CO2 Australia Native Vegetation Econd® Method

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Native Vegetation Econd® Method

A methodology for assessing condition of terrestrial wooded ecosystems of Australia

Version 3 – October 2023

VERSION

Ver	Date	Description
1	4 May 2020	Issued to Accounting for Nature™ for review and accreditation
2	30 July 2020	Updated method addressing Standards & Accreditation Committee feedback
3	18 October 2023	Updated to reflect Accounting for Nature™ terminology changes

	Name	Date
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Cover image

Revegetation project in the northern Nandewar Bioregion near Texas in southern Queensland. The Native Vegetation Econd® can be used to measure and monitor the condition of all types of woody vegetation communities; from a revegetation project in southern Queensland, to grazed mulga communities of central Western Australia, paperbark forests of Northern Territory, eucalypt woodland remnants embedded in agricultural land of New South Wales, to *Nothofagus* rainforest of south-west Tasmania.

Suggested citation

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CO2 Australia acknowledges Traditional Owners and Custodians of Country throughout Australia and recognises their ongoing connection to lands, waters and communities. We pay our respects to Aboriginal and Torres Strait Islander Elders past and present.

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1 BACKGROUND AND SCOPE

In 2008, the Wentworth Group of Concerned Scientists and other industry experts in the fields of science, statistics and economics, proposed a conceptual framework known as Accounting for Nature® (Wentworth Group, 2016), to create a robust and practical environmental accounting method to measure changes in the biophysical condition of environmental assets at any scale over time. Following this, the Accounting for Nature Limited ('AfN') was then established in 2018 as an independent non-for-profit organisation licensed by the Wentworth Group of Concerned Scientists to implement the Accounting for Nature® model across Australia and internationally. The Accounting for Nature® framework is now consistent with various highly acclaimed environmental accounting frameworks including, the United Nations System of Environmental-Economic Accounting 2012 (SEEA)(United Nations 2012).

According to the Wentworth Group of Concerned Scientists (2016), accounting for the condition of environmental assets must address several challenges, including:

- No two environmental assets are the same
- No single indicator can provide a complete picture of ecosystem health
- Often different indicators are needed to describe the same asset in different locations, and
- The cost of data collection creates variation in the quality of information collected.

To address these challenges, Accounting for Nature® has adopted a common unit of measurement, called an 'Econd®' to assess the condition of an environmental asset against established reference condition benchmarks. More specifically, an Econd® represents a metric between 0 and 100, where 100 refers to an asset in an undegraded (reference) state. An 'undegraded state' is the default reference against which condition is assessed. For the purpose of this method, an environmental asset refers to a single or aggregation of several native terrestrial vegetation communities dominated by woody vegetation stratums (e.g. trees and shrubs) in a defined project area.

To build upon current environmental accounting of native terrestrial wooded ecosystems, the method herein supports the Accounting for Nature® framework through the calculation of an Econd® as a surrogate measure of native terrestrial wooded ecosystem environmental assets at a point in time, allowing for subsequent assessments to detect the change in condition of those environmental assets over time. CO2 Australia Limited has developed this method, to be accredited under the Accounting for Nature® Framework, as a basis for third-party certification of measurement and reporting of broad biodiversity values of environmental accounting assets. This method has been developed and designed with the intention of it being able to be utilised across all terrestrial wooded ecosystems throughout Australia (Figure 1).

This Native Vegetation Econd® method provides a practical, affordable, repeatable and robust step-by-step approach to assessing native vegetation condition. In accordance with the *Technical Protocol for developing Native Vegetation Condition Account Methods* (Butler et al. 2020), the current methodology incorporates 'Composition' and 'Configuration' indicators of native vegetation condition, represented by site-based assessments of native terrestrial vegetation attributes and a vegetation configuration assessment (respectively). For the purposes of the current method document, the 'Composition' indicator of native vegetation condition defined by Butler et al. (2020) is herein divided into 'Species richness', 'Structure' and

‘Function’ indicators. Each of these vegetation attributes contributing to the species richness, structure and function indicators are compared against pre-determined ‘benchmark’ values relevant to the vegetation community being assessed and, in combination with the vegetation configuration indicator, generates a final Native Vegetation Econd® assigned to each Econd® site within the environmental accounting asset. The purpose of this Econd® assessment is to not only measure changes in the Econd® metric over time, but to also facilitate ongoing adaptive management to improve biodiversity values of an environmental accounting asset.

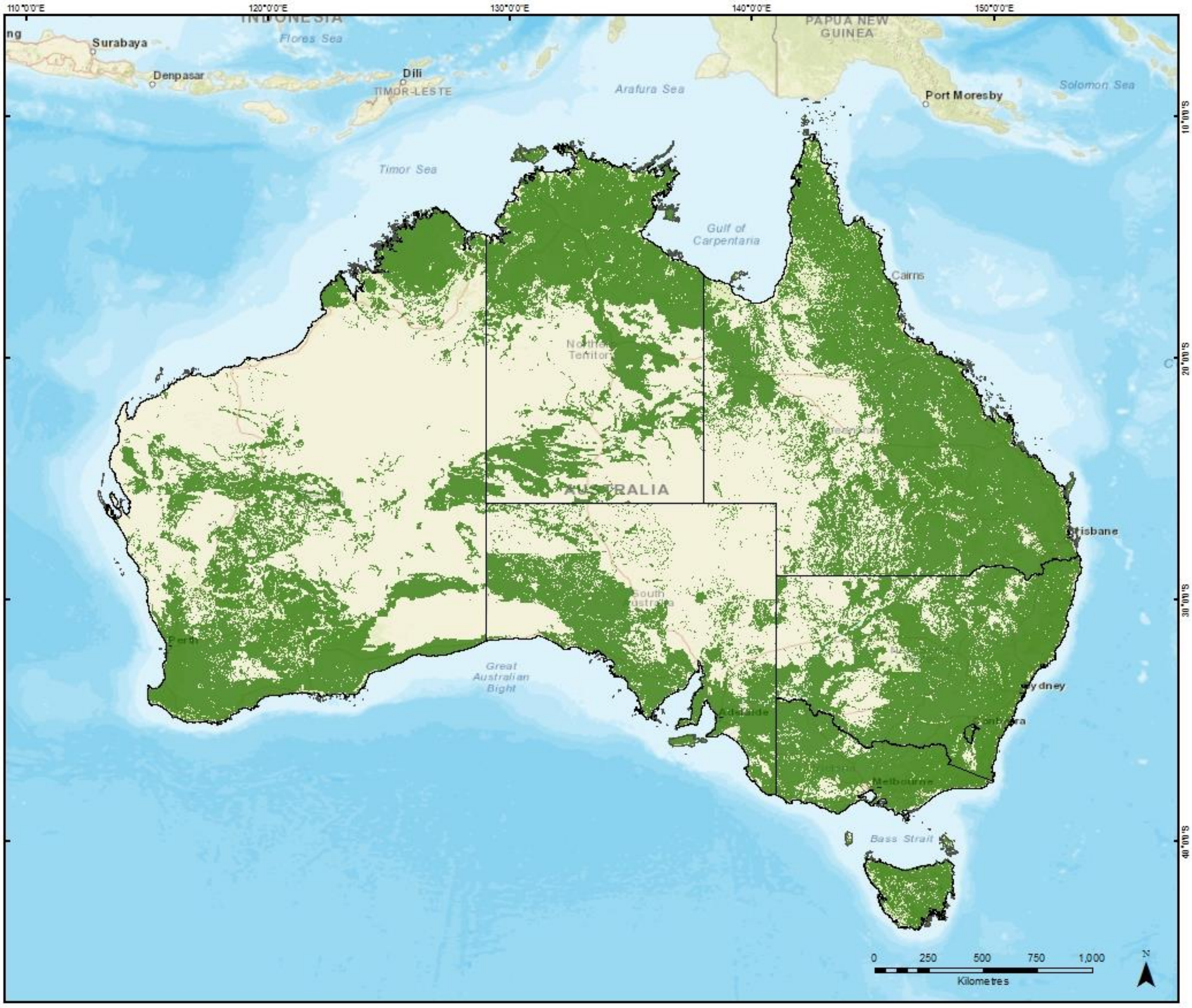

Figure 1: Map of Australia showing the areas within which the current method is intended to be used (green areas). These mapped areas correspond to native terrestrial wooded ecosystems derived from NVIS Major Vegetation Groups (Version 5.1).

This method is intended for use across all Australian states and territories (Figure 1), particularly projects containing a combination of remnant (intact) and/or native regrowth comprising predominantly terrestrial woody vegetation communities. This method is adapted from the methodology set out in Queensland BioCondition method (Eyre *et al*., 2015) and the New South Wales Biodiversity Assessment Method (OEH 2017); to be read in conjunction with the Accounting for Nature® Standard v1.42 (AfN 2019).

This Native Vegetation Econd® method has been intentionally designed such that individuals utilising the method (assessors) do not require expert knowledge of plant species identification and vegetation community identification. However, working knowledge in these skills, specifically regional-specific knowledge is preferable in order to maximise reliability of results. Assessors will require access to relevant, local reference material including, known or potential vegetation communities, corresponding vegetation community maps and benchmark documentation (if available).

1.1 ASSUMPTIONS

Successful and effective application of the Native Vegetation Econd® methodology to establish environmental accounts assumes the following:

- The method is intended to only be used in vegetation communities that support trees; however, it may also be defined by a non-vegetated area that is intended to be planted with trees as part of an environmental planting program or carbon estate, or where trees are anticipated to re-establish following a cessation of disturbance (i.e. human-induced regeneration projects). The method is also not intended for vegetation communities where benchmark documentation or benchmark values derived from reference sites indicate that trees are naturally absent (Refer to Section 6).
- Assessors must be appropriately trained in the use of this methodology and must be trained in the interpretation of benchmark documents for the geographical region within which this method is implemented. Ideally, the assessor will be formally trained in BioCondition assessments (Qld), be an accredited Biodiversity Assessment Method (BAM) assessor (NSW) or other state-based accreditation methods (where they exist) relevant to assessing vegetation communities.
- The method should be applied prior to or well after major management measures are implemented (e.g. weed control, prescribed burning) or any unplanned events occur (e.g. cyclones, wildfire) to avoid calculation of a Native Vegetation Econd® reflecting atypical and/or stochastic events.
- The method should be applied in consideration of seasonal (month) and climatic (rainfall temperature) variation, and where possible, repeated at a comparable time of year, in order to avoid seasonal influences on the calculation of the Native Vegetation Econd® (refer to Section 4.3 for regional survey timing considerations).

2 OVERVIEW OF PROCESS

Implementing this Native Vegetation Econd® method involves the following steps:

- Step 1. Define environmental accounting area.
- Step 2. Compile existing relevant, local data (e.g. vegetation mapping).
- Step 3. Identify available reference (benchmark) documentation, or if unavailable, establish reference sites.
- Step 3. Stratify environmental accounting area into assessment units, and nominate Accuracy Level accordingly.
- Step 4. Project area survey site setup – design field surveys, including accounting for seasonality.

- Step 5. Field-based assessment of vegetation attributes – locate, mark and measure species richness, structure and function attributes.
- Step 6. Undertake spatial analysis in order to calculate the vegetation configuration score.
- Step 7. Calculate Native Vegetation Econd® scores of all sites and the overall Native Vegetation Econd® for the environmental account.

3 GETTING STARTED

3.1 DEFINING AN ENVIRONMENTAL ACCOUNTING AREA

The first step in establishing an environmental account is to define the spatial extent of the account in accordance with the following considerations. The environmental accounting area may include only vegetated areas of an entire property or smaller selected wooded areas of varying scales. When defining an environmental accounting area of this type, it is intended that the extent of native terrestrial wooded assets are maintained through time. Areas that should be excluded from such an accounting area include the following:

- Areas dominated by infrastructure
- Areas subject to intensive cultivation or grazing
- Areas subject to subsequent destruction of woody vegetation by means of logging, thinning, ringbarking, poison treatment, burning, flooding or draining
- Where land-use change other than for conservation purposes is planned.

For environmental accounting areas that only consider vegetated areas, the final Native Vegetation Econd® is an area-weighted average score for all native vegetation types contributing to the environmental account.

Alternatively, an environmental accounting area can be defined by whole properties, collection of properties, a catchment or any other defined spatial scale. For these types of accounts, the Native Vegetation Econd® for each native vegetation type as the average condition of that native vegetation type across its pre-clearing or pre-European (reference) extent. Ordinarily, the non-vegetated areas of these native vegetation types derived from pre-clearing or pre-European mapping, have an Econd® score of 0. The Native Vegetation Econd® for each native vegetation type is therefore the product of an *extent* metric (amount of that native vegetation type retained from pre-clearing or pre-European extent in the accounting area) and a *quality* index (native vegetation type Native Vegetation Econd® score).

For example, for a whole-of-property environmental accounting area, if 50% of the property supports pristine, intact eucalypt woodlands (e.g. Native Vegetation Econd® score of the native vegetation type = 100/100), with the remaining 50% comprising intensive agriculture (cultivation or grazing with assumed Econd® of 0/100), its Native Vegetation Econd® would therefore be no more than 50. If that eucalypt woodland, covering 50% of the property, is degraded in some way (e.g. Native Vegetation Econd® score of the native vegetation type = 60/100), then the Native Vegetation Econd® is therefore 30 (i.e. 60% of 50%).

The overall Native Vegetation Econd® for an environmental account area is therefore calculated as the weighted average of the Econd® of each native vegetation type, scaled by their proportional extent at reference. Extent at reference (e.g. pre-clearing or pre-European) is used rather than current extent in order to obtain a representative measure of condition across the entire account area (Butler et al. 2020).

3.2 COMPILE EXISTING DATA

Following definition of the environmental accounting area, the next step is to compile all available vegetation and spatial information relating to the area to be assessed, including spatial data relating to known or likely vegetation communities. This information will be used to understand the extent of fieldwork required to establish the environmental account, including consideration of opting for very high or high Accuracy Level (refer to Section 3.3). It will also be required to understand availability of reference (benchmark) data from which site vegetation community data is compared (refer to Section 3.4).

Vegetation community data can be compiled based on the availability of any site-specific, ground-truthed vegetation surveys. Where that is not available, state, territory or national-based vegetation mapping should be used. Appendix A outlines the known native vegetation classification systems for each state and territory, including Regional Ecosystem (RE) mapping in Queensland, Plant Community Type (PCT) mapping in NSW, Ecological Vegetation Class (EVC) mapping in Victoria, Vegetation Association mapping in WA and Vegetation Community mapping in ACT and Tasmania. This vegetation community mapping is ordinarily available at scales between 1:10,000 and 1:100,000. In addition to considering individual vegetation communities, the broader vegetation grouping of those vegetation communities needs to be assigned. These broad vegetation groupings define the assessment units from which survey effort is calculated and thus the Accuracy Level is chosen (refer to Section 3.3). Where available, broad vegetation grouping can be based on scales up to 1:2,000,000. Examples of higher order groupings of vegetation communities in state and territory-based mapping systems include Broad Vegetation Groups (BVG) in Queensland and Vegetation Classes (VC) in NSW and ACT.

An example of a nested hierarchy of vegetation communities within broader vegetation groupings is provided for a Queensland BVG in Table 1.

Table 1: Example of the hierarchical nested structure of vegetation community classification in Queensland, with regional ecosystems (RE) grouped into broad vegetation groups (BVG) at the 1:1,000,000 scale; themselves grouped at the 1:2,000,000 scale. In Queensland, there are 1,424 REs, 98 BVGs at the 1:1,000,000 scale and 35 BVGs at the 1:2,000,000 scale.

Broad Vegetation Group (BVG)		Regional Ecosystem (RE)
1:2,000,000 (n = 35)	**1:1,000,000 (n = 98)**	**1:25,000 – 1: 100,000 (n = 1,424)**
8. Wet eucalypt tall open forests on uplands and alluvia	8a. Wet tall open forests dominated by species such as *Eucalyptus grandis* (flooded gum) or *E. saligna*, *E. resinifera* (red mahogany), *Lophostemon confertus* (brush box), *Syncarpia* spp. (turpentine), *E. laevopinea* (silvertop stringybark)	7.12.22a – *Eucalyptus resinifera, E. acmenoides, Corymbia intermedia, Syncarpia glomulifera* tall open forest on uplands and highlands
		11.10.5 – *Eucalyptus sphaerocarpa ±E. mensalis, E. saligna*, tall open forest
		12.3.2 – *Eucalyptus grandis* tall open forest on alluvial plains
	8b. Moist open forests to tall open forests mostly dominated by *Eucalyptus pilularis* (blackbutt) on coastal sands, sub-coastal sandstones and basalt ranges. Also includes tall open forests dominated by *E. montivaga, E. obliqua* (messmate stringybark), and *E. campanulata* (New England ash)	12.12.2 – *Eucalyptus pilularis* tall open forest on Mesozoic to Proterozoic igneous rocks especially granite
		12.2.8 – *Eucalyptus pilularis* open forest on parabolic high dunes

As a rule of thumb, the following scales represent those appropriate for consideration as vegetation community mapping and/or broad vegetation grouping:

- Greater than 1:2,000,000 – generally not appropriate for use as either broad vegetation grouping or vegetation community mapping
- Between 1:2,000,000 and 1:100,000 – appropriate for use as broad vegetation grouping, but generally not appropriate for use as vegetation community mapping
- Less than 1:100,000 – appropriate for vegetation community mapping, with grouping of vegetation communities required to assign broad vegetation grouping

Where vegetation community datasets are not available, other available mapping should be interrogated and used, including the National Vegetation Information System (NVIS) mapping. The NVIS mapping is a comprehensive data system that provides information on the extent and distribution of vegetation types in Australian landscapes, available from the Australian Government Environment Department. As this mapping is generally available at scales below 1:2,000,000, it can be used to assist with defining BVG (and thus assessment units), and vegetation communities if in accordance with the abovementioned limitations regarding scale, and when used in conjunction with accompanying lookup tables which detail 10,774 vegetation types across Australia.

Where no higher order grouping of vegetation communities is available, appropriate broad grouping of vegetation communities should be assigned. This grouping should be based on vegetation structure (e.g. cover, height and growth form) of the ecologically dominant layer; however, should also considering floristic, structural, functional, biogeographic and landscape attributes. The Broad Vegetation Groups of Queensland document (Neldner et al. 2019) provides details on what to consider as part of any proposed grouping of vegetation communities.

3.3 ACCURACY LEVELS AND SURVEY EFFORT

In accordance with the Accounting for Nature® Standard v1.42 (AfN 2019), assessors using this Native Vegetation Econd® method can opt for one of two Accuracy Levels. The levels are referred to as 95% (Very High) or 90% (High) and are described as follows:

- A **95% (Very High)** Accuracy Level applies to Methods that include a comprehensive set of indicators and are likely to have very high accuracy (≥95%) when measuring the condition of environmental assets and detecting change in their condition through time.
- A **90% (High)** Accuracy Level applies to Methods that include a relatively comprehensive set of indicators and are likely to have high accuracy (≥90%) when measuring the condition of environmental assets and detecting change in their condition through time.

Two Accuracy Levels are assigned in the current method, corresponding to survey effort within assessment units. For the purpose of this method, (discussed in Section 3.2), assessment units are defined as broad vegetation groups, which themselves may comprise one or a number of different vegetation communities. Once an environmental accounting area has been delineated into assessment units, the number of survey sites can be calculated. Where the size of an assessment unit is less than 2 ha, a minimum of one survey site is required to be established. The minimum number of survey sites increases to a maximum of nine survey sites where the assessment unit area is greater than 500 ha, where a very high Accuracy Level is sought. Table 2 outlines the minimum number of survey sites required per assessment unit by Accuracy Levels . Refer to the Accounting for Nature® Standard v1.42 (AfN 2019) for more details on Accuracy Levels. If not decided beforehand, any decision on whether to proceed with establishing an environmental accounting area with either a very high or high Accuracy Level based on survey effort required can be instructed by this process.

Table 2: Accuracy levels as a function of survey effort.

Assessment unit area	Minimum number of survey sites Accuracy Level – 95%	Minimum number of survey sites Accuracy Level – 90%
<2 ha	1	1
≥2 ha to ≤20 ha	3	2
>20 to ≤60 ha	5	3
>60 ha to ≤500 ha	7	5
>500 ha	9	7

Once the number of survey sites has been calculated for each assessment unit, those sites are apportioned across the vegetation communities contributing to that assessment unit. Where there are more vegetation communities within an assessment unit than the minimum number of survey sites, the number of sites need to be increased to ensure at least one site within each vegetation community. Where the number of survey sites for a given assessment unit is greater than the number of vegetation communities associated with that assessment unit, the sites are apportioned proportional to the area of those vegetation communities.

3.4 ESTABLISHING APPROPRIATE REFERENCE (BENCHMARK) CONDITION

Central to the Native Vegetation Econd® method is the comparison of vegetation attributes measured at an Econd® site to those attributes in a reference (benchmark) condition; represented either by attribute values collated by the assessor from reference sites or from available “benchmark” documents. The reference condition is intended to represent the condition of a corresponding vegetation community in a relatively undisturbed condition, reflecting natural variability in structure and floristic composition under a range of natural disturbance regimes throughout the geographic extent of the given vegetation community. The comparison of Econd® sites to an appropriate reference condition is essential in order to make valid comparisons of the condition of a given Native Vegetation Econd® site over time and across the different patches of that vegetation community contributing to its assessment unit and, ultimately to the whole environmental accounting area. The reference condition also provides a consistent and logical reference point for ‘naturalness’ against which loss of a sites condition or quality (i.e. Econd® score) and direction for improvement can be considered (Parkes *et al*. 2003). The intent of this method is for the reference condition (whether derived from reference sites or from benchmarks documentation) to represent a baseline reference condition for each corresponding vegetation community for all subsequent survey events. Implementing a baseline condition approach to calculating the Native Vegetation Econd® score over the life of the environmental account, rather than a dynamic reference condition ensures detection of long-term, relative changes over time.

3.4.1 Use of existing benchmark documentation

Once the number and identity of vegetation communities has been determined, a search is undertaken to ensure benchmark documentation is available and consistent with all the types of vegetation communities represented across the environmental account area. Published benchmark documents have been developed by relevant state herbaria and/or government departments, derived from field-based assessments at reference sites specific to each vegetation community. This Native Vegetation Econd® method acknowledges that the methodologies used in different states and territories to develop benchmark documentation may not be identical. For example, vegetation condition studies in NSW, including sites established for development of NSW benchmark sites, generally utilise a 0.04 ha plot for the measurement of floristic attributes (Sivertsen 2009); whether from the standard 20 m x 20 m plot or an alternative, appropriate dimension (e.g. 40 m x 10 m). However, Sivertsen (2009) acknowledges that observer characteristics (e.g. local experience, time allowed for plot) or vegetation type may be a more significant consideration than plot size. Accordingly, data collected from a 50 m x 10 m (0.05 ha) plot as per the current method, is considered appropriate for scoring against benchmarks that may be derived from plots of alternative dimensions where those alternatives are identified as appropriate for collating benchmark floristic attributes.

Available, known benchmark documentation in each state and territory is outlined in Appendix B.

In the absence of existing benchmark documentation for vegetation communities in the environmental accounting area, or the absence of benchmark values for specific vegetation attributes contributing to indicators, consultation should be sought from relevant state or territory herbaria to provide advice about the availability of any draft and/or unpublished benchmarks. Alternatively, an appropriately qualified assessor can nominate an alternative benchmark of a comparable vegetation community (e.g. a benchmark for a floristically and geographically similar vegetation community, or one in the same broad vegetation group). Furthermore, where vegetation mapping identifies a mixed (heterogenous) vegetation community (e.g. mapping polygon with 50/50 mix of two vegetation communities), the assessor will nominate the appropriate benchmark document to use based on the dominant, representative vegetation community at the given site.

Where no benchmark documentation exists for a given vegetation community, or an alternative vegetation community benchmark is not available, the only option is to establish local reference sites.

3.4.2 Establishing local reference sites

Where local benchmark data is required to be developed, it must be derived from measurements taken at reference sites that measure the same vegetation community. Eyre et al. (2017) outlines specific considerations relating to the establishment and surveying of reference sites, which this method closely aligns. Specifically, where practicable, a reference site should:

- be homogenous with regard to vegetation community and overall condition status
- be selected in vegetation communities with no extensive chemical or mechanical disturbance to the predominant canopy evident on the ground and where available, from historical aerial photograph since the 1960s
- represent an undisturbed, late mature or best-on-offer version of the vegetation community, representing sites with minimal modification through timber harvesting, grazing, fire, erosion, dieback, flood, and/or weed infestation
- be located within a reasonably large (> 5 ha) intact patch of remnant (intact) vegetation to minimise potential of edge effects
- be located at least 50 m from a roadside, track, or other major disturbance and be remote from artificial water sources
- exclude areas subject to recent major management change.

A minimum of three reference sites should be assessed in order to obtain a reasonable representation of the natural variation inherent in vegetation condition attributes within the geographic range of a vegetation community (sensu Eyre et al. 2017). Where possible, reference sites for a given vegetation community should be surveyed at the appropriate time of year and following favourable seasonal conditions (refer to Section 4.3) and be established surveyed at least 3 km apart to account for potential geographic variation. This is however subject to the extent and accessibility of those areas supporting vegetation communities in accordance with the abovementioned conditions.

Where a reference site supports only a subset of vegetation attributes in an undisturbed state, benchmark data for only some of the field-based attributes may be able to be collected. Where required, it is acceptable to establish a reference site that provides benchmark data for one or more attributes only. This is also acceptable to supplement an existing benchmark document where there is an absence of benchmark values for specific vegetation attributes (refer to Section 3.4.1).

4 PROJECT AREA SURVEY SITE SETUP

4.1 SURVEY SITE LOCATION

The location of survey sites will be permanent for the length of the project, with the intent of repeating surveys at those same permanently established sites. Survey sites will be permanently marked by way of either capped, steel stake or some other recognisable marker (refer to Section 4.2).

Site locations should be determined using a random selection of intersections in a grid overlayed on each assessment unit. Site locations that are randomly selected but are less than 100 m from the edge of any assessment unit, ecotonal area and/or disturbance area can be moved so that they are centred at least 100 m from these areas. The orientation of plots should follow the contour across a slope unless they are required to be orientated otherwise to be positioned within the assessment unit or to remain at least 100 m from the edge of an assessment unit, ecotonal area and/or disturbance area. Where possible, selection of survey sites should consider discontinuous patches of the same assessment unit. For further details on establishing a grid overlay refer to Appendix C.

An alternative method for random assignation of survey site location may be required in the following circumstances:

- Where intersections in a grid overlay do not overlap with assessment units when they are small (e.g. <1 ha) or obscure in shape, or
- Where an assessment unit is considered in two broad condition states after a period of management and additional survey sites are required.

In both instances survey sites should be located randomly by either:

- Randomly stratifying additional sites in the assessment unit on aerial imagery, or
- Nominating an additional site by pacing a random distance in a random direction into the assessment unit.

4.2 ESTABLISH SURVEY PLOTS

Details of establishing survey plots are presented here. Once the location of the survey site has been decided, establish a 100 m x 50 m plot, within which the 13 site-based vegetation attributes will be measured. The site should be marked out by laying a 100 m tape measure that follows the contour across a slope.

Once the 100 m transect has been established, install star pickets at the start (0 m) and mid-point (50 m) of the survey plot mid-line and record the GPS location of these. The 100 m x 50 m survey plot (blue plot, Figure 2) will encompass the following nested plots straddling the survey plot mid-line:

- 1 m x 1 m quadrat plots (green squares).
- 50 m x 10 m plot (brown plot).
- 50 m x 20 m plot (red plot).
- 100 m transect along the survey plot mid-line (pink dashed line).

Where a standard survey plot does not fit (e.g. in a narrow or discontinuous patch), a modified plot of an equivalent 0.5 ha area (e.g. 200 m x 25 m or multiple short transects equivalent of 100 m) can be substituted to allow for attributes to be sufficiently sampled. Figure 2 shows a schematic of the standard survey plot layout for each survey site.

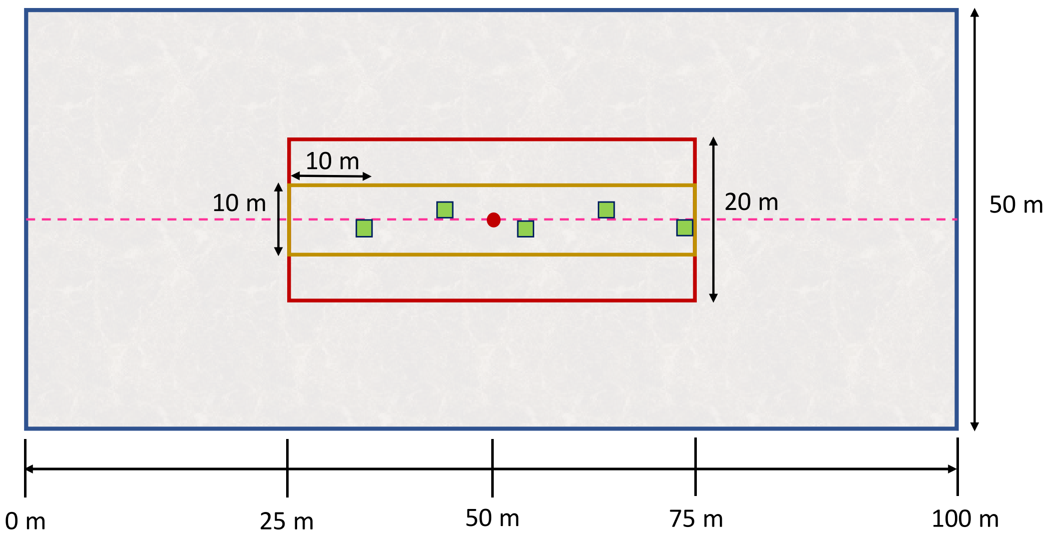

Figure 2: Standard survey plot layout for each survey site, showing the nested plots within.

Useful materials to take into the field to assist with a Native Vegetation Econd® assessment and ensure the appropriateness of the plot location include:

- Aerial photography of the site – this may require use of a Geographic Information Systems (GIS) layer to close into the site scale and the addition of layers such as infrastructure (tracks, dams, fences) riparian zones, and cadastral boundaries.
- Vegetation community map – this may require use of a GIS layer at the appropriate scale. In general, vegetation community maps must show the existing remnant (intact) and native regrowth areas of the study site as well as the defined vegetation community (assessment unit) at the study site.
- Field equipment for survey – a list of all survey equipment recommended to establish the survey plot and undertake the survey is outlined in Appendix D.

4.3 SURVEY TIMING

It is recommended that surveys are conducted during favourable growth periods of the year in order to maximise opportunities to identify/differentiate flowering plants. The optimal time for assessment outside of the arid zone is therefore the months immediately following the dominant rainfall season (refer to Table 3). Typically, for sites north of the Tropic of Capricorn in QLD, WA and NT, surveys should be conducted between April and June. For sites between the Tropic of Capricorn and the Hunter Valley on the east coast (Qld and NSW), surveys should generally be conducted between March and May. In the balance of NSW to the south and west of the Hunter Valley and the ACT (characterised by largely uniform monthly rainfall), surveys can be conducted year-round. In Victoria and Tasmania, as well as non-arid areas in South Australia and south of the Tropic of Capricorn in Western Australia, surveys should be conducted between August and November following the predominantly wet winter months.

Table 3: Recommended survey timing as determined by geographical location of project

Project location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
QLD (N of Tropic of Capricorn)			✓	✓	✓	✓						
QLD (S of Tropic of Capricorn)			✓	✓	✓							
NSW (N of Hunter Valley)			✓	✓	✓							
NSW (S and W of Hunter Valley)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ACT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
VIC								✓	✓	✓	✓	
TAS								✓	✓	✓	✓	
SA								✓	✓	✓	✓	
WA (N of Tropic of Capricorn)			✓	✓	✓	✓						
WA (S of Tropic of Capricorn)								✓	✓	✓	✓	
NT			✓	✓	✓	✓						
Arid zone in all states	Months following major rainfall event											

4.4 SURVEY INTERVALS

Following an initial baseline survey using this method, ongoing surveys will be repeated at regular pre-determined intervals to assist in measuring changes throughout the management period of the environmental accounting area. While more regular surveys are more sensitive to detecting change, and are thus able to inform management focusing on improving Econd® scores, it is recognised that survey intervals are subject to budget constraints or other commercial decisions. Notwithstanding, it is recommended that detailed Econd® surveys are repeated at least every 5 years. In those intervening years where detailed surveys are not undertaken, photo monitoring (Section 4.5) is encouraged and recommended to demonstrate no significant land use change and to verify the detailed Econd® surveys and annual accounts when they are undertaken.

4.5 ADDITIONAL/SUPPORTING INFORMATION

4.5.1 Photo monitoring

In addition to the quantitative assessment of vegetation site condition, photo monitoring will also be undertaken as a qualitative analysis technique, providing the opportunity for a visual time series analysis of changes in vegetation composition, structure and integrity. In areas where active management is being undertaken, photo monitoring offers a simple and effective means by which to enable visual assessment of habitat changes over time and capture the response of the project area to management actions.

At each of the star pickets installed at the 0 m and 50 m mark along each survey plot's mid-line, five photos will be taken from ~1.5 m height above ground level in the direction of magnetic north, south, east, and west with a ground photo taken looking down at an angle of ~45° to the north-west of the star picket such that the horizon is just in view at the top of the photo. The ground shot should be chosen to give a representative indication of cover and species composition for the general area if possible. A record of the photographs will be recorded on the Vegetation Survey Pro Forma including, GPS co-ordinates, date and time of each photograph, and the direction in which the photograph was taken.

5 ASSESSMENT OF VEGETATION INDICATORS

An array of vegetation attributes contributing to the three vegetation indicators (species richness, structure and function) will be assessed from each permanently established survey site. Table 4 outlines the assessment indicators, measurable attributes and their corresponding survey areas at each survey site.

Table 4: Assessment indicators, measurable attributes and their corresponding survey area

Indicators	Measurable attribute	Unit of measure	Survey area
Species richness	Tree species richness	Species count	100 m x 50 m plot
	Shrub species richness	Species count	50 m x 10 m plot
	Grass species richness		
	Forbs/other species richness		
Structure	Large trees	Count	100 m x 50 m plot
	Tree canopy height	m	50 m x 20 m plot
	Tree canopy cover	%	100 m transect
	Shrub canopy cover	%	
Function	Recruitment of dominant canopy species	%	100 m x 50 m plot
	Woody debris	Length of logs (m)	50 m x 20 m plot
	Organic litter cover	%	5 x 1 m² plots
	Native grass cover	%	
	Non-native plant cover	%	50 m x 10 m plot

Indicators	Measurable attribute	Unit of measure	Survey area
Vegetation configuration	Remnant (intact) vegetation and native regrowth	%	1 km circular buffer

5.1 ASSESSMENT OF SPECIES RICHNESS

5.1.1 Native plant species richness attributes

Assessment of the species richness indicator is based on a measurement of native plant species richness (count of species) from four life/growth forms including, native tree species within the 100 x 50 m plot and shrub species, grass species and forbs/other species within the 50 m x 10 m plot of each survey site (refer to Figure 2). Where a species occurs in more than one layer with different lifeforms (e.g. *Acacia* shrubs), which can occur as a shrub in the shrub layer as well as a tree in the canopy, then the species is counted for each layer it is observed in. Where a species has two lifeforms in the same layer (e.g. *Eucalyptus viridis*), such as which can occur as a multi-stemmed 'shrub' growth form and also as a single-stemmed 'tree' growth form, then it is to be recorded as the most frequent growth form in that layer. The definition of each life/growth form is as follows, as per Appendix 7 of the Queensland BioCondition Manual (Eyre *et al*. 2015):

- Tree – woody plants, more than 2 m tall with a single stem or branching at least 200 mm from ground level.
- Shrub – woody plant multi-stemmed from the base (or within 200 mm from ground level) or if single stemmed, less than 2 m.
- Grass – a collective term for the following plant life forms: tussock grass with distinct individual shoots; hummock grass with a mound-like form often dead in the middle; and other grasses of the family Poaceae, but having neither a distinctive tussock nor hummock appearance.
- Forbs – herbaceous or slightly woody, annual or sometimes perennial plant; not a grass or life form defined under 'Other species'.
- Other Species – all plant life-forms that are not trees, shrubs, grasses or forbs. This includes all vines/scramblers, epiphytic species etc.

If a project is located where mallee vegetation can occur, the aforementioned tree and shrub definitions are replaced with the following:

- Mallee tree – woody perennial plant usually of the genus *Eucalyptus*. Multi-stemmed with fewer than 5 trunks of which at least three exceed 10 cm diameter at breast height (DBH[1]). Usually 8 m or more in height.
- Mallee shrub – typically less than 8 m in height, usually with 5 or more trunks, of which at least three of the largest do not exceed 10 cm DBH.

When recording native plant species richness, assessors should indicate what the three most dominant or conspicuous species are from each stratum layer. While it is recognised that the occurrence of a given species at any one time is dependent on seasonality, stages of community succession and degree of disturbance, this information (in combination with photo monitoring) can be interrogated to understand

[1] DBH – diameter at breast height, taken to be 1.3 m

differences in Econd® scores between replicate sites. This will assist with implementing specific management actions to maximise opportunities to enhance the Native Vegetation Econd® score.

The species richness of trees, shrubs, native grasses and forbs/other is compared to the relevant available benchmarks and scored in accordance with Section 6.

5.2 ASSESSMENT OF STRUCTURE

Assessment of the vegetation structure indicator is based on an assessment of four structural attributes, including a count of large trees, measurement of tree canopy height (m) and canopy crown cover (%) of native trees and shrubs along the 100 m transect (refer to Figure 2). The method for assessing each of these vegetation structural attributes is outlined below.

5.2.1 Large tree attribute

The large tree attribute is measured as a count of all living tree stems per hectare with a DBH greater than the DBH threshold provided in the relevant benchmark document. Standing dead trees are not included. Native trees larger than the DBH threshold are counted within the 100 m x 50 m assessment area. Where there is no benchmark data available for large trees, local benchmark data is required to be developed in accordance with Section 3.4.2. However, the default DBH threshold to be used when counting large trees at reference sites is:

- 30 cm for eucalypt trees (Eucalyptus, Corymbia, Syncarpia, Lophostemon), and
- 20 cm for non-eucalypt trees (e.g. *Melaleuca*, *Acacia*, *Callitris*, *Eremophila* and *Casuarina*).

In some vegetation communities, where there are no benchmark counts of large trees, there may be exceptions to these the size threshold rules. If while establishing a reference site it is clear that the vegetation community does not support trees with a DBH larger than 20 cm, it may necessitate a smaller large tree threshold. For example, some *Melaleuca* and *Acacia* dominated communities, as well as many eucalypt mallee dominated vegetation communities may not support trees larger than 15 cm DBH. In those communities, it may necessitate consideration of large trees as those with DBH larger than 10 cm to ensure a benchmark large tree attribute is made available to compare to.

The total count of large trees is multiplied by two to represent the number of large trees per hectare, in order to compare to benchmark or reference site values, and scored in accordance with Section 6.2.1.

5.2.2 Tree canopy height attribute

Tree canopy height (measured using a tape measure (<2 m), clinometer or an alternative method) is based on the median canopy height of the ecologically dominant layer (EDL) within the 50 m x 20 m plot (refer to Figure 3). The EDL refers to the layer containing the greatest amount of above-ground vegetation biomass of the site and the vegetation community. The median canopy height is the height that has 50% of canopy trees higher and lower than it. The median height is generally synonymous with average height except when there are some trees that are substantially higher or lower than the median.

For the purposes of this method, only tree canopy stratum (EDL) is included when measuring and scoring tree canopy height. All other tree strata including, subcanopy and emergent layers are excluded from measurements and scoring.

The calculated tree canopy height is compared to the relevant available benchmark and scored in accordance with Section 6.2.2.

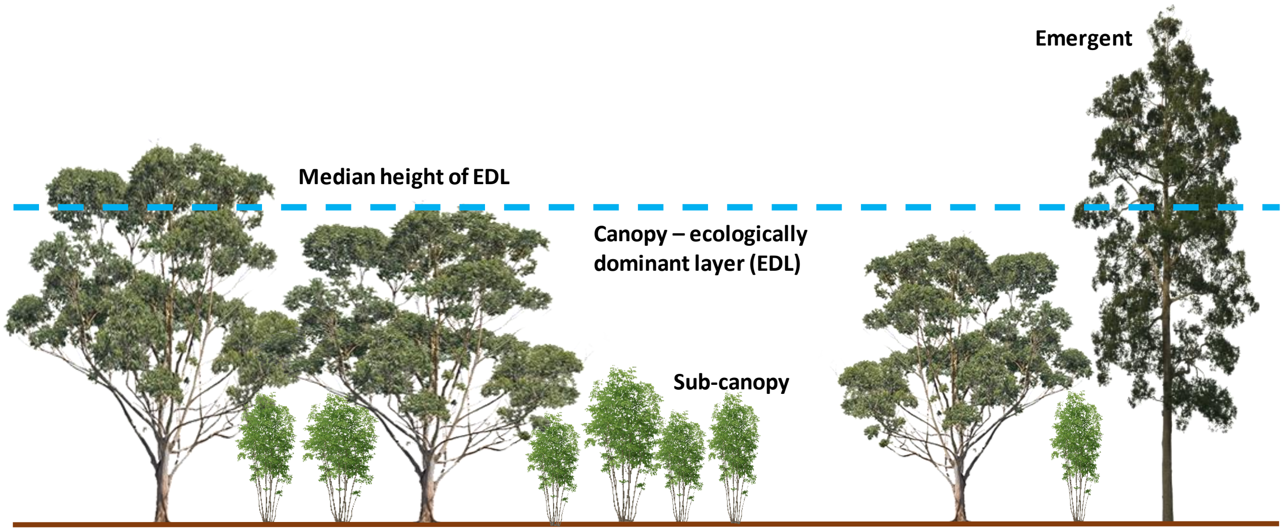

Figure 3: Tree canopy height and the ecologically dominant layer (EDL)

5.2.3 Canopy cover attributes (trees and shrubs)

Canopy cover is assessed by measuring the percentage canopy (i.e. crown) cover of all living, native trees and native shrubs along the 100 m transect, using the line intercept method. Other tree strata including, sub-canopy and emergent trees, as well as all exotic species are omitted from this method. Canopy cover equates to crown cover as defined by Walker and Hopkins (1990). The total length of the canopy cover of each layer (i.e. trees and shrubs) is then divided by the total length of the transect (i.e. 100 m) to give an estimate of percentage canopy cover at the survey site, in accordance with the line-intercept method (Figure 4).

The canopy cover of trees and shrubs is compared to the relevant available benchmarks and scored in accordance with Section 6.2.3.

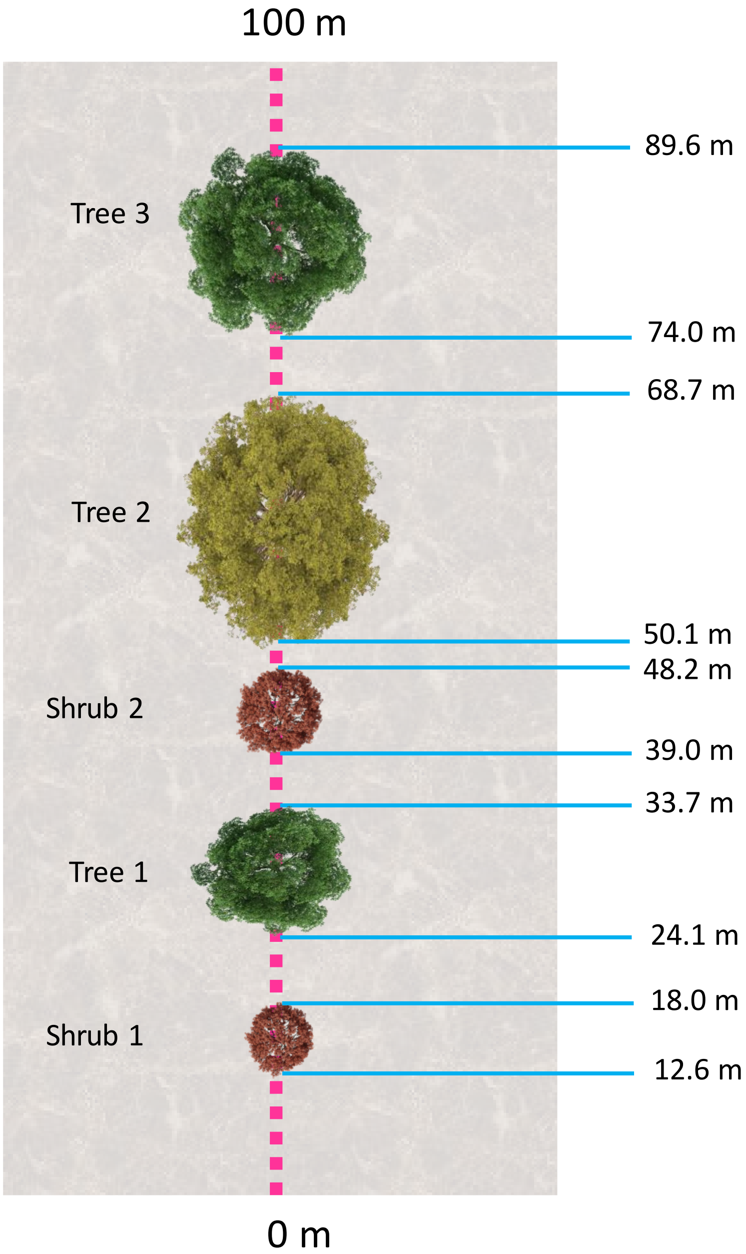

Figure 4: Example of canopy (crown) cover of native trees and shrubs using the line-intercept method

5.3 ASSESSMENT OF FUNCTION

Assessment of the vegetation function indicator is based on a measurement of five functional attributes including recruitment of dominant canopy species, woody debris volume, organic litter cover, native grass cover, and non-native plant cover. Measurements of five vegetation function attributes are assessed within all of the sub-plots of the survey site and the 100 m transect (refer to Figure 2). The method for measuring vegetation function is outlined below.

5.3.1 Recruitment of dominant canopy species attribute

Recruitment of dominant canopy species is assessed in the 100 m x 50 m plot and is defined as the proportion of dominant native woody tree species within the plot that are regenerating with stems <5 cm DBH. The recruitment of dominant canopy species attribute is scored in accordance with Section 6.3.1.

If the Econd® site is located within a carbon estate asset which includes planted trees (e.g. environmental planting projects), individual trees known or reasonably assumed to have been planted (i.e. are positioned and/or spaced consistent with likely planted specimens) are excluded from the recruitment assessment.

5.3.2 Woody debris attribute

Woody debris is assessed by measuring the length (in metres) of fallen logs on the ground within the 50 m x 20 m (0.1 ha) plot (refer to Figure 2). To be considered, all logs must be greater than 10 cm in diameter, >0.5 m in length, and be at least 80% in contact with the ground. Where logs extend outside of the plot, only the length of the fallen log within the plot is recorded. The total measured value is multiplied by 10 to convert to a metre per hectare value. The woody debris length is then compared to the relevant available benchmark and scored in accordance with Section 6.3.2.

5.3.3 Organic litter cover attribute

Organic litter cover is assessed by recording the average percentage cover of organic litter from five 1 m x 1 m plots (refer to Figure 2). Organic litter cover refers to all fine and coarse organic material such as fallen leaves, twigs and branches <10 cm diameter. The organic litter cover is compared to the relevant available benchmark and scored in accordance with Section 6.3.3.

5.3.4 Native grass cover attribute

Native grass cover is assessed by recording the average percentage projected cover of native grasses from the five 1 m x 1 m plots (refer to Figure 2). The native grass cover is compared to the relevant available benchmark and scored in accordance with Section 6.3.4.

5.3.5 Non-native plant cover attribute

Non-native plant cover is assessed by recording the average percentage projected cover of non-native plant species within the 50 m x 10 m plot (refer to Figure 2). Non-native plants refer to exotic (introduced) species or non-endemic species (i.e. native species outside of their natural range). Where non-native plants are present in more than one layer (e.g. in the shrub layer and the ground layer), then the cover across all layers are projected vertically to estimate the cover. The estimate of non-native plant cover can be improved at a site by dividing the 50 m x 10 m plot into smaller areas (e.g. twenty 5 m x 5 m sub-plots) and then averaging the cover estimates. The cover of non-native plants is scored in accordance with Section 6.3.5.

5.4 ASSESSMENT OF VEGETATION CONFIGURATION

The vegetation configuration indicator is represented by a single attribute, based on a calculation of the amount of remnant (intact) vegetation and/or native regrowth within the landscape immediately surrounding the survey site. Vegetation configuration is measured within a 1 km radius of the survey site, defined by the centre of the 100 m survey site transect (Figure 5). Within the 1 km circular buffer, the percentage of the following vegetation types are calculated:

- Remnant (intact) vegetation – defined as one or more areas of contiguous, largely intact (structurally and compositionally) native vegetation.
- Native regrowth – defined as the combined area of native regrowth vegetation endemic to the area, as well carbon-based estates (e.g. environmental plantings or human-induced regrowth), or native vegetation that has been subject to significant disturbance (e.g. heavily thinned or logged).

Based on the results of these two calculations, the percentage of native remnant (intact) and native regrowth vegetation is scored based on the percentage thresholds outlined in Section 6.4.

The percent thresholds used to categorise the scores are consistent with that in the Queensland BioCondition Assessment Manual (Eyre *et al*. 2015). These have themselves been derived from peer-reviewed 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), while also recognising the differing ecological value of remnant (intact) vegetation from native regrowth.

Undertaking an assessment of the vegetation configuration attribute requires interrogation of available mapped vegetation communities and aerial photo interpretation using Geographic Information Systems (GIS) software. Refer to Appendix A for available state, territory and national-based native vegetation classification systems, as well as data and mapping sources available to assist in assessment of vegetation communities and vegetation configuration.

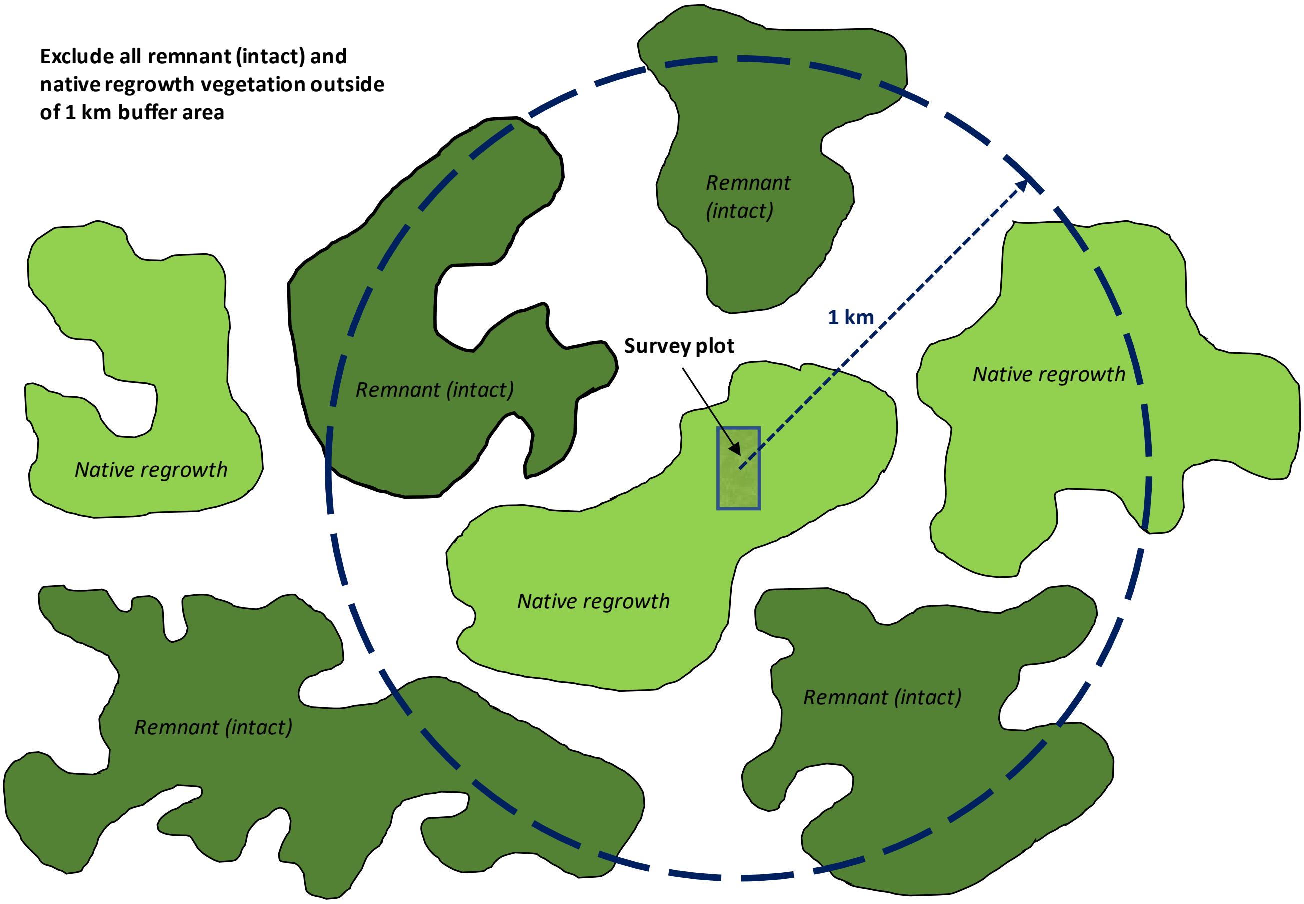

Figure 5: Vegetation configuration assessment area (1 km buffer).

6 SCORING OF VEGETATION INDICATORS

Once all attributes have been appropriately measured during the survey, the assessor must calculate, for each survey site, the scores for each measurable vegetation attribute comparing each to the corresponding benchmarks. In addition, scoring of the vegetation configuration attribute must be undertaken in a Geographic Information System (GIS). Not until all measurable attribute scores have been calculated, can the final Native Vegetation Econd® be calculated (refer to Section 7).

Table 5 summarises the scoring contribution for each measurable attribute and their contributions to indicators comprising the final Native Vegetation Econd® (out of 100).

Table 5: Summary of measurable attributes surveyed and their contribution to Indicator condition score and the final Native Vegetation Econd®.

Indicator	Measurable attributes		Attribute score	Indicator condition score
Species richness	Species richness (count)	Trees	5	**20†**
		Shrubs	5	
		Grasses	5	
		Forbs/Other	5	
Structure	Large trees (count)		15	**30**
	Canopy tree height (m)	Trees	5	
	Canopy cover (%)	Trees	5	
		Shrubs	5	
Function	Recruitment of dominant canopy species (%)		5	**30**
	Coarse woody debris (total length of logs)		5	
	Organic litter cover (%)		5	
	Native grass cover (%)		5	
	Non-native plant cover (%)		10	
Vegetation configuration	Remnant (intact) vegetation and native regrowth within 1 km of site		20	**20**
			Final Native Vegetation Econd®	**100**

† Dynamic weights are applied to unweighted species richness scores for each growth form attribute to calculate the final species richness indicator score (Section 6.1).

For some vegetation communities, one or a number of the 13 field-based attributes may be naturally absent. For example, some open grassy woodland vegetation communities do not always support a shrub layer. Where a benchmark document or benchmark values derived from reference sites for a particular vegetation community identify attributes that are naturally absent (i.e. where the benchmark value for an attribute is assigned as either 'not applicable' (NA) or is recorded as '0'), that attribute is excluded from the Econd® calculation for the site. Instead, the score for the remaining attributes within the corresponding vegetation indicator group are re-weighted and scored accordingly. The current method has been developed to assess projects comprising predominantly terrestrial woody vegetation. As such, this is not intended to be used for vegetation communities where benchmark documentation or benchmark values derived from reference sites indicate any of the following benchmark scores:

- Tree species richness = NA or 0,
- Tree canopy height = NA
- Tree canopy cover = NA

The method for scoring of species richness, structure and function indicators represents an adaptation of the method outlined in the Queensland BioCondition Manual (Eyre et al. 2017) and the NSW Biodiversity Assessment Manual (OEH 2017). Namely, the relative weightings of species richness, structure and function indicators and their constituent attributes contributing to the final Native Vegetation Econd® score are the same as for the BioCondition Manual (i.e. maximum score for large trees is 15, *cf* non-native plant cover maximum score out of 10, *cf* other attributes maximum score out of out of five). However, the method used in the current method calculates the score for each attribute on a continuous curvilinear scale rather than using a semi-quantitative approach as per the Queensland BioCondition Manual (Eyre et al. 2017). This curvilinear scoring method is a modified version of that outlined in the BAM (OEH 2017), which derives scores using the Weibull distribution; representing a curvilinear distribution. This continuous curvilinear scoring approach avoids the steep thresholds of semi-quantitative approaches that score conditions as whole numbers. The Weibull distribution derived from BAM (OEH 2017) incorporates a sigmoidal, curvilinear growth in attribute score between 0% and 100% of benchmark; assuming minimum score when 0% of benchmark; rising to a maximum attribute score once achieving 100% of benchmark. The current method does however incorporate a variety of attribute-specific delay and discounting functions, reflecting various scoring thresholds identified for corresponding attributes in the Queensland BioCondition Manual (Eyre et al. 2017).

For example, a site's species richness for a given growth form attribute does not exceed the minimum score of zero out of five until at least 25% of the benchmark species richness is realised (refer to Section 6.1). Furthermore, the current method incorporates a discount factor for a site's score for a number of attributes (shrub and tree canopy cover, coarse woody debris and organic litter cover) where it exceeds 200% of benchmark value. This is consistent with Eyre et al. (2017) and a vegetation community not in equilibrium; whether (in the case of elevated canopy or shrub cover) there is an issue associated with woody vegetation thickening, which can arise under particular climatic conditions from the interactions of varying fire and grazing regimes. In the case of coarse woody debris, an overabundance is likely indicative of disturbance from selective clearing or silvicultural treatment. For these attributes, discounting is imparted in accordance with an inverse Weibull function, reducing to a minimum score of either three or two out of five. The only exception to the use of the Weibull curvilinear function to score attributes is the scoring of the non-native plant cover attribute which uses an exponential decay function (refer to Section 6.3.5).

The following sections outline the procedure to calculate and score each measurable attribute contributing to the Econd® score. A scoring workbook is being finalised by CO2 Australia, which will incorporate prompted inputs and automatically calculate relevant indicator and final Native Vegetation Econd® scores. This workbook includes worksheets that store the exact location and raw survey data from individual survey sites, as well as the identification of vegetation communities, broad vegetation grouping and benchmark justifications for all sites. This workbook (or any other data entry solution) and any reporting must be made retrievable and accessible so as to allow for auditing, and to track and interrogate changes over time.

6.1 SPECIES RICHNESS INDICATOR SCORING

The species richness indicator comprises the native plant species richness attributes for the four life form groups: trees, shrubs, grasses and forbs/other. The observed species richness values for each growth form group are converted to a continuous condition score in accordance with Equation 1 (Weibull function, Figure 6). This equation calculates a score out of five for each growth form attribute, with a final species richness indicator score calculated in accordance with a dynamic weight function based on the benchmark species richness of all growth form attributes (see below).

Equation 1: Calculation of the species richness score for the four growth form attributes (trees, shrubs, grasses, forbs/other) contributing to species richness indicator.

$$where\ {x_i}/{B_i} \leq 0.25 \qquad GFAS_i = 0$$

$$where\ {x_i}/{B_i} = 0.25 - 0.9 \qquad GFAS_i = 5.034 \times \left(1 - e^{-13.1\left(({x_i}/{B_i})-0.25\right)^{2.5}}\right)$$

$$where\ {x_i}/{B_i} > 0.9 \qquad GFAS_i = 5$$

where: $GFAS_i$ = growth form attribute score for the i^{th} growth form attribute

x_i = recorded species richness of the i^{th} growth form attribute

B_i = benchmark species richness value for the i^{th} growth form attribute

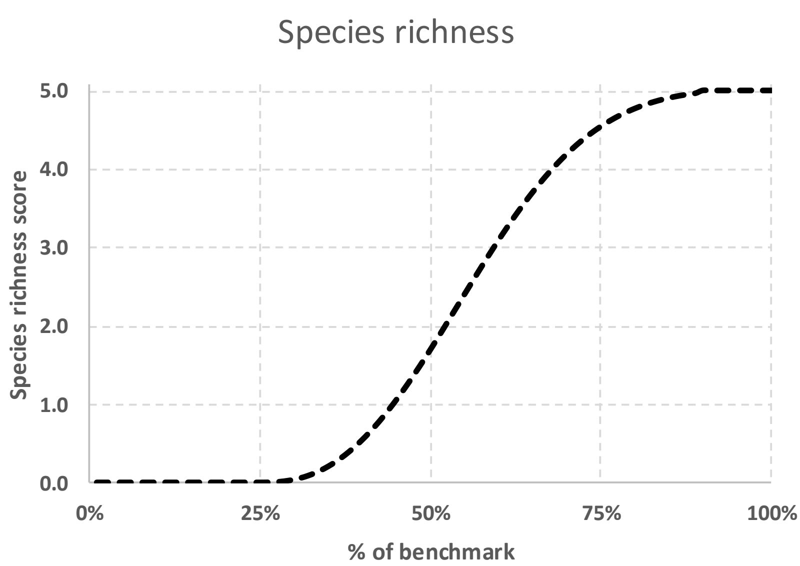

Figure 6: Species richness attribute score as a function of % of benchmark, in accordance with Equation 1.

The final species richness indicator score is calculated in accordance with a dynamic weigh function. Dynamic weights are applied to unweighted species richness scores for each growth form attribute based on the proportional contribution of each growth form attribute's benchmark species richness to the benchmark total species richness (i.e. sum of benchmark richness across all growth form attributes). Only those growth form attributes with a benchmark value greater than zero are used to calculate the dynamic weight score. Dynamic weights are calculated in accordance with Equation 2.

Equation 2: Dynamic weight calculation for each species richness growth form attributes.

$$w_i = B_i / \sum_{i=1}^{n} B_i$$

where: w_i = dynamic weight for the i^{th} growth form attribute

B_i = benchmark species richness value for the i^{th} growth form attribute

n = number of growth form attributes

The final species richness indicator score contributes 20% to the final Native Vegetation Econd® (refer to Table 5).

6.2 STRUCTURE INDICATOR SCORING

The vegetation structure indicator comprises four attributes. Of the four attributes, three contribute 5% each toward the final Native Vegetation Econd® (canopy tree height, tree and shrub canopy cover), with the large tree attribute contributing 15% alone (Table 5). As with the species richness attributes, values for each of the structural attributes are converted to a continuous condition score in accordance with modified Weibull functions.

6.2.1 Large tree attribute score

The large tree attribute is scored in accordance with Equation 3, which assumes a curvilinear increase from a score of zero for no large trees, rising to 15 once at least 100% of the benchmark value for large trees is attained (Figure 7).

Equation 3: Calculation of the large tree attribute score contributing to the vegetation structure indicator.

$$where\ {}^{x}/_{B} < 1 \qquad LTS = 15.102 \times \left(1 - e^{-5\left({}^{x}/_{B}\right)^{2.5}}\right)$$

$$where\ {}^{x}/_{B} \geq 1 \qquad LTS = 15$$

where: LTS = large tree score

x = recorded number of large trees

B = benchmark number of large trees

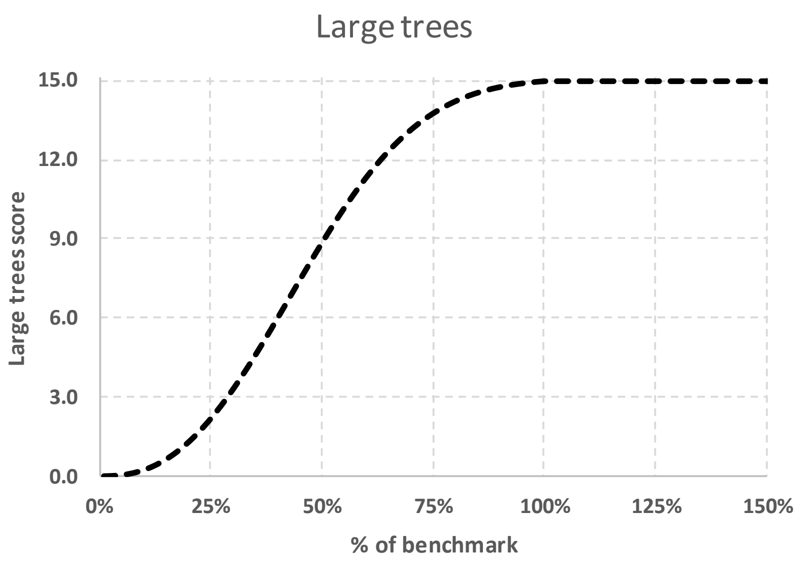

Figure 7: Large tree attribute score as a function of % of benchmark, in accordance with Equation 3.

6.2.2 Tree canopy height attribute score

The canopy tree height attribute is scored in accordance with Equation 4, which assumes a score of zero for up to 25% of benchmark height, rising to a maximum score of five once tree canopy height reaches 70% of the benchmark value (Figure 8).

Equation 4: Calculation of the tree canopy height attribute score contributing to the vegetation structure indicator.

$$where\ {}^{x}/_{B} \leq 0.25 \qquad TCHS = 0$$

$$where\ {}^{x}/_{B} = 0.25 - 0.7 \qquad TCHS = 5.034 \times \left(1 - e^{-33\left(\left({}^{x}/_{B}\right)-0.25\right)^{2.5}}\right)$$

$$where\ {}^{x}/_{B} > 0.7 \qquad TCHS = 5$$

where: TCHS = tree canopy height attribute score

x = recorded tree canopy height

B = benchmark tree canopy height

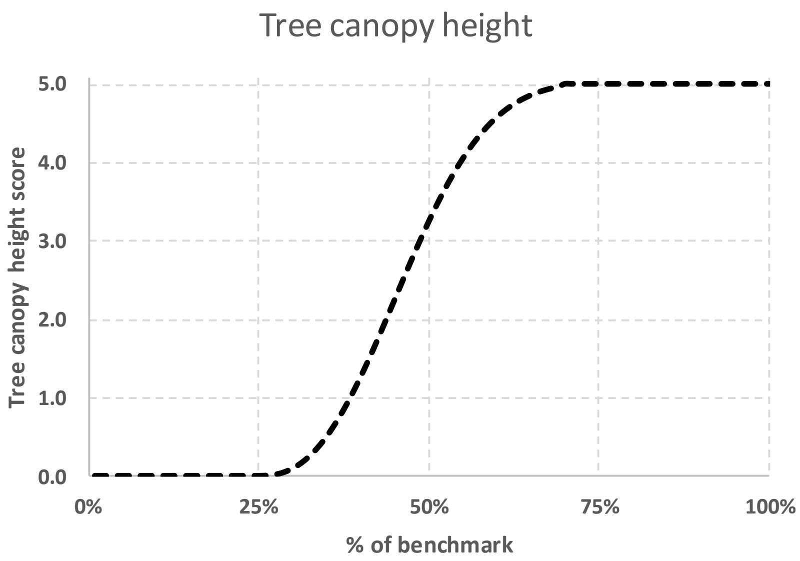

Figure 8: Tree canopy height attribute score as a function of % of benchmark, in accordance with Equation 4.

6.2.3 Tree and shrub cover attribute score

The tree and shrub cover attributes contributing to the structure indicator are scored using the same function, in accordance with Equation 5. Scoring of these cover attributes assumes a score of zero for cover less than 25% of the benchmark, rising to a maximum score of five once at least 70% of the benchmark value for tree and shrub cover is attained. Unlike the canopy tree height attribute, the scoring for tree canopy and shrub canopy attributes incorporate a discounting function, represented as a reduction in score from five once their respective cover exceeds 200% of the benchmark, via an inverse curvilinear function, down to a maximum of three (Figure 9).

Equation 5: Calculation of the two cover attribute scores (tree and shrub) contributing to vegetation structure indicator.

$$where\ {}^{x_i}/_{B_i} \leq 0.1 \qquad CFS_i = 0$$

$$where\ {}^{x_i}/_{B_i} = 0.1 - 0.5 \qquad CFS_i = 5 \times \left(1 - e^{-44\left(({}^{x_i}/_{B_i}) - 0.1\right)^{2.5}}\right)$$

$$where\ {}^{x_i}/_{B_i} > 0.5 - 2 \qquad CFS_i = 5$$

$$where\ {}^{x_i}/_{B_i} > 2 \qquad CFS_i = 5 \times \left(1 - e^{-44\left(\frac{({}^{x_i}/_{B_i}) - 2.5}{-1}\right)^{2.5}}\right)$$

$$where\ {}^{x_i}/_{B_i} > 2\ \ AND\ \ CFS_i < 3 \qquad CFS_i = 3$$

where: CFS_i = cover attribute score for the i[th] cover attribute

x_i = recorded cover value of the i[th] cover attribute

B_i = benchmark cover value for the i[th] cover attribute

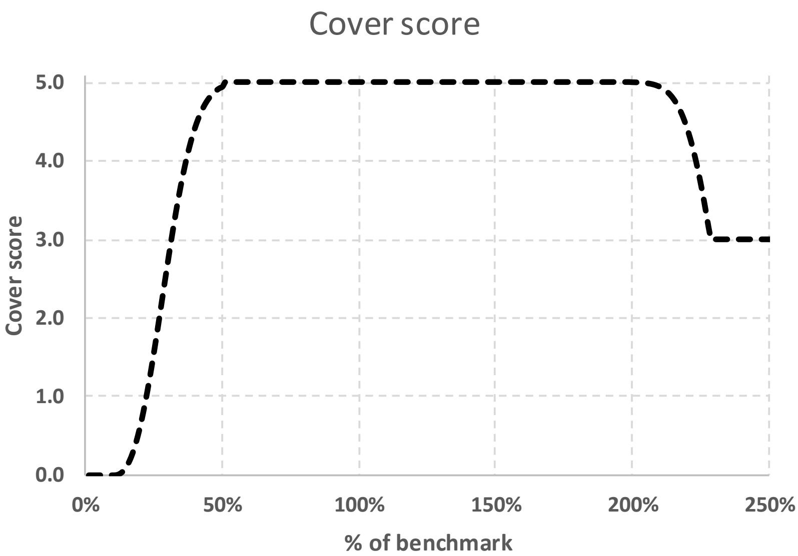

Figure 9: Tree and shrub cover attribute score as a function of % of benchmark, in accordance with Equation 5.

The final structure indicator score is calculated as sum of scores of the four attributes contributing to the structure indicator; up to a maximum score of 30. The final structure indicator score contributes 30% to the final Native Vegetation Econd® (refer to Table 5).

6.3 FUNCTION INDICATOR SCORING

The vegetation function indicator score comprises five attributes. Of the five attributes, four contribute 5% each toward the final Native Vegetation Econd®, with the non-native plant cover attribute contributing 10% alone. Values for all functional attributes are represented by a curvilinear condition score, with all attributes scored in accordance with modified Weibull functions with the exception of the non-native plant cover attribute scored using an exponential decay function.

6.3.1 Recruitment of dominant canopy species attribute score

The recruitment of dominant canopy species attribute is scored in accordance with Equation 6, which assumes a curvilinear growth from a score of zero when less than 20% of the dominant canopy species show evidence of recruitment, rising to five once at least 75% of the dominant canopy species show evidence of recruitment (Figure 10).

Equation 6: Calculation of the recruitment of dominant canopy species attribute score contributing to vegetation function indicator.

$$where\ x \leq 0.2 \qquad RCSS = 0$$

$$where\ x = 0.2 - 0.75 \qquad RCSS = 5.034 \times \left(1 - e^{-20(x-0.2)^{2.5}}\right)$$

$$where\ x > 0.75 \qquad RCSS = 5$$

where: RCSS = recruitment of canopy species attribute score

x = recorded proportion of dominant canopy trees with evidence of recruitment

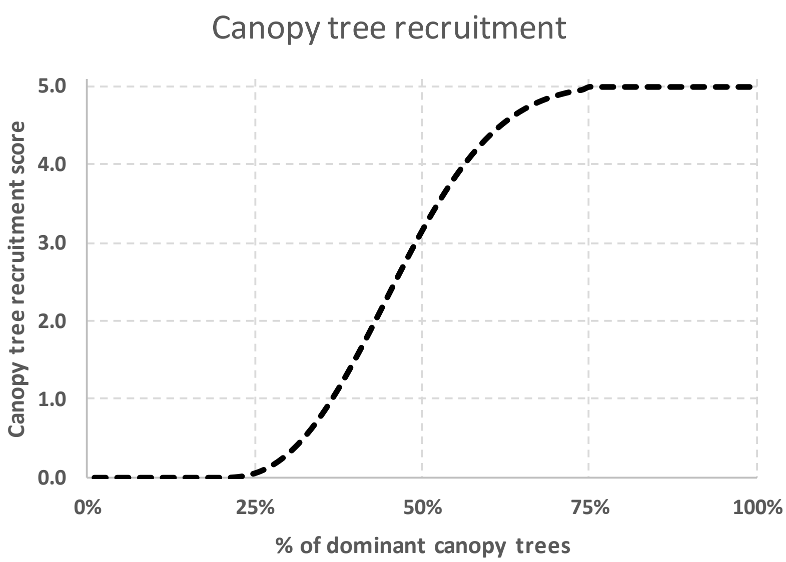

Figure 10: Dominant canopy species recruitment attribute score as a function of % of dominant canopy trees, in accordance with Equation 6.

6.3.2 Coarse woody debris attribute score

The coarse woody debris attribute contributing to the vegetation structure indicator is scored in accordance with Equation 7. Scoring of this attribute assumes a score of zero where coarse woody debris is less than 10% of the benchmark, rising to a maximum score of five once at least 50% of the benchmark value is attained. The coarse woody debris attribute incorporates a discounting function, represented as a reduction in score from five once their respective cover exceeds 200% of the benchmark, via an inverse function, down to a maximum of two (Figure 11).

Equation 7: Calculation of the coarse woody debris attribute score contributing to the vegetation function indicator.

$$where\ {}^{x}/_{B} \leq 0.1 \qquad CWDS = 0$$

$$where\ {}^{x}/_{B} = 0.1 - 0.5 \qquad CWDS = 5 \times \left(1 - e^{-44\left(\left({}^{x}/_{B}\right) - 0.1\right)^{2.5}}\right)$$

$$where\ {}^{x}/_{B} \geq 0.5 - 2 \qquad CWDS = 5$$

$$where\ {}^{x}/_{B} > 2 \qquad CWDS = 5 \times \left(1 - e^{-44\left(\frac{\left(\left({}^{x}/_{B}\right) - 2.5\right)}{-1}\right)^{2.5}}\right)$$

$$where\ {}^{x}/_{B} > 2\ \ and\ \ CWDS < 2 \qquad CWDS = 2$$

where: CWDS = coarse woody debris attribute score

x = recorded coarse woody debris value

B = benchmark coarse woody debris value

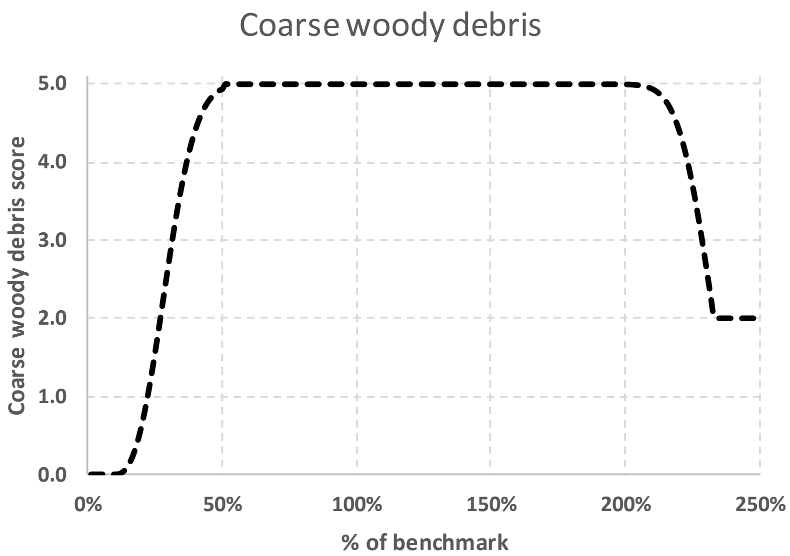

Figure 11: Coarse woody debris attribute score as a function of % of benchmark, in accordance with Equation 7.

6.3.3 Organic litter cover attribute score

The organic litter cover attribute contributing to the vegetation structure indicator is scored in accordance with Equation 8. Scoring of this attribute assumes a score of zero where organic litter cover is less than 10% of the benchmark, rising to a maximum score of five once at least 50% of the benchmark value is attained. As with coarse woody debris, the organic litter cover attribute incorporates a discounting function, represented as a reduction in score from five once their respective cover exceeds 200% of the benchmark, via an inverse function, down to a maximum of three (Figure 12).

Equation 8: Calculation of the organic litter cover attribute score contributing to the vegetation function indicator.

$$where\ {}^{x}/_{B} \leq 0.1 \qquad OLCS = 0$$

$$where\ {}^{x}/_{B} = 0.1 - 0.5 \qquad OLCS = 5 \times \left(1 - e^{-44\left(({}^{x}/_{B}) - 0.1\right)^{2.5}}\right)$$

$$where\ {}^{x}/_{B} \geq 0.5 - 2 \qquad OLCS = 5$$

$$where\ {}^{x}/_{B} > 2 \qquad OLCS = 5 \times \left(1 - e^{-44\left(\frac{({}^{x}/_{B}) - 2.5}{-1}\right)^{2.5}}\right)$$

$$where\ {}^{x}/_{B} > 2\ \ and\ \ OLCS < 3 \qquad OLCS = 3$$

where: OLCS= organic litter cover attribute score

x = recorded organic litter cover value

B = benchmark organic litter cover value

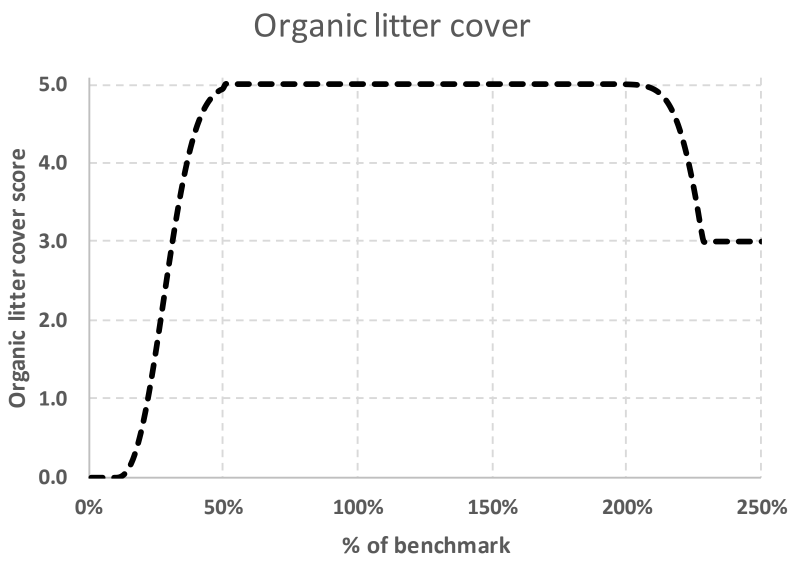

Figure 12: Organic litter cover attribute score as a function of % of benchmark, in accordance with Equation 8.

6.3.4 Native grass cover attribute

The native grass cover attribute is scored in accordance with Equation 9, which assumes a curvilinear growth from a score of zero where native grass cover is less than 10% of the benchmark, rising to five once native grass cover reaches at least 90% of the benchmark value (Figure 13).

Equation 9: Calculation of the native grass cover attribute score contributing to the vegetation function indicator.

$$where\ {}^{x}/_{B} \leq 0.1 \qquad NGCS = 0$$

$$where\ {}^{x}/_{B} = 0.1 - 0.9 \qquad NGCS = 5.034 \times \left(1 - e^{-7.8\left(({}^{x}/_{B}) - 0.1\right)^{2.5}}\right)$$

$$where\ {}^{x}/_{B} > 0.9 \qquad NGCS = 5$$

where: NGCS = native grass cover attribute score

x = recorded native grass cover value

B = benchmark native grass cover value

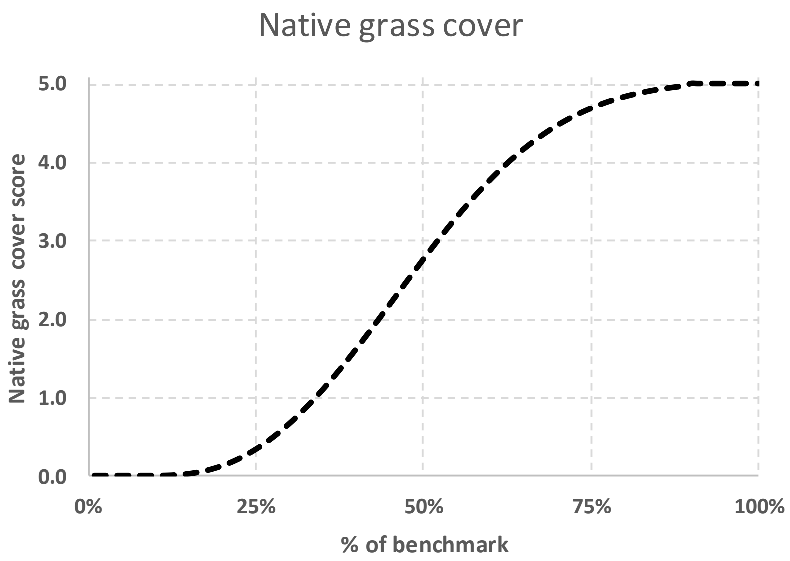

Figure 13: Native grass cover attribute score as a function of % of benchmark, in accordance with Equation 9.

6.3.5 Non-native plant cover attribute

The scoring of the non-native plant cover attribute differs from all other scored attributes, as it incorporates a decay function in the form of an exponential decay function (Equation 10). This scoring function assumes a curvilinear decay from an initial maximum score of 10 where non-native plant cover is <10%. This score drops to a score of zero in accordance with the decay function once non-native plant cover exceeds 50% (Figure 14).

Equation 10: Calculation of the non-native plant cover attribute score contributing to the vegetation function indicator.

$$where\ x \leq 0.05 \qquad NPCS = 10$$

$$where\ x = \ 0.05 - 0.5 \qquad NPCS = 10 \times (1.05 - x)^9$$

$$where\ x > 0.5 \qquad NPCS = 0$$

where: NPCS = non-native plant cover attribute score

x = recorded proportion of non-native plant cover value

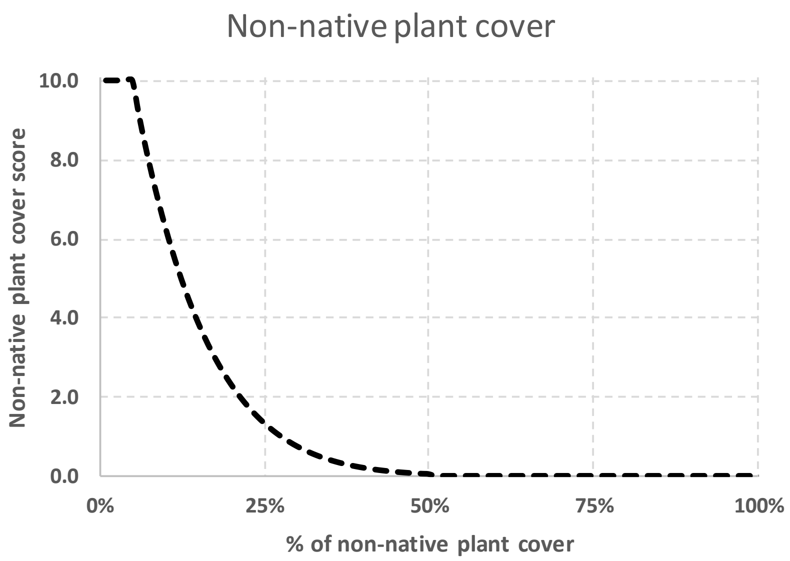

Figure 14: Non-native plant cover attribute score as a function of the cover of non-native plants.

The final function indicator score is calculated as the sum of scores of the five attributes contributing to the function indicator; up to a maximum score of 30. The final function indicator score contributes 30% to the final Native Vegetation Econd® (refer to Table 5).

6.4 VEGETATION CONFIGURATION SCORING

The vegetation configuration score is scored in accordance with the results of GIS analysis identifying the percentage of the 1 km buffer around an Econd® site supporting remnant (intact) vegetation and/or native regrowth. Table 6 outlines the scoring for the vegetation configuration indicator which contributes 20% toward the final Native Vegetation Econd® (Table 5).

Table 6: Vegetation configuration indicator scoring.

Vegetation configuration scoring	Score (/20)
< 10% remnant (intact) vegetation **AND** < 30% native regrowth	0
≥ 10 to 30% remnant (intact) vegetation **AND** < 30% native regrowth vegetation **OR** < 10% remnant (intact) vegetation **AND** ≥ 30% native regrowth vegetation	8
≥ 10% to 30% remnant (intact) vegetation **AND** ≥30% native regrowth vegetation **OR** ≥ 30 to 75% remnant (intact) vegetation	16
≥ 75% remnant (intact) vegetation	20

7 CALCULATING THE FINAL NATIVE VEGETATION ECOND®

Following collection and collation of the field data (Section 5), and subsequent scoring of the relevant native vegetation attribute scores (Section 6), a Native Vegetation Econd® score is calculated out of 100 for each site based on the combined weighted scores for species richness, structure, function and vegetation configuration indicators.

The Native Vegetation Econd® score for each assessment unit is then calculated as the average of all the scores for all sites within the assessment unit (correcting for natural absent attributes). Where relevant, an average Native Vegetation Econd® score can then be calculated for separate spatial areas (defined as sub-assets) contributing to the accounting area. These are calculated as the area-weighted average scores for the assessment units contributing to each sub-asset. In presenting this data, the indicator scores (scaled up to 100) contributing to the sub-asset should be presented (Table 7).

Table 7: Example summary table of indicators contributing to the sub-asset Native Vegetation Econd®.

Sub-asset	Assessment units	Indicator	Indicator condition score (/100)	Sub-asset Native Vegetation Econd® score (/100)
Area A	1, 2, 3	Species richness	55.1	**43.6**
		Structure	38.6	
		Function	43.2	
		Vegetation configuration	40	

Lastly the overall Native Vegetation Econd® score for the entire environmental account can then be calculated and presented as the area-weighted average of scores from each sub-asset (Table 8).

Table 8: Example summary table of Native Vegetation Econd® for sub-assets and overall Environmental Account area.

Sub-asset	Total area	Assessment units	Native Vegetation Econd® score (/100)	
			Sub-asset	Environmental account area
Area A	43.3 ha	1, 2, 3	**43.6**	**50.7**
Area B	122.6 ha	2, 3	**54.4**	
Area C	15.3 ha	1, 3	**41.4**	

Where the environmental account comprises whole properties, collection of properties, a catchment or any other defined spatial scale, the Native Vegetation Econd® for an environmental account area is calculated as the weighted average of the Econd® of each native vegetation type, scaled by their proportional extent at reference (Section 3.1). Table 9 shows an example environmental account summary for a property wide account.

A scoring workbook is being finalised by CO2 Australia, which will incorporate prompted inputs and automatically calculates relevant indicator and final Native Vegetation Econd® scores, including provisions for appropriate weighting as well as dynamic weightings of the species richness indicator, naturally missing attributes etc.

Table 9: Example Environmental Account summary table for a property-wide account.

	Farm area (ha)	Indicator score (Extent)	Indicator score (Species richness)	Indicator score (Structure)	Indicator score (Function)	Indicator score (Vegetation configuration)	Accounting area NATIVE VEGETATION ECOND®
	530.0 ha	34	73	50	62	71	21

Asset category	Indicator	Reference benchmark	% total area	2019 Condition measure	2019 Indicator score	2019 NATIVE VEGETATION ECOND®
Ivy Grove Farm		530.0 ha				**21**
Assessment unit 1: *Eucalyptus populnea* woodland on alluvial plains						**58**
	Extent	119 ha	22.5	63 ha	52.9	
Composition	**Species richness**	100		43.2	43	
	Structure	100		65.2	65	
	Function	100		73.2	73	
	Vegetation configuration	100		40	40	
Assessment unit 2: *Eucalyptus tereticornis* and/or *Eucalyptus* spp. woodland on alluvial plains						**66**
	Extent	278 ha	52.5	24 ha	8.6	
Composition	**Species richness**	100		88	88	
	Structure	100		43.3	43	
	Function	100		65.5	66	
	Vegetation configuration	100		80	80	
Assessment unit 3: *Eucalyptus coolabah* woodland on alluvial plains						**58**
	Extent	133 ha	25.1	94 ha	70.7	
Composition	**Species richness**	100		67	67	
	Structure	100		52.1	52	
	Function	100		43.9	44	
	Vegetation configuration	100		80	80	
		Total vegetation area on farm:		181 ha		

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APPENDIX A NATIVE VEGETATION CLASSIFICATION SYSTEMS ACROSS AUSTRALIA

Table A-1: State, territory and national-based native vegetation classification systems and available data and mapping products.

State or Territory	Native vegetation classification system	Source	
Australia-wide	10,774 Vegetation Types 80 Major Vegetation Sub-groups (MVS) 31 Major Vegetation Groups (MVG)	National Vegetation Information System (v 5.1)	https://www.environment.gov.au/land/native-vegetation/national-vegetation-information-system/data-products#mvg51 Data provided by Commonwealth of Australia, 2018.
QLD	1,424 Regional Ecosystems (RE) 98 Broad Vegetation Groups (BVG) at 1:1,000,000 35 BVG at 1:2,000,000	Biodiversity status of pre-clearing regional ecosystems – Queensland (v 11)	http://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={22E1BC4E-BDFA-470A-AED8-04F38B4FCFC3} Data provided by State Government of Queensland and Department of Environment and Science 2018.
NSW	~1500 NSW Plant Community Types (PCT) 99 Vegetation Classes 16 Vegetation Formations	NSW Bionet Vegetation Map Data Collection	https://datasets.seed.nsw.gov.au/dataset/nsw-bionet-vegetation-map-catalogue-collection36515 Data provided by State Government of NSW and Department of Planning, Industry and Environment, 2016.
ACT	64 Vegetation Communities 16 Vegetation Classes 8 Vegetation Formations	ACT Vegetation Map 2018	https://actmapi-actgov.opendata.arcgis.com/datasets/act-vegetation-map-2018 Data provided by the ACT Government, 2018.
VIC	660 Ecological Vegetation Classes (EVC)	Native Vegetation - Modelled 1750 Ecological Vegetation Classes	https://discover.data.vic.gov.au/dataset/native-vegetation-modelled-1750-ecological-vegetation-classes Data provided by the Victorian Government and Department of Environment, Land, Water and Planning, 2020 https://www.environment.vic.gov.au/biodiversity/naturekit (online map)
TAS	156 Vegetation Communities 11 Broad Vegetation Categories	TASVEG – The Digital Vegetation Map of Tasmania (v 3.0)	www.dpipwe.tas.gov.au/tasveg Data able to be provided by the Tasmanian Government by contacting the Geodata Client Services Section of the Information and Land Services Division, Department of Primary Industries, Parks, Water and Environment.
SA	Vegetation Groups (using NVIS framework)	NVIS framework	No vegetation mapping download product available (as of May 2020). Online mapping available (see below), otherwise NVIS v5.1 data should be used. https://data.environment.sa.gov.au/NatureMaps (online map)
WA	818 Vegetation Associations 75 Major State Vegetation Types	Pre-European Vegetation (DPIRD-006)	https://catalogue.data.wa.gov.au/dataset/pre-european-dpird-006
NT	Vegetation Associations (using NVIS framework)	NVIS framework	No state-wide vegetation mapping download product available (as of May 2020), although various vegetation resource surveys are available, otherwise NVIS v 5.1 data should be used. https://nrmaps.nt.gov.au/nrmaps.html (online map) https://denr.nt.gov.au/land-resource-management/info-systems/natural-resource-maps/spatial-data-requests (geospatial data catalogue)

APPENDIX B AVAILABLE BENCHMARK DOCUMENTATION

Table B-1: Available published benchmark documents for states and territories (as of April 2020)

State/territory	Name of benchmark documents	Source
QLD	BioCondition Benchmarks	https://www.qld.gov.au/environment/plants-animals/biodiversity/benchmarks#benchmarks
NSW	BioNet Vegetation Condition Benchmarks	https://www.environment.nsw.gov.au/research/Visclassification.htm
VIC	Bioregions and EVC benchmarks	https://www.environment.vic.gov.au/biodiversity/bioregions-and-evc-benchmarks
ACT	Vegetation Benchmarks Database	https://www.environment.act.gov.au/__data/assets/excel_doc/0004/719122/Vegetation-Benchmarks-Database.xls
TAS	TASVEG Vegetation Community Benchmarks	https://dpipwe.tas.gov.au/conservation/development-planning-conservation-assessment/planning-tools/monitoring-and-mapping-tasmanias-vegetation-(tasveg)/vegetation-monitoring-in-tasmania
SA	Native Vegetation Council (NVC) Bushland Assessment Manual	https://www.environment.sa.gov.au/topics/native-vegetation/clearing/vegetation-assessments
WA	Not available	
NT	Not available	

APPENDIX C ESTABLISHING A GRID OVERLAY

The following outlines the required steps for establishing a grid overlay when determining random plot locations within an assessment unit:

- Establish a grid consisting of square cells
- The scale of the grid must be such that a minimum of 10 grid intersects are established within each assessment unit
- An anchor point is established for the grid by randomly selecting easting and northing coordinates within the ranges of the coordinates for the accounting area. Some accounting areas may require setting up more than one grid anchor point. Easting and northing coordinates should use Map Grid of Australia (GDA94), or an equivalent Australian standard that replaces MGA94 (including GDA2020 from 1 June 2020)
- The axis of the grid must be aligned to the datum being used, and must be orientated either north-south, or along an azimuth calculated by randomly, selecting a whole number angle within the range of zero and 89 degrees inclusive, where zero degrees is true north
- A unique identifier must be assigned to each grid intersect
- Final plot locations must be within 10 metres of each intended plot location

APPENDIX D NATIVE VEGETATION ECOND® SURVEY EQUIPMENT LIST

Table D-1: Equipment list for undertaking Native Vegetation Econd® surveys

Equipment	Purpose
This method document	Details the methodology
Field data sheets	Record all survey plot details and vegetation survey data
GPS	Record GPS coordinates of survey sites, including location of star pickets and associated photo monitoring points
Compass	To identify orientation of the survey plot and assist in delineating quadrat boundary
Camera	Taking photos as part of the photo monitoring
Star pickets	Installed (with caps) at the 0 m and 50 m point along the transect
100 m tape measure	Mark out survey plot mid-line (transect) and assist with delineating survey plot boundary
50 m tape measure	Assist with marking out survey sub-plots
10 m builders tape measure	Measuring tree height (<2 m tall) and woody debris
Diameter tape	Measuring DBH of trees
Clinometer	Measuring tree height (>2 m tall)
1 x 1 m quadrat (optional)	Assist with estimating ground cover indicators (grass cover and organic litter), otherwise 1 m sticks can be used.
Flagging tape	Assist with marking out boundary of survey plot
Binoculars	Assisting identification of taller trees
Field guides	Regional specific field guides (where available) to assist in identification of flora species