomes), with reproduction generally from seed.
Assessment unit	Relatively homogenous unit that is one RE type in one broad condition state (remnant or non-remnant).
Benchmark	A description of a RE that represents the median or average characteristics of a mature and relatively undisturbed ecosystem of the same type.
BioCondition Score	The score assigned to the assessed site that indicates its condition relative to the benchmarks set for the RE being assessed. The score can be expressed as a percentage, on a scale of zero to one, or as a category of 1, 2, 3 or 4.
Biodiversity	The diversity of life forms from genes to kingdoms and the interactions and processes between.
Canopy	The layer formed collectively by the crowns of adjacent trees or shrubs in the case of shrub lands. It may be continuous or discontinuous. The canopy usually refers to the ecological dominant layer.
Cryptogam	Collective term which includes lichens, liverworts, mosses and hornworts.
Diameter at breast height (DBH)	DBH is a measure of the size of the tree and is consistently measured at 1.3 m from the ground. On sloping ground, DBH is measured on the high side of the tree from bare earth ground level. Ensure that the tape is horizontal or at a tangent to the trunk when reading the diameter. On leaning trees, on level ground, 1.3 m is measured from the underside of the lean. If a whorl, bump scar or other abnormality occurs at the 1.3 m mark, measure the diameter at a nominated height (measured in whole 0.1 m increments) above the defect. If a representative measure as described above cannot be taken (e.g. presence of strangler figs), a reasonable estimate of the diameter should be made viewing the tree from two different directions. For multiple stems, a diameter is recorded for each stem, when it divides below 1.3 m.
Dominant species	A species that contributes most to the overall above-ground biomass of a particular stratum (= predominant species).
Ecologically dominant (predominant) layer or species (EDL)	The layer or species making the greatest contribution to the overall biomass of the site and the vegetation community.
Emergent layer	The tallest layer/stratum is regarded as the emergent layer if it does not form the most above-ground biomass, regardless of its canopy cover e.g. poplar box (*Eucalyptus populnea*) trees above a low woodland of mulga (*Acacia aneura*).
Eucalypt species	Under BioCondition, a eucalypt species is any species from the following genera: *Eucalyptus*, *Corymbia*, *Angophora*, *Lophostemon*, and *Syncarpia*.
Forb	Herbaceous or slightly woody, annual or sometimes perennial plant that is not a grass or life form defined under 'Other species'.

Grass	A collective term for the following plant life forms: tussock grass which forms discrete but open tussocks usually with distinct individual shoots; hummock grass which are coarse xeromorphic grasses with a mound-like form often dead in the middle e.g. genus *Triodia*; other grasses of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.
Grassland RE	A remnant RE described as having a structure code that does not include the terms 'forest', 'scrub', 'vine land', 'shrub land', 'heath' or 'woodland' in the Regional Ecosystem Database.
High-value regrowth	Vegetation that is endangered, of concern and least concern REs that have not been cleared since 31 December 1989
Large tree	A living tree identified as 'large' by a DBH threshold as defined in the benchmark document relevant to a RE. In some REs a different large tree threshold will be identified for eucalypt and non-eucalypt species due to the variation in potential size of these two tree types. For the purpose of defining large trees eucalypts include trees of genera *Angophora, Eucalyptus, Corymbia* and *Lophostemon.* If a large DBH threshold is not provided in the benchmark document, then generic thresholds of >20 cm DBH for non-eucalypts and >30 cm DBH for eucalypts can be used.
Landscape Context	Relates to the size, connectivity and the context or neighbourhood landscape that the site sits within.
Layer	See stratum
Non-eucalypt species	Under BioCondition, a non-eucalypt species is defined as any species that is not listed as a eucalypt.
Non-native plant	Any plant that requires some form of action to reduce its harmful effects on the economy, the environment, human health and amenity. This definition includes both exotic and non-indigenous native species.
Non-remnant vegetation	Non-remnant vegetation is vegetation that fails to meet the structural and/ or floristic characteristics of remnant vegetation. It may include regrowth, heavily thinned or logged and significantly disturbed vegetation, and cleared areas. Non-remnant vegetation may retain significant biodiversity values and includes areas mapped as 'high-value' regrowth.
Organic litter	Includes both fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter.
Other species	All plant life-forms that are not trees, shrubs, grasses or forbs.
Perennial species	Perennial species are long-lived plants, tending to persist for three or more years. Generally perennial grasses are characterized by larger bulk than annual grasses i.e. forming tussocks and large root mass with evidence of previous seasons growth i.e. remains of last years tiller bases, and presence of stolons or rhizomes.
Reference site	A site that represents an example of a RE in its reference state, i.e. the natural variability in attributes of an ecosystem relatively unmodified since the time of European settlement. As not all RE's will have examples of totally unmodified states, reference sites represent the "Best On Offer" reference state for that RE in a local area. Data obtained from reference sites are used to establish benchmarks for each of the attributes used within BioCondition (a separate method for collecting data at reference sites is available as a companion document to the BioCondition manual—see Eyre *et al.* (2011).

Regional Ecosystem (RE)	REs were defined by Sattler and Williams (1999) as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil.
Remnant vegetation	Remnant vegetation is defined in the *Vegetation Management Act 1999* as vegetation shown on a RE or remnant map. A map showing remnant RE is the same as a 'remnant endangered (or of concern or not of concern) RE map' defined under the *Vegetation Management Act 1999.* Where there are no maps available, remnant vegetation is defined as vegetation where the dominant canopy has greater than 70% of the height <u>and</u> greater than 50% of the cover relative to the undisturbed height and cover of that stratum and dominated by species characteristic of the vegetation's undisturbed canopy.
Shrub	Woody plant that is multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m tall.
Shrub canopy cover	The estimation of the percentage canopy cover of the living shrub layer (see Shrub).
Shrub canopy height	The median canopy height in metres, as estimated for the shrub layer (see Shrub canopy cover).
Stratum	A layer in a community produced by the occurrence at approximately the same level (height) of an aggregation of plants of the same habit (Beadle and Costin 1952).
Tree	Woody plants, more than 2 m tall with a single stem or branches well above the base.
Tree canopy cover	Refers to the estimation of the percentage canopy cover of the canopy tree layer
Tree canopy height	The median canopy height in metres, as estimated for the canopy tree layer (see Tree canopy cover).

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10 Appendices

Appendix 1: Field assessment summary guide

Step 1: **Lay out the plot -** The site can be marked with a 100 m transect that follows the contour i.e. along a slope as opposed to up or down a slope. Mark the 50 m point on the transect with a star picket or temporary marker—this point acts as the centre of the assessment site. Record the compass bearing that the transect follows from the zero point, and also record the location of the zero metre point by GPS.

Step 2: **The field assessment -** Start at the centre of the plot (50 m mark on the transect), and record the site number, Regional Ecosystem (RE), the date of assessment and the property or location name. Using a GPS, mark the position of the 50 m point on the transect. Take landscape photos north, south, east and west (Appendix 4), to provide a record of the tree and shrub layers and the general condition of the site. The assessment of the 10 site-based attributes is conducted within five assessment areas on the 100 x 50 m site, as shown in figure below.
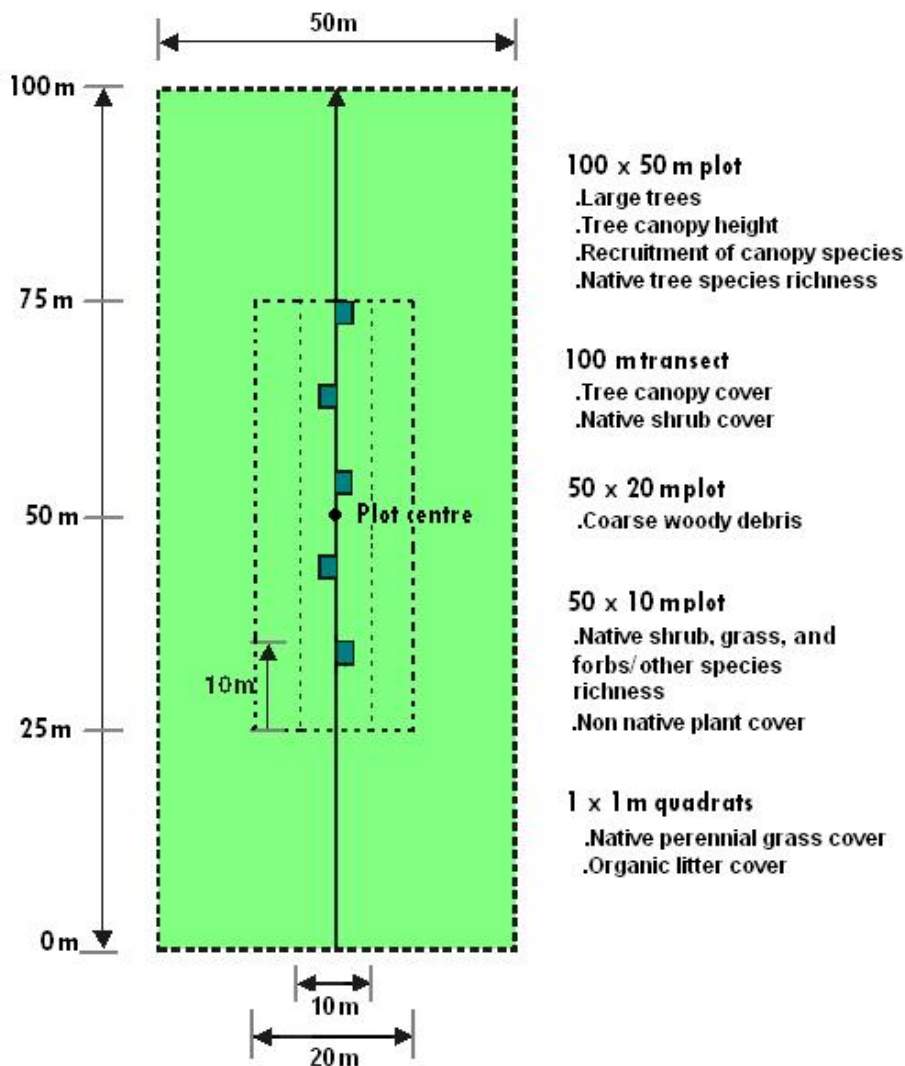
Step 3: Area 1; 50 x 10 m sub-plot, incorporates 25 m to 75 m along the transect, and encompasses 5 m either side of the transect.

- **Native plant species richness** is assessed by slowly walking along each side of the centre-line and tallying the number of species in each of three life-forms: shrubs, grasses and forbs/other. *NB: Tree species richness is assessed in the 50 x 100 m plot.*

- **Non-native plant cover** is assessed by estimating the cover of exotic species as a component of the overall vegetation cover. The estimate can be improved by dividing the 50 x 10 m plot into smaller areas and then averaging the cover estimate over the entire area. For example, 20 x 5 x 5 m (i.e. 10 plots each side of the tape).

Step 4: Area 2; 50 x 20 m sub-plot, incorporates 25 m to 75 m along the transect, and encompasses 10 m either side of the transect.

- **Coarse woody debris** is assessed by measuring the length of all logs >10 cm diameter, 0.5 m in length and within the 50 x 20 m sub-plot. Logs are assessed if 80% of the log is in contact with the ground. Measure only the portion of the log that is greater than 10 cm diameter or lies within the sub-plot, i.e. only measure the length of the log to the boundary of the sub-plot.

Step 5: Area 3; Five 1 x 1 m sub-plots, starting at the 35 m point, assess ground cover in 1 x 1 m quadrats located 10 m apart, on alternate sides along the transect. If the quadrat location coincides with a feature such as a tree or large log it is acceptable to move the quadrat 1 m up or down the transect. Assess each of the ground cover components so that the cover totals 100% (use figure below as a guide on cover estimates). Although not all components are used in the scoring for BioCondition, assessment of all attributes improves ability to estimate cover of the assessable attributes. Spot photos can be taken of each quadrat to document change in ground cover over time.
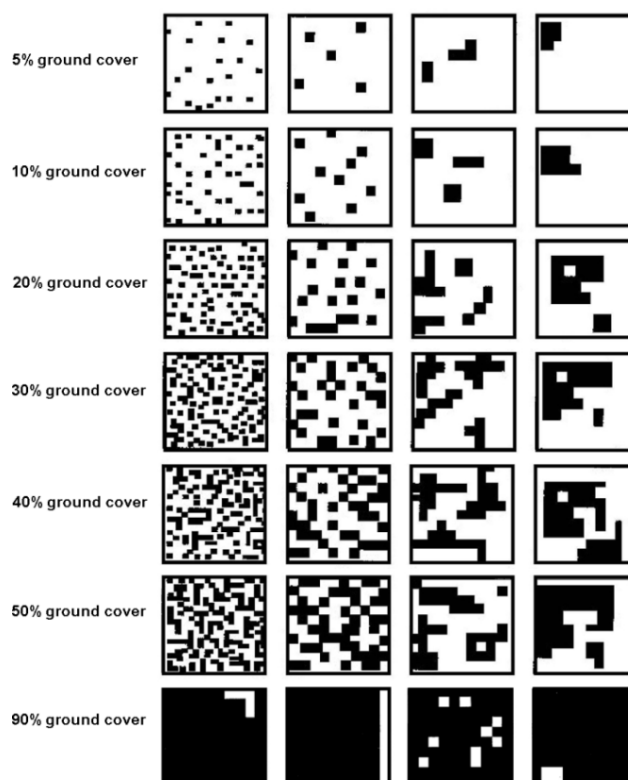
- **Native perennial grass cover** refers to the percentage cover of native perennial grasses, assessed within each of the five 1 x 1 m quadrats and averaged to give a value for the site. Depending on the nature of your assessment all perennial grasses can be assessed, or the native perennial grass cover can be split into those species listed in the land type documents as preferred and intermediate or as non-preferred.

- **Organic litter** is assessed by estimating the cover of fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter from the five quadrats and then averaged.

Step 6: Area 4: 100 x 50 m area: Visualising or marking out 25 m either side of the transect line forms the larger assessment area of 100 x 50 m. A greater need arises for precision when assessing the numbers of large trees (i.e. measuring the distance to trees that appear to be 'borderline' within the site). Refer to the benchmark document to determine if there are separate benchmarks for the canopy, emergent and/or subcanopy layers. If more than one layer is identified in the benchmark document, then assessment of each layer is required for the recruitment, canopy height and cover attributes.

- **Number of large trees** is assessed by counting the number of trees within the 100 x 50 m plot area over a certain size threshold, as recorded on the benchmark document for the RE that you are assessing. If no benchmark exists for the RE of interest, use the threshold of 30 cm DBH for 'eucalypt' trees (genera *Eucalyptus, Corymbia, Angophora, Lophostemon* and *Syncarpia*) and 20 cm DBH for 'non-eucalypts'.

- **Recruitment of canopy species** is assessed by observing the proportion of the dominant canopy (EDL) species regenerating (<5 cm DBH) within the 100 x 50 m plot area. Only one regenerating individual is required of each species (e.g. if there are four dominant species of trees then four species need to occur as regeneration to get 100%).

- **Tree canopy height** (measured to the top of the highest leaves) refers to the median canopy height in metres (see figure below), estimated for trees in the EDL (canopy layer). If there are emergent and/or subcanopy layers identified in the benchmark document, median height of these layers needs to be assessed also. The median canopy height is the height that has 50% of canopy trees larger and smaller than it. It is recommended that a clinometer or hypsometer be used if available.
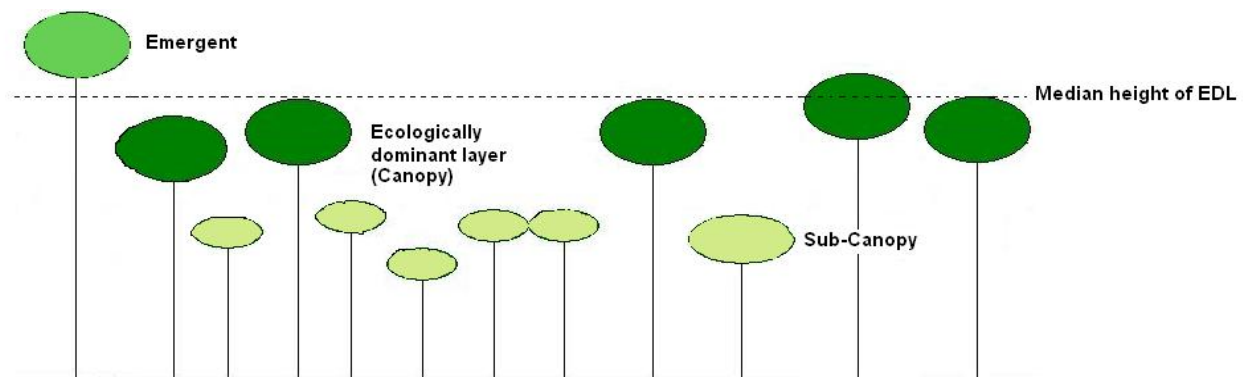
- **Tree species richness** is the count of different tree (single stemmed over 2m) species over the whole 100 x 50m area.

Step 7: Area 5: 100 m transect: tree canopy and shrub canopy cover are assessed along the 100m transect using the line intercept method.

- **Tree canopy cover** refers to the estimation of the percentage canopy cover of the living, native tree canopy overlapping the 100 m transect. For this attribute, in the majority of

cases, only the cover of the trees making up the canopy layer are included. The canopy equates to the ecologically dominant layer (EDL) for forests and woodlands. However, if the benchmark document lists values for more than one layer, then the heights and covers of these layers are assessed separately. Assessors work along the transect line and record the start and finish distance of tree canopies that overlap the transect line[7]. If overlapping trees are in the same layer then they can be recorded as the one tree group.

- **Native shrub canopy cover** uses the same method as for tree canopy cover using a vertical projection of shrub crowns downwards and above the line.

---

[7] and assign them to canopy and/or subcanopy and/or emergent layers if these layers are distinguished within the benchmark document

Appendix 2: BioCondition field assessment sheet

BIOCONDITION SITE ASSESSMENT DATASHEET

OFFICE USE ONLY
Entered:...................
Checked:................
Corrected:..............

Site ID: ....

DATE: ..../........./..........

BioCon survey number:..................

OBSERVERS: ....

Queensland Government

SITE INFORMATION

General habitat survey number:..................

LOCATION: (GPS reference)   Bioregion: _ _ _ _ _ _ _ _ _ _ .

Datum: ☐ AGD84   ☐ GDA94 (WGS84) OTHER: _ _ _ _ _ _   Location derivation: _ _ _ _ _ _

Road: zone: ._ _ easting: _ _ _ _ _ northing: _ _ _ _ _ _ _   Plot Centre Direction: ._ _ _ _ m at _ _ _ degrees

Plot Origin: zone: ._ _ easting: _ _ _ _ _ _ _   northing: _ _ _ _ _ _ _   Accuracy: _ _ _.

Plot Centre zone: ._ _ easting: _ _ _ _ _ _ _   northing: _ _ _ _ _ _ _   Accuracy: _ _ _.

Plot bearing: ._ _ _   Plot alignment description: _ –

Locality description (include tenure and reserve number):_ _

_ _

_ _

REGIONAL ECOSYSTEM AND TREE HEIGHTS:

Habitat Description _

_ _

_ _

Regional Ecosystem:_ _ _ _ _ _   Tree Canopy (EDL*) height:.........   Tree subcanopy and/or emergent ht: S: _____   E: _____

SITE PHOTOS:

(Photo Numbers)   Plot centre:

North [   ]   South [   ]   East [   ]   West [   ]

Landscape photo(s): [   ]   Spot photo(s): [   ]

---

50 x 20m area: (NB: All logs >10cm, >0.5m within 50 x 20m area measured to the plot boundary)

Coarse woody debris:

Length: ....
....
....
....
....
....
....

Site Total: ....
Per ha Total: ....

100 x 50m area: (NB: *Ecologically Dominant Layer. Tree defined as single stemmed over 2m. All tree species in the 100 x 50m (not just EDL species)

Total native tree spp richness:

....
....
....
....
....
....

Total: ....

Proportion of dominant canopy (EDL) species with evidence of recruitment: .... %

---

50 x 10m area: Native Plant Spp Richness: (NB: List species if known or count if unknown. Shrub is defined as single stemmed below 2m or multi-stemmed from base or below 20cm)   **Total**

Shrub spp. richness: ....
....
....

Grass spp. richness: ....
....
....

Forbs and others spp. richness: ....
....
....

Non-native plant cover (%): ....   %

BIOCONDITION SITE ASSESSMENT DATASHEET cont....

Five 1 x 1m plots: *attributes are essential to assess as used in scoring, however assessment of all attributes improves your ability to more accurately visualise proportions of each of the attributes.

Ground Cover:	1	2	3	4	5	Mean
Native perennial ('decreaser') grass cover*						
Native other grass (if relevant)*						
Native forbs and other species (non-grass)						
Native shrubs (<1m in height)						
Non-native grass						
Non-native forbs and shrubs						
Litter*						
Rock						
Bare ground						
Cryptograms						
Total	100%	100%	100%	100%	100%	

100 x 50m area: *from benchmark doc.

Eucalypt large tree DBH*: ....

Non-eucalypt large tree DBH*: ....

No. of large eucalypt trees: ....

No. of large non-eucalypt trees: ....

Total large trees: ....

100m transect:

Tree Canopy Cover: (Only assess Emergent (E) or Subcanopy (S) layers if the benchmark document stipulates that layers are present *If trees are in the same layer and continuous along the transect you can group them)

Tree or tree group* (C or S or E)	Distance (m)	Total	Tree or tree group* (C or S or E)	Distance (m)	Total	Tree or tree group* (C or S or E)	Distance (m)	Total	Tree or tree group* (C or S or E)	Distance (m)	Total
										Total C:	
										Total S:	
										Total E:	

Shrub Canopy Cover: * denote as native or exotic. Only native shrub cover is used in the scoring.

Shrubs*	Distance (m)	Total	Shrubs*	Distance (m)	Total	Shrubs*	Distance (m)	Total	Shrubs*	Distance (m)	Total	Shrubs*	Distance (m)	Total
												Total native:		
												Total exotic:		

Version 2.2 27/01/2015 The Database Manager, DSITIA Queensland Herbarium: 3896 9230

Appendix 3: Resources/Contacts for further information

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Appendix 4: Taking photos

(Adapted from Land Manager's Monitoring Guide Photopoint Monitoring, and Land Management Agreement - Rural Leasehold Land Self-Assessment Guideline and BioCondition v1.6).

Taking photographs of site features from a fixed point is a great way to keep a permanent visual record of how attributes have changed over time. Photographs can be the most reliable and useful record collected in any monitoring program, as they best represent how things were over time, in comparison to our memories which aren't as reliable as we think.

Each time you do an assessment, two photo types are recommended to be taken at each site.

1. Spot photo

This is a photo taken from head height looking nearly vertically down on a spot marked with a one square metre frame or quadrat, as shown in Figure 12. You can use the base of your plot centre marker to relocate the same spot each time you visit. Spot photos provide a detailed picture of the ground cover, organic litter and plant species for a standard-sized area. It is common to find a great variety in ground cover at any given site so taking more spot photos will help record this variation. It is important to have a system that allows you to take the spot photos in the same place each time you do an assessment. For example, spot photos could be taken along the transect line where you are doing your ground and litter cover assessments (i.e. 35, 45, 55, 65 and 75 m).

Figure 12: Taking a spot photo—try and keep the top of your feet out of the frame and angle the camera down as straight as possible

2. Landscape photo

Landscape photos are taken of features in the intermediate distance or further to provide an overview of the entire site and its surrounds. They illustrate the general condition of the site, showing changes in tree, shrub and ground layers over time. These site specific landscape photos can also be used to record particular disturbance events such as flood levels and damage or the impacts of a bushfire.

The landscape photo is taken from near the plot centre, holding your camera so that the image is taken with a 'landscape' perspective—that is where the picture is wider than it is high. Stand next to the plot centre marker (Figure 13), facing south (recommended direction – see 'photo tips'), and position the horizon so it cuts the photo frame in half (half above the horizon and half below). Then take the photo focusing on infinity. Recording how the photo was lined up or simply taking a copy

of the picture with you on future visits will make lining up the shot easier. Alternatively, taking a series of plot centre landscape photos in a north, south, east and west direction (with the aid of a compass), allows you to pick up more of the variation across the site and is easy to replicate next time an assessment is done.
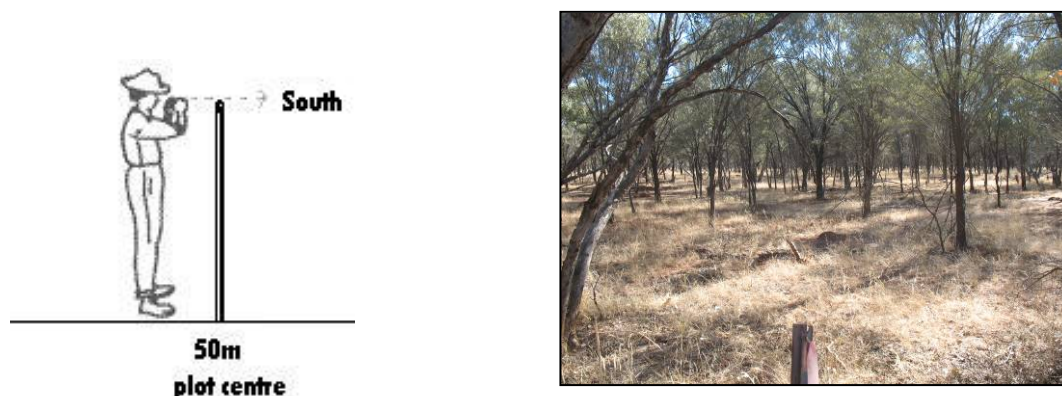

Figure 13: Taking landscape photos—record the bearing or direction of the photo in order to assist with replicate photos on subsequent visits.

Photo tips

- *Any type of camera from colour print film to a digital camera can be used to take these photos. Digital cameras are ideal, allowing instant review of an image for clarity and colour—this ensures you always have a good photo for your records.*

- *The best photos are generally taken on a clear day between 9 am and 3 pm. Before 9 am and after 3 pm will generally result in more shadowing and different colour cast which may conceal some important features. Overcast days are great for photography in closed communities such as rainforests, scrubs and thickets, as the even light removes much of the shadowing.*

- *A common problem is too much light blanking out the colour and detail of the image. If you have control over your camera settings, this can be reduced by setting the exposure compensation to a negative setting. This is done by using the auto-exposure lock (AE lock) or by using spot metering. Your camera's user guide will explain how to use these functions on your particular camera. The troubleshooting section is often a good place to find these and other useful solutions.*

- *You will always get a better photo by having the sun behind you with the sunlight shining on the landscape facing you. If you are only taking one photo it is best to be facing south to avoid having the sun shining into your lens.*

- *For each photograph, record the relevant area, land type and site, the date the photo was taken, and the direction the photo was taken (N/S/E/W). The date stamp feature on your camera may be useful if it does not obscure important components of a photograph. Photos can be stored in a database (scanned if not digital) and/or printed and kept on file with the monitoring records.*

Appendix 5: Measuring tree height

a) Stick or pencil method

(Extracted from Abed, T., and Stephens, N.C. (2002). *Tree measurement manual for farm foresters - Practical guidelines for farm foresters undertaking basic inventory in farm forest plantation stands.* National Forest Inventory, BRS, Canberra.)

1. Take a straight stick of known length (preferably 30 – 40 cm long)

2. Place a mark on the stick at the point 1/10th of its length from the bottom. For example, if the stick is 30 cm long, place the mark at 3 cm from the bottom.

3. Holding the stick vertically at full arm's length, walk backwards from the tree you wish to measure, until the top and bottom of the stick match with the top and bottom of the tree.

4. Note where your mark lines up with the tree trunk and have your co-worker, standing at the tree, put their hand up to this point on the tree trunk. Then measure the distance from the ground to this point on the tree. Call this the 'tree mark height'.

5. As the mark on the stick was 1/10th of it total length, the mark on the tree is also 1/10th of the total tree height. Therefore multiply the tree mark height by 10 to get the total tree height.

Hint 1: Depending on the height of the trees you may need a longer or shorter stick. Alternatively a tape measure or ruler can be used instead of a stick.

Hint 2: The stick or pencil method has the disadvantage of having a high level of error and is time consuming. It is recommended that, if possible, a vertex hypsometer or clinometer (see next section) should be used to determine tree height. Optical hypsometers use lasers to calculate the horizontal distance to the tree, and then automatically calculate the height of the tree once the angle to the highest part of the tree and to its base is recorded.
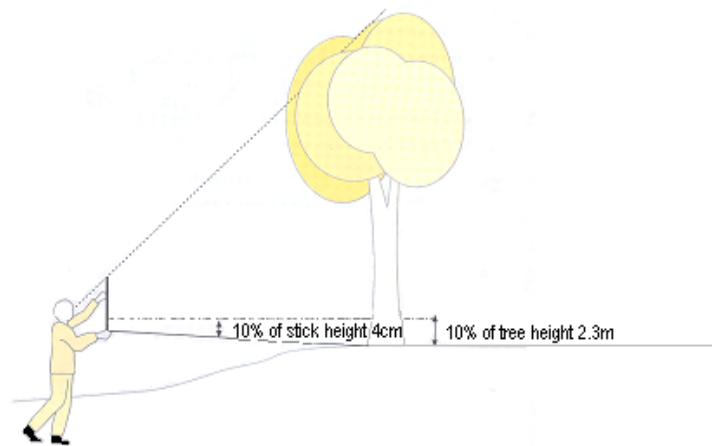
b) Clinometer method

(Extracted from Abed and Stephens 2002)

The Suunto clinometer (clino) is a tool commonly used by foresters to measure tree heights and slope angles. At the rear of the clino is a peephole, which shows a percentage scale and a horizontal line (see figure below).

1. First measure the horizontal distance between the base of the tree and the operator.

2. Looking through the peephole, line up the horizontal line with the top of the tree (the highest part of the tree—usually foliage) and read off the corresponding number from the percentage scale, which is on the right hand side. The scale on the left is in degrees and should not be used.

3. Line up the horizontal line with the base of the tree and again read off the corresponding number from the percentage scale.

4. If the base of the tree is above you (i.e. you're on the downward slope) then subtract the number from step 3 from the number in step 2 and multiply by the horizontal distance to get a total tree height.

5. If the base of the tree is level with you or below you (i.e. you're on the upward slope) then add the numbers together and multiply by the horizontal distance to get a total tree height.

6. If the tree is leaning, stand at right angles to the lean so the tree isn't leaning towards or away from you. If the highest part of the tree is not directly above the trunk, then adjust the horizontal distance so that it relates directly to the highest part of the tree.

> *Hint: If you can't see the bottom of the tree because of branches or understorey, sight to a point up the stem that can be seen and treat this as the base of the tree and continue with the procedure as described above. Then add the height from the base to the point you could see to get your estimate of total height.*

Looking through a clinometer
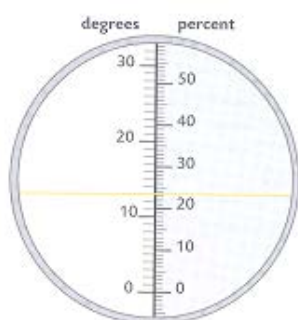
Using a clinometer

The heights of the crown can also be measured using a laser instrument called a hypsometer. Where the top of the tree is not directly above the base of the trunk, it is important to also measure the point directly below the highest point of the tree canopy to get an accurate crown height.

EXAMPLE:

Jenny wants to determine the height of two trees, with the first tree slightly below her and the second tree slightly above her. Using a tape measure, she measures the distance between her and the first tree, which is 25 m away. Using the clinometer, she sights to the top of the tree and sees the horizontal line align with the percentage number 64, she then sights to the base of the tree and finds the percentage number to be 6. She adds both percentage numbers and multiplies the distance to get a tree height of 17.5 m.

Tree height   = 25 x (0.64 + 0.06)

= 17.5 m
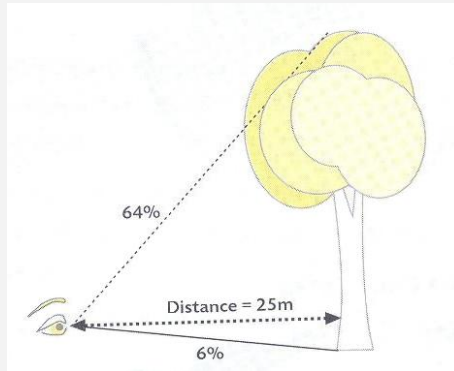
Jenny then repeats the procedure with the second tree and measures a distance of 20 m from the tree. The percentage to the top of the tree is 80. The percentage to the bottom of the tree is 15. Therefore tree height of the second tree is 13 m.

Tree height   = 20 x (0.8 –0.15)

= 13 m
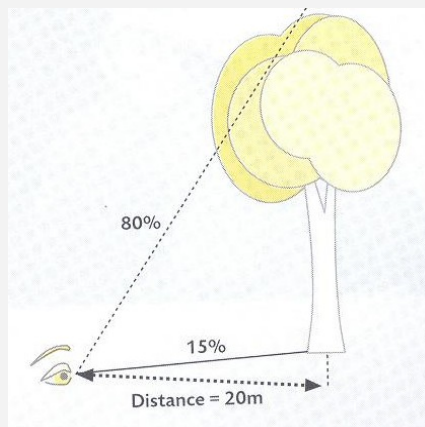
Appendix 6: Stratifying vegetation

In BioCondition, assessment of the tree height, recruitment and tree canopy cover attributes require consideration of the distinct vegetation layers or strata that make up the community. In general, site-based assessment of vegetation uses structure (vertical and horizontal distribution of vegetation: its growth form, height, cover and strata) and floristics (dominant genera or species in various strata and characteristic species) (Hnatiuk *et al.* 2009). In Queensland, the structural and floristic characteristics of the vegetation are used in defining and describing REs. Details of the methods used to classify vegetation and regional ecosystems in Queensland are described in Neldner *et al.* (2012).

Determining the ecologically dominant layer

Once the vegetation community has been classified into strata (see Box 9), the determination of the ecologically dominant layer (EDL) is made. The EDL contains the greatest amount of above-ground vegetation biomass (Neldner 1984).
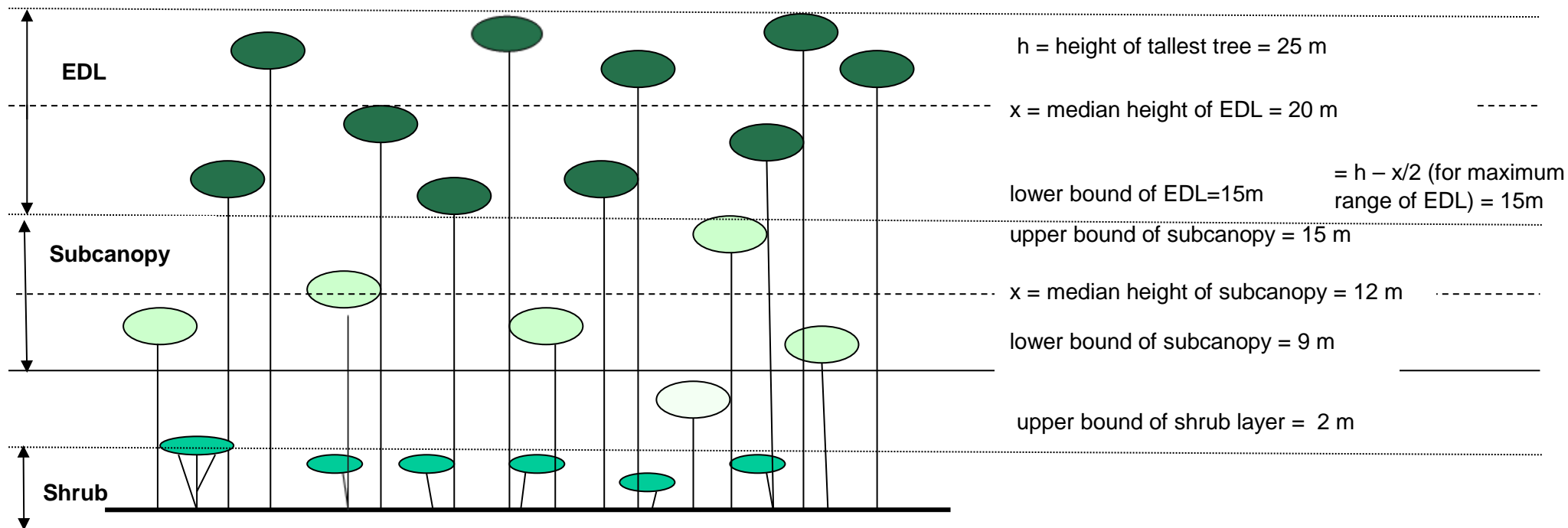
Example 1: EDL; RE 3.5.24, *Eucalyptus chlorophylla* open-woodland (EDL), Cape York Peninsula

EDL

Here the above-ground biomass of the trees is estimated to be larger than the grass layer, and is the EDL. Generally if the tree layer in these situations has a canopy cover of 8% or more, then the trees will form the EDL.

In the majority of cases in wooded communities, it is the tallest layer that forms the most above-ground biomass, except in the case of widely scattered emergent trees. Therefore, in most cases only the EDL layer is assessed for the attributes tree canopy cover, height and recruitment in BioCondition. Exceptions include rainforest canopies with emergent species and mixed genus woodlands (e.g. poplar box and mulga woodlands).

Box 9: Method to determine vegetation strata, when not obvious

EDL

Subcanopy

Shrub

h = height of tallest tree = 25 m

x = median height of EDL = 20 m

lower bound of EDL=15m

$= h - x/2$ (for maximum range of EDL) = 15m

upper bound of subcanopy = 15 m

x = median height of subcanopy = 12 m

lower bound of subcanopy = 9 m

upper bound of shrub layer = 2 m

1. The median EDL tree height (x) is 80% of the height of the tallest tree (excluding emergents).
2. The height range for the EDL = x/2
3. The lower height bound of the EDL = h – x/2.
4. Repeat the process to obtain the height range for the subcanopy.
5. The shrub layer contains all woody plants that are either multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m tall.

Example (above diagram): height of tallest tree h = 25 m. Therefore the height range for the EDL is 15 to 25 m with a median = 20 m (80% of h); the subcanopy is 9 to 15 m, the shrub layer is <2 m.

Example 2: Emergent layer and EDL; RE 5.7.2, *Acacia catenulata* low woodland (EDL) with emergent
Eucalyptus thozetiana.

Emergent
layer

EDL

Example 3: EDL and shrub layer; RE 2.5.15, *Melaleuca viridiflora* low woodland (EDL) with a distinct shrub layer of *Petalostigma banksii* on western Cape York Peninsula.

EDL

Shrub
layer

Example 4: EDL and shrub layer; RE 2.5.12, *Eucalyptus pruinosa* low woodland (EDL) with low shrub layer of *Acacia* spp.

EDL

Shrub layer

Example 5: Multi-layers: RE 8.5.1, coastal *Corymbia* spp. woodland (EDL) with a subcanopy layer of *Melaleuca viridiflora* and immature canopy trees. The layers in some forest communities can be relatively indistinct.

EDL

Sub-canopy layer

Shrub layer

The impact of disturbance on vegetation structure

While in an undisturbed state, a vegetation community will develop a distinct structure (height and cover) based on the growth forms of the species present and their abundance. Frequently different species define and dominate different layers. However, within an ecosystem the structural attributes (height and cover) will frequently vary depending on the environmental conditions at the site (e.g. rainfall and soil depth). Where there has been significant natural (e.g. cyclones, fires or floods) or human disturbance (e.g. clearing or logging), the structure and floristics of the vegetation can be significantly altered. At these sites, the development of distinct layers may not occur or be indefinite, and the resultant communities may develop a number of structural outcomes (see below). In these situations, it is important to compare the heights and canopy covers of the vegetation at the site to the defined layers in the benchmark documents. For example, in the RE 6.5.3 *Eucalyptus populnea* predominates forming a distinct but discontinuous canopy (10 - 20 m tall). A lower tree layer (subcanopy) of *Acacia aneura* is sometimes present. After disturbance, at least three structures may develop (1) *E. populnea* woodland with little or no subcanopy, (2) *A. aneura* woodland with none or only scattered *E. populnea* emergents, or (3) regenerating woodland of both species. In each structural type it is important to compare the heights and covers of both *E. populnea* and *A. aneura* with the layers they dominate in the benchmark site.

RE 6.5.3: *Eucalyptus populnea* **predominates forming a distinct but discontinuous canopy (10 – 20 m tall) (EDL). A subcanopy of** *Acacia aneura* **is sometimes present.**

Examples of benchmarks for REs with more than one layer

RE 6.5.3 *Eucalyptus populnea* woodland with *A. aneura* subcanopy.

Canopy (EDL) of *Eucalyptus populnea*
Benchmark height = 15 m. Benchmark canopy cover = 18%

Subcanopy of *Acacia aneura*
Benchmark height = 8 m. Benchmark canopy cover = 30%

SCENARIO 1. Assessment of 6.5.3, where the site has all or most of *A. aneura* cleared, and remaining vegetation is *E. populnea* woodland.

All *Acacia aneura* cleared.

Height of canopy (EDL) = 15 m, height of subcanopy = 0 m. Measured canopy (EDL) cover = 18%, subcanopy cover = 0%. Using BioCondition scores, this site will score 5 for canopy (EDL) height (15/15 = 100% of benchmark) and a score of 5 for canopy (EDL) cover (18/18 = 100% of benchmark), but 0 for subcanopy height (0/8 = 0% of benchmark) and subcanopy cover (0/30 = 0% of benchmark). Therefore, when the scores for canopy and subcanopy are averaged for the attributes height and cover, the overall scores are 2.5 for height and 2.5 for canopy cover.

SCENARIO 2. All or most of *E. populnea* has been cleared, and remaining vegetation is *A. aneura* low woodland.

Most *Eucalyptus populnea* cleared

Even though *A. aneura* is the EDL at this site, values are compared to subcanopy benchmarks as this is where it dominates in the undisturbed state. Height of subcanopy (*A. aneura*) = 8 m, height of canopy (EDL, *E. populnea*) is 15 m. Measured subcanopy cover = 30%, canopy (EDL) cover = 8%. This site scores 5 for height (15/15 =100% of canopy benchmark gets score of 5 and 8/8 = 100% of subcanopy benchmark gets score of 5) and 4 for cover (8/18 = 44% of canopy benchmark gets score of 3 and 30/30 = 100% of subcanopy benchmark gets score of 5).

SCENARIO 3. All vegetation has been cleared, and regrowth vegetation is an *E. populnea, A. aneura* low woodland

All vegetation cleared. Single layer of regrowth.

Height of canopy = 5 m (both species). Measured canopy cover = 15% *E. populnea* and 30% *A. aneura.* This site scores 3 for canopy height (5/15 = 33% of benchmark) and 5 for subcanopy height (5/8 = 63% of benchmark), giving an average score of 4 for height. This site scores 5 for both canopy and subcanopy cover (15/18 = 83% of canopy benchmark and 100% of subcanopy benchmark), giving an average score of 5 for cover.

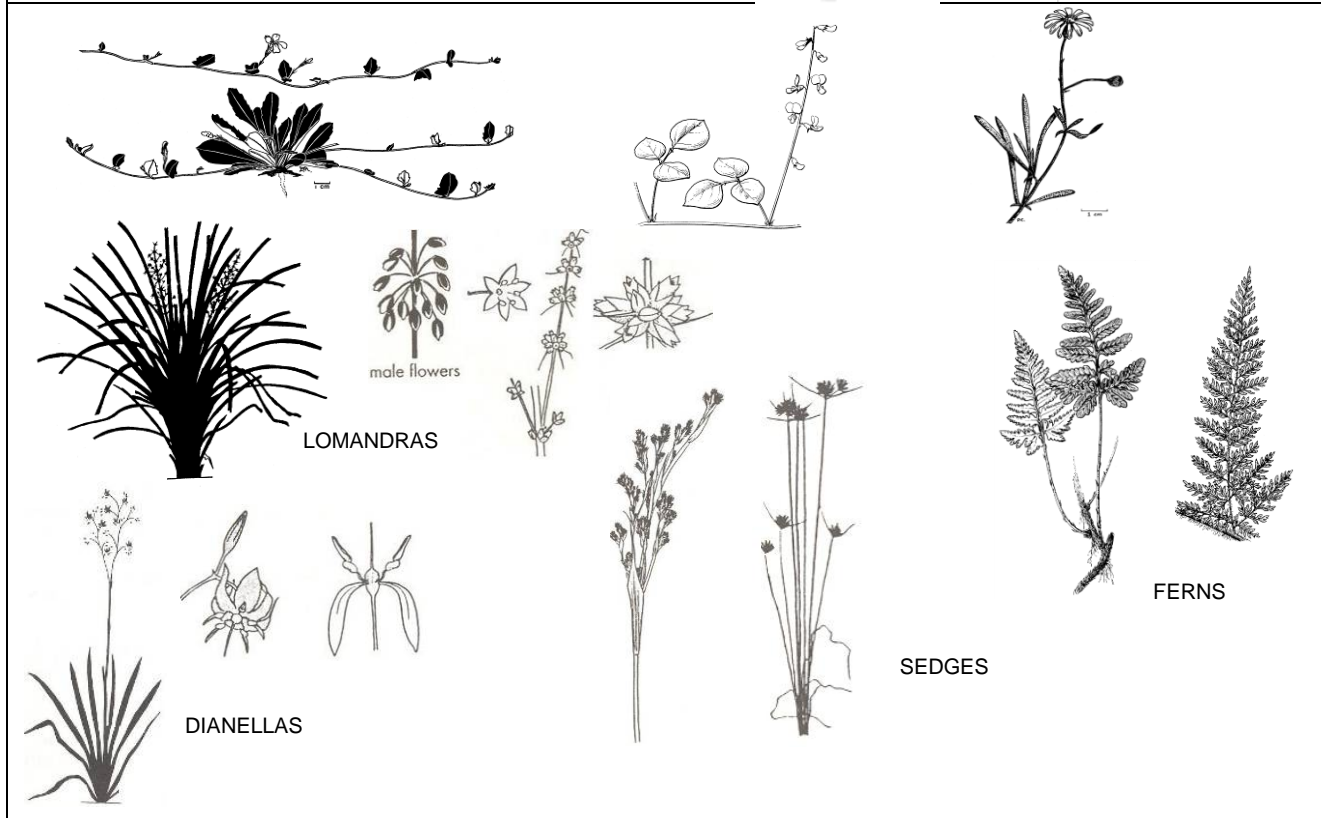# Appendix 7: Life/growth forms used in BioCondition

Code	Name	Description	BioCondition Category
T	TREE	Woody plants, more than 2 m tall with a single stem or branches well above the base	Tree
M	TREE MALLEE	Woody perennial plant usually of the genus *Eucalyptus*. Multi-stemmed with fewer than 5 trunks of which at least 3 exceed 10 cm diameter at breast height (DBH). Usually 8 m or more.	Tree
S	SHRUB	Woody plant multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m.	Shrub
Y	MALLEE SHRUB	Commonly less than 8 m tall, usually with 5 or more trunks, of which at least three of the largest do not exceed 10 cm DBH.	Shrub
Z	HEATH SHRUB	Shrub usually less than 2 m, commonly with ericoid leaves (nanophyll or smaller). Often a member of one of the following families: Ericaceae, Myrtaceae, Fabaceae and Proteaceae. Commonly occur on nutrient-poor substrates.	Shrub
C	CHENOPOD SHRUB	Single or multi-stemmed, semi-succulent shrub of the family Chenopodiaceae exhibiting drought and salt tolerance.	Shrub
U	SAMPHIRE SHRUB	Genera (of Tribe Salicornioideae, viz: *Sarcocornia*, and *Tecticornia*) with articulate branches, fleshy stems and reduced flowers within the Chenopodiaceae family, succulent chenopods. Also the genus *Suaeda*.	Shrub
G	TUSSOCK GRASS	Forms discrete but open tussocks usually with distinct individual shoots, or if not, then forming a hummock. These are the common agricultural grasses.	Grass
H	HUMMOCK GRASS	Coarse xeromorphic grass with a mound-like form often dead in the middle; genus *Triodia*	Grass
W	OTHER GRASS	Member of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.	Grass
V	SEDGE	Herbaceous, usually perennial erect plant generally with a tufted habit and of the families Cyperaceae and Restionaceae.	Other
R	RUSH	Herbaceous, usually perennial erect plant. Rushes are grouped into families Juncaceae, Typhaceae, Restionaceae and the genera *Lomandra* and *Dianella*.	Other
F	FORB	Herbaceous or slightly woody, annual or sometimes perennial plant; not a grass, and including ground orchids.	Forbs
D	TREE FERN	Spirally arranged crowns on erect trunks several metres high (U.N.E 1989), characterised by large and usually branched leaves (fronds), arborescent and terrestrial; spores in sporangia on the leaves.	Shrubs
E	FERNS AND FERN ALLIES	Characterised by large and usually branched leaves (fronds), herbaceous to arborescent and terrestrial to aquatic; spores in sporangia on the leaves.	Other

Code	Name	Description	BioCondition Category
B	BRYOPHYTE	Mosses and Liverworts. Mosses are small plants usually with a slender leaf-bearing stem with no true vascular tissue. Liverworts are often moss-like in appearance or consisting of a flat, ribbon-like green thallus.	Other
N	LICHEN	Composite plant consisting of a fungus living symbiotically with algae; without true roots, stems or leaves.	Other
K	EPIPHYTE	Epiphytes (including orchids), mistletoes and parasites. Plant with roots attached to the aerial portions of other plants. Often could also be another growth form, such as fern or forb.	Other
L	VINE	Climbing, twining, winding or sprawling plants usually with a woody stem.	Other
P	PALM	Palms and other arborescent monocotyledons. Members of the Arecaceae family or the genus *Pandanus*. (*Pandanus* is often multi-stemmed).	Trees
X	XANTHORRHOEA	Australian grass trees. Members of the family Xanthorrhoeaceae.	Shrubs
A	CYCAD	Members of the families Cycadaceae and Zamiaceae	Shrubs
J	SEAGRASS	Flowering angiosperms forming sparse to dense mats of material at the subtidal and down to 30m below MSL. Occasionally exposed.	Grass
Q	AQUATIC	Plant growing in a waterway or wetland with the majority of its biomass under water for most of the year. Fresh, saline or brackish water.	Other
O	LOWER PLANT	Alga, fungus.	Other
UNK	UNKNOWN		Other

# Appendix 8: Life-form identification

Diagrams reproduced from the Queensland Herbarium and with permission from Robinson, L. (1991). *Field guide to the Native Plants of Sydney*. Kangaroo Press, Sydney.

Diagrams (not to scale)	Description
	Trees: Trees include all single stemmed woody plants (with the exception of mallee species, which are multi-stemmed) greater than 2 m tall.
	Shrubs: Includes woody plants with multiple stems (excluding mallees.). Includes Cycads and Xanthorrhoeas.

Diagrams (not to scale)	Description
	Grasses: Includes all perennial and annual grasses (annual grasses are characterised by short growth, and don't form large tussocks or root mass like perennial grasses, no evidence of previous seasons growth (i.e. remains of last year's tiller bases, and absence of stolons or rhizomes, tussock, hummock and other grass species belonging to the family Poaceae).
	Forbs: Herbaceous or slightly woody, annual or sometimes perennial plants other than grasses. **Other species**: Slightly woody plants (subshrubs) or ferns, vines, sedges or rushes. Less than 1 m. Sedges and rushes such as Lomandra and Dianella can often be mistaken for grass. Distinction is based on the flowers. In the case of Lomandra the leaves are often flat with some parallel venation and are often quite tough. Although some species have cylindrical leaves and can be difficult to distinguish unless there are flowers, which are typically yellow. Dianella are similar often with broad flat leaves, usually arising from a flat base, flowers tend to be rich blue.

Appendix 9: Aerial photograph area calculation guide

From: Jones, K.L. (2000) *Aerial Photography Interpretation standards and guidelines for mapping forest resource and condition in Queensland.* Department of Natural Resources, Brisbane. ISBN 073451 6584.
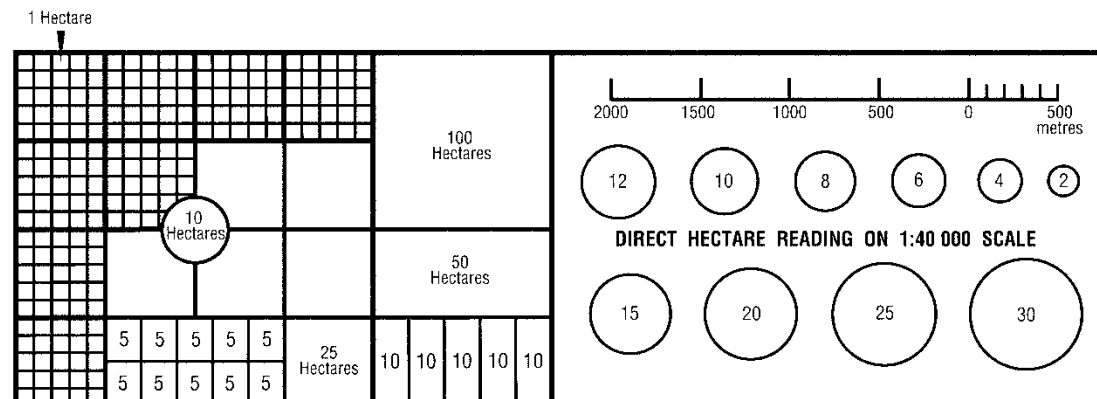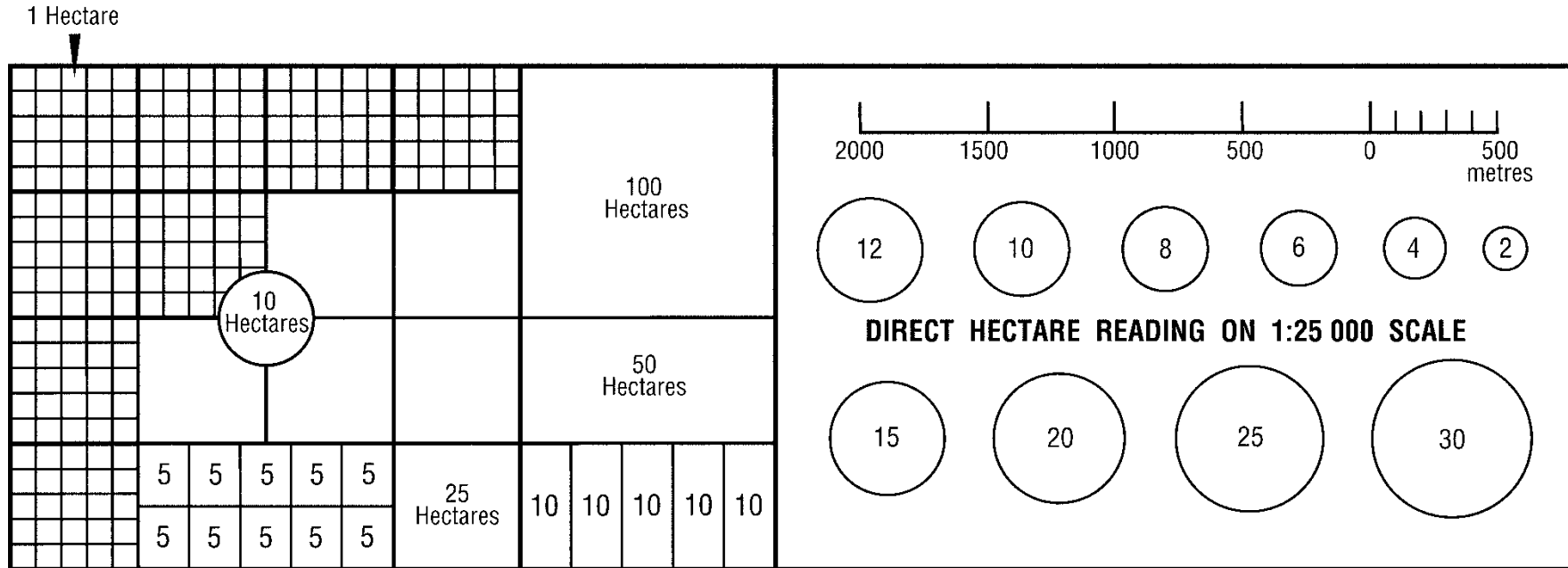
Appendix 10: A method to display BioCondition scores for attributes at a site

There are a number of methods that have been used to display the results of vegetation condition site assessments (Neldner and Ngugi 2014; Oliver et al. 2014). One of these is the radar or "spider web" graphs which can be constructed in Microsoft Excel. The spider web diagrams of the BioCondition attribute scores provide a comparison between site scores and the benchmark for each attribute. This can assist in the clear detection of attributes requiring management attention during monitoring programs in vegetation rehabilitation and/or areas undergoing changes in management.

Table 22. BioCondition scores relative to the maximum score for each attribute.

Attribute	Large trees	Tree canopy height	Recruit-ment	Tree canopy cover	Shrub layer cover	Coarse woody debris	Native plant species richness	Non-native plant cover	Native perennial grass cover	Litter cover
maximum score for attribute	15	5	5	5	5	5	20	10	5	5
score _2010	5	2	3	3	3	2	10	10	3	3
site score relative to maximum score_2010	33.33	40	60	60	60	40	50	100	60	60
score _2013	10	3	3	3	5	5	14	5	3	5
site score relative to maximum score_2013	66.67	60	60	60	100	100	70	50	60	100
score _2015	10	5	5	5	5	5	17.5	5	5	5
site score relative to maximum score_2015	66.67	100	100	100	100	100	87.5	50	100	100

The example in Figure 14 shows the change in site scores relative to the maximum score for each attribute from measurements made at a site in 2010, 2013 and 2015, using a radar graph. The sub-scores for each of the life-forms contributing to the native plant species richness attribute score (i.e. trees, shrubs, grasses and forbs/other) could be also be graphed if required. Similarly, the landscape attributes could also be displayed on the graph.
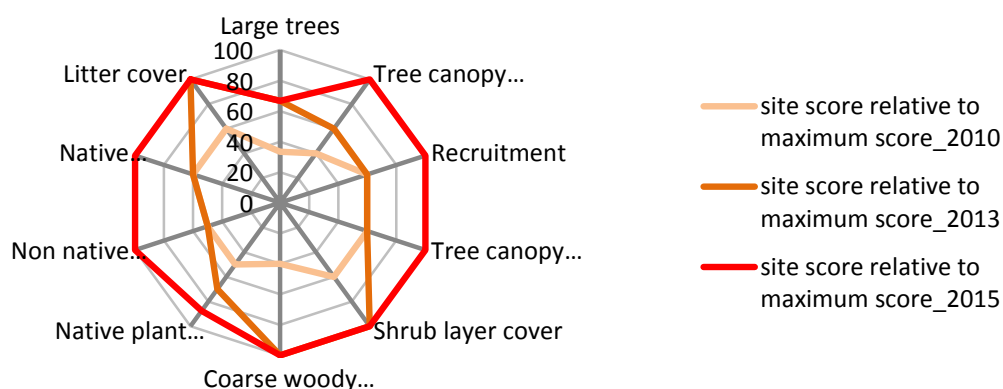

Figure 14 BioCondition scores relative to the maximum score for each attribute