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Draft Protocol for Constructing a Native Vegetation Condition Account

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Summary

Two hundred years of intensive land use and land management has transformed the condition of native vegetation, particularly in southern and eastern Australia. Many types of native vegetation are highly fragmented and modified. In central and northern Australia the effects of land use and land management pressures have been less intensive, nevertheless native vegetation has been transformed, particularly through grazing practices and changed fire management practices.

Condition information is needed to inform regional priorities, to establish policies, and to design and evaluate natural resource management programs for maintaining, restoring and rehabilitating native vegetation assets to improve the health of rivers, wetlands and estuaries, protect degraded landscapes against soil erosion, mitigate against dryland salinity, and improve habitat for Australia's unique native plants and animals. The public understanding of these effects on native vegetation condition is hindered by a lack of a simple reporting system which assesses the condition of native vegetation, and reports changes over time. Currently there is a dearth of robust scientific evidence at the regional scale about the condition of native vegetation that decision makers can call on. Native vegetation is an important, identified asset in 80% of NRM regions across Australia (GHD 2012). An accounting framework, which provides a consistent and regular structure for reporting changes, is proposed. Development of a regional native vegetation condition account, using this protocol, has the aim of improving decision making relating to policy development, investment, monitoring, review of outcomes and reporting on progress.

As a consequence of each region's different land use and management history, it is necessary to establish condition at a point in time ie extent and quality of the native vegetation, so that future assessments of changes in extent and quality of vegetation types can be accurately monitored and reported over time. Application of this protocol will establish each region's current level of condition for native vegetation and provide the framework for measuring change through time.

The use of the protocol provides commonality between the regional accounts as data is collected against standardised indicator sets: Extent, Composition and Configuration. Ongoing and regular spatial and temporal data collection and analysis, using a common national protocol, is essential if Australia is to consistently measure and report changes in the condition of native vegetation types.

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Introduction

The purpose of this *Protocol for Constructing a Native Vegetation Condition Account* is to assist Australia's 54 natural resource management bodies (NRM regions) in preparing an account of native vegetation.

Condition information is needed to inform regional priorities, to establish policies, and to design and evaluate natural resource management programs for maintaining, restoring and rehabilitating native vegetation assets associated with healthy rivers, wetlands and estuaries, protecting degraded landscapes against soil erosion, mitigating against dryland salinity, and improving habitat for Australia's unique native plants and animals. Development of a regional native vegetation condition account, using this protocol, has the aim of improving decision making relating to policy development, investment, monitoring, review of outcomes and reporting on progress

The rationale for a consistent national protocol for assessing the condition of native vegetation is because Australia's regions have been modified and fragmented to varying degrees, for different purposes and from different processes. Landscapes have been transformed by harvesting native food and fibre, removing vegetation and regolith to extract minerals, removing vegetation to provide housing and urban infrastructure, draining floodplains to create productive agricultural soils, irrigating previously dryland native vegetated areas. Landscapes have also been transformed inadvertently through the combined effects of feral animals, weeds and changed fire regimes. The resultant landscapes are a diverse spatial mosaic of fragmented and modified native vegetation and converted and replaced vegetation cover types (Thackway and Lesslie 2005).

As a consequence of each region's different land use and management history, it is necessary to establish condition at a point in time ie extent and quality of the native vegetation, so that future assessments of changes in extent and quality of vegetation types can be accurately monitored and reported over time. Application of this protocol will establish each region's current level of condition for native vegetation and provide the framework for measuring change through time.

The *Accounting for Nature* methodology (Wentworth Group of Concerned Scientists 2008) underpins the protocol for regional accounts of native vegetation. The *Accounting for Nature* methodology places environmental information into an accounting framework in order to understand the effects of degradation. It is built on two concepts:

1. Environmental asset condition should be measured at the regional scale, where biophysical processes operate, and where the majority of economic and policy decisions are made; and
2. Asset condition accounts are constructed using an environmental condition index – an ***Econd*** - so that the relative condition of different assets can be compared.

The *Econd* is a composite index which describes the relative condition of any environmental asset against a scientific estimate of the natural or potential condition of that asset, where 100 indicates the asset is in the same condition as it was prior to significant post-industrial human alteration, and 0 indicates system function is absent (modified from Cosier and McDonald 2010).

Regional native vegetation accounts constructed using this protocol and a process called the Seven Steps (**Figure 1**) outlined in the *Quick Guide (Sbrocchi 2013)* and discussed further in the following sections.

Establishing a regional account of native vegetation using this protocol is only as good as the data that underpins it and the analytical processes used to generate the account. The Seven Steps are designed to provide consistency in compiling the accounting tables and generating the accounts, which are used to help create repositories of data, and calculate and present condition information for assets (Sbrocchi 2013). The developers who implement this protocol for native vegetation accounts will provide confidence that the resulting data are fit for their intended use and suit their context in the form of an Information Statement (see Step 7).

The Seven Steps outlined in the *Quick Guide* can be applied in a uniform way to constructing regional environmental accounts. Outlined in **Figure 1** are the same set of steps for generating accounts for the following range of assets: native fauna, soil, rivers, wetlands, floodplains, groundwater, estuaries, marine fauna, and fish stocks. As such, this paper forms one of several working papers for environmental assets designed to accompany the *Quick Guide (Sbrocchi 2013)*.

This working paper provides advice for constructing an account of native vegetation condition at the regional (sub-continental landscape) scale and is targeted for use by natural resource management organisations in all states and territories of Australia. The structure of this report follows the Seven Steps in **Figure 1**.

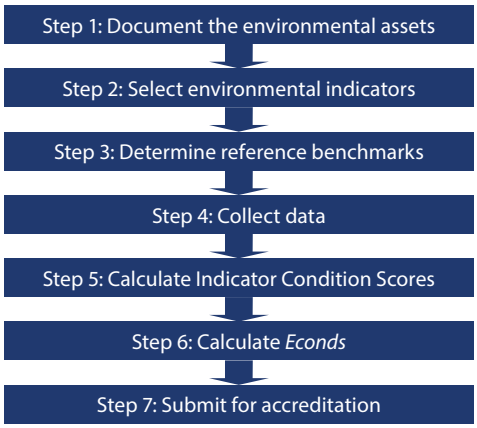


Figure 1: Seven Step process for constructing an environmental asset condition account (Sbrocchi 2013)

Step 1: Define the Native Vegetation Asset

Vegetation assets are vegetation types (ie plant communities), which are commonly described and mapped using a combination of structural and floristic attributes. These are based on guidelines for surveying, classifying and mapping of native vegetation at particular scales for different purposes (Thackway *et al.* 2008).

Before 1980, each state and territory used and maintained separate guidelines for surveying, classifying and mapping of native vegetation types. In the early 1980s Australia's vegetation information management agencies, led by CSIRO, recognised the need to develop a consistent way of surveying, classifying and mapping of native vegetation types at the regional scale. As a result, a field survey handbook was developed enabling consistent collection and classification of native vegetation across Australia (Walker and Hopkins 1984). That handbook was later revised in 1990 to account for feedback received from the various jurisdictions, vegetation managers and researchers (Walker and Hopkins 1990). Throughout the 1990s most states and territories continued to maintain their separate guidelines for surveying, classifying and mapping of native vegetation and also acknowledged these national guidelines.

In the late 1990s the Australian Government established the National Land and Water Resources Audit and initiated a project to develop a consistent regional scale database and map of Australia's native vegetation (Cofinas *et al.* 1999). Application of, and familiarity with, the national guidelines (Walker and Hopkins 1984; 1990) provided a sound basis for establishing a national partnership of Australia's vegetation information management agencies with the aim of translating and compiling the state and territory mapped native vegetation datasets using those guidelines.

That partnership resulted in the development of the National Vegetation Information System (NVIS), and a database and maps of Australia's native vegetation (National Land and Water Resources Audit 2001; Thackway *et al.* 2001; ESCAVI 2003).

Products developed from the NVIS database included national maps of Major Vegetation Groups (MVGs) and 'Major Vegetation Subgroups (MVSs)' (DEWR (Department of the Environment and Water Resources) 2007). Despite a strong initial start made to produce a national classification and map of vegetation types, which is consistent at the regional level, based on the NVIS dataset, each state and territory continued to maintain the state-based native vegetation classification system. From 2000, up to the present day, most states and territories have continued to maintain separate systems for classifying and mapping native vegetation (ie assets) and have developed the capacity to supply data and maps that comply with the NVIS attribute framework (see **Table 1**).

In practice, these state- or region-based native vegetation classification and mapping systems have continued to be used at the regional level in each jurisdiction (**Figure 2**). To populate regional Native Vegetation Condition Accounts, NRM regions may use the national classification and maps derived from NVIS (ie Major Vegetation Groups (MVGs) and Major Vegetation Subgroups (MVSs)) as it provides consistency across jurisdictions, or the NRM region may supply their (usually more detailed) regional and/or state-based datasets.

The best available nationally consistent native vegetation maps are those derived from the NVIS framework, ie MVGs and MVSs. These map products, ie native vegetation types and their extents, represent a national vegetation classification system which is appropriate when assessing the condition of Australia's native vegetation overall, for example in the State of the Environment Reports, and for setting state or national priorities for conservation or reservation.

Table 1: Native vegetation classification systems within states and territories

Jurisdiction	Native Vegetation Classification System(s)
Australian Government	33 Major Vegetation Groups (MVG) 85 Major Vegetation Subgroups (MVS) (Department of the Environment)
Australian Capital Territory	Ecological Communities
New South Wales	16 Vegetation formations 99 Vegetation (Keith) Classes ~1500 NSW Plant Community Types (NSW Office of Environment and Heritage 2014) Variable Regional Vegetation Communities (RVC) and Broad Vegetation Types (Spatial Vision 2013)
Northern Territory	Vegetation associations (Northern Territory Department of Land Resource Management 2014)
Queensland	1384 Regional Ecosystems (RE) (Queensland Department of Environment and Heritage Protection 2014b) 16 Broad Vegetation Groups (BVG) (Queensland Department of Environment and Heritage Protection 2014a)
South Australia	NVIS framework (Department of Environment)
Tasmania	~ 158 TASVEG Vegetation Communities (Harris and Kitchener 2005)
Victoria	897 Ecological Vegetation Classes (EVC) (Department of Sustainability and Environment Victoria 2013)
Western Australia	819 Vegetation Associations (Shepherd et al. 2001)

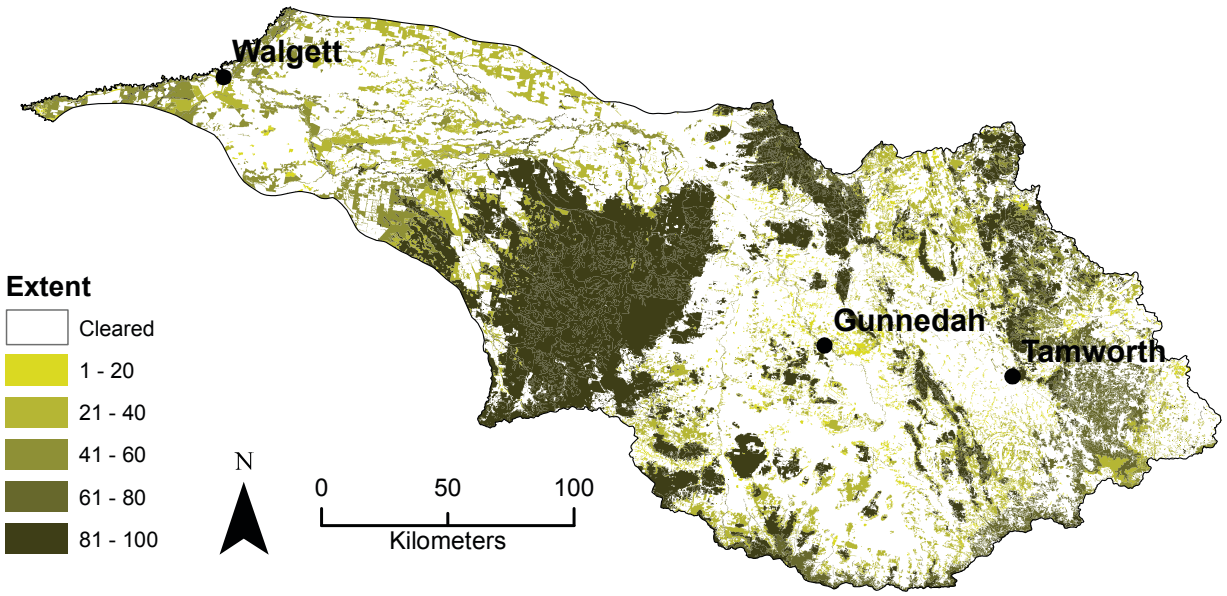


Figure 2: Extent of native vegetation types in the Namoi River Catchment, NSW, mapped by regional vegetation community (Namoi Catchment Management Authority 2012).

Step 2: Select Indicators for Native Vegetation

Indicators provide a means of measuring the condition of an asset (Karr 2006), and can also be used to track changes in an asset's condition due to reported changes in land management practices and management actions (Thackway 2014). The *Quick Guide (Sbrocchi 2013)* requires that indicators should be relevant, simple, sensitive, measurable, timely and aggregative and must reflect an asset's vigour (level of ecological productivity), organisation (structure and interactions), and resilience (ability to rebound from a shock) (Rapport *et al.* 1998).

A condition account for native vegetation must therefore incorporate elements of both the quantity and the quality of native vegetation. Quantity, in the context of a native vegetation account, is reflected in the extent indicator. Quality, in the context of a native vegetation account, comprises two aspects: composition and configuration.

Within ecological fields the term 'condition' is generally used to imply the quality of the native vegetation whereas extent is used to describe the quantity. In the *Accounting for Nature* method, both quantity and quality metrics are required to describe the overall condition of the asset (in this case, native vegetation), represented by the *Econd*. As such, for the purposes of the regional environmental accounts, what has more broadly been termed 'condition' of native vegetation has been described as 'composition' to differentiate between the quality metric and the *Econd*.

Extent

Extent of native vegetation is the total area of each vegetation type distributed across the landscape measured at a particular resolution and point(s) in time. The extent of native vegetation is an important indicator because the extent of native vegetation in many landscapes is strongly correlated to measures of biodiversity (Bennett and Ford 1997; Fahrig 2003; Bennett and Radford 2004; Radford *et al.* 2005; Bennett *et al.* 2006).

While extent is a valuable measure of native vegetation, it must also be accompanied by a measure of the quality of the native vegetation type for it to be accredited in an account of native vegetation condition. This is because extent alone is not a sufficient or appropriate measure of the condition of a native vegetation type. For example, an area may be mapped as native vegetation, but may be dominated by weeds, may have been excessively grazed, or may have had its composition changed by altered fire regimes.

Composition

Composition refers to the functional and structural integrity of the native vegetation asset. It provides valuable information about the relative condition of a native vegetation type in terms of the attributes which make up that vegetation type (such as key species, vertical structure, proportion of weedy or endemic plants).

Composition indicators are assessed at sites and have the advantage that changes can be reported regularly, even though the native extent may not have changed. For example, about 20% of the 9,000 vascular plants of south-west Western Australia may be at risk from dieback disease (caused by *Phytophthora cinnamomi*) (Williams *et al.* 2001). Regular surveys of key compositional indicators associated with disease can show incursions into new areas which can be reported as changes in condition, whereas indicators of extent are not likely to be as responsive because technically the area would still be mapped as native vegetation.

Configuration

Configuration is the spatial arrangement of native vegetation types and their extent across an area. Configuration serves an important function in population viability, population connectivity, seed dispersal and habitat suitability. A similar term to configuration is Landscape Alteration Levels (ie degrees of fragmentation and modification) of native vegetation in an area (Mutendeudzi and Thackway 2008). Assessing the degree and types of connectivity of patches of native vegetation and habitat is also recognised as important for assessing the contribution of individual patches in the broader landscape (Parkes *et al.* 2003).

Aggregating Indicators Into a Composite Index

A summary index or model which incorporates all components of extent (quantity), composition (quality) and configuration will give the most complete picture of the condition of native vegetation at both, the site and landscape scales (see **Table 7** and Discussion).

Each regional body should check with experts in state/territory Government or other agencies to determine which composition and configuration metrics are appropriate for them. There are a number of state/territory-based monitoring programs which should serve as a starting point for selecting composition and configuration indicators relevant to the vegetation communities of interest, such as the Habitat Hectares approach in Victoria (Parkes *et al.* 2003) and the Bushland Condition Monitoring approach in South Australia (Croft *et al.* 2005) which are discussed in more detail in following sections.

Step 3: Determine Reference Benchmarks

To assess change in extent and composition it is first necessary to establish a reference state for the extent and composition of native vegetation.

Potential Data for Establishing Extent Reference States

Native vegetation extent reference states are generally based on a pre-European (1750) reference state, which depicts landscapes prior to significant development and disturbance by European land management practices (Department of the Environment v4.1). The whole landscape is mapped as two broad land cover classes 1) naturally bare (where the land cover is naturally not vegetated eg open water, mud, sand and salt lakes), and 2) native (where the dominant structuring species are native). A spatial coverage of the reference state is established at a particular resolution eg 100m ground distance.

The choice of 1750 was primarily to provide a consistent reference point for 'naturalness' to provide comparisons of loss of extent. It does not imply native vegetation prior to 1750 was in an ideal state, nor that the aim should necessarily be to return the quality of all native vegetation to a 1750 state (Parkes *et al.* 2003).

Potential Data for Establishing Compositional Reference States

Reference data for native vegetation composition is most often undertaken through the study of reference sites and expert assessments (or expert developed guidelines) specific to each composition indicator. While this working paper is not intended to be a substitute to well recognised guidelines for the selection of reference sites (such as Casson *et al.* 2009) the following should be considered:

- reference sites should be of the same vegetation type to the specific site in question, as well as being subject to similar environmental conditions (temperature, rainfall, elevation, slope, aspect etc.)
- the season when the greatest number of plant species can be found and identified (often flowers and fruits are required for identification)
- assess condition at the reference site(s) at the same time (or as close to) assessing the site(s) of interest to ensure they have been receiving similar environmental conditions prior to assessment (and to compensate for seasonal changes which do not necessarily represent declines in condition)
- if reference sites are selected using satellite or aerial imagery, field visits will be required to test their suitability
- take into account natural disturbances, such as time since last fire, to avoid bias in the reference values
- visit several sites over different years to gain an understanding of background variation in characteristics such as vegetation cover.

Potential Data for Establishing Configuration Reference States

The natural state for some native vegetation communities shows their distribution is associated with specific environmental conditions (for example, vegetation communities found only in cast landscapes, alpine areas or ground water fed areas). However, in highly cleared or fragmented landscapes, the additional effects of fragmentation are detrimental to the structure and composition of native vegetation (McIntyre and Hobbs 1999; Mutendeudzi and Thackway 2008).

Integral to assessing configuration is defining a suitable reference state for the 'connectedness' of the vegetation communities. Models, guidelines and expert opinion are usually the most appropriate ways to ascertain reference benchmarks for configuration indicators due to their spatial nature.

It may be possible to utilise a similar process as that for fire metrics to determine an appropriate reference or range of patches across a landscape. Further work is needed to assess and recommend methods and to determine levels of co-linearity between indicators.

Step 4: Collect Data

Data for Assessing Change in Extent

Guidelines

The extent of native vegetation is the aggregate areas of all native vegetation types distributed across the landscape assessed at a particular resolution and at points in time.

Assessments of change in extent should be assessed relative to the reference state, eg pre-European (1750), by spatially comparing the present extent of native vegetation relative to the reference state. Spatial coverage of the present extent of native vegetation is established at the same resolution as for the reference state eg 100m ground distance.

Appropriate sources of reference benchmarks for native vegetation extent are generally models, expert opinion and/or local knowledge of the distribution and extent of native vegetation, as up to date as possible. Most state and territory governments have datasets of representing a reference state extent and one or more contemporary spatial coverages which can be used to assess changes in extent over time.

Examples of Approaches

Fine Scale Extent Datasets

Availability of fine scale native vegetation extent reference state datasets vary from state/territory to state/territory and data may or may not be available from the relevant state agencies. Where a region has high quality mapping of existing vegetation, but does not have pre-European mapping, the region will need to establish the reference benchmark for each vegetation type it wishes to incorporate into its native vegetation asset condition account.

This could be achieved by:

- engaging a qualified vegetation expert from within the Regional body, relevant state/territory government agency or a tertiary institution to compile a preliminary or interim reference benchmark map, from which to derive the reference benchmark for each vegetation type (see Box 1); or
- commissioning a specific study, such as has been conducted by the Central West (DECC 2006) and Namoi Catchment Management Authorities in NSW, where a combination of soil, native vegetation maps and other sources of data are used to derive reference benchmarks.

Box 1: Collecting reference condition and current data on native vegetation extent in the absence of existing records, Eyre Peninsula, SA (Poole and Wiebkin 2013)

The Eyre Peninsula Natural Resources Management Board did not have estimates of pre-European extent of native vegetation available. In order to obtain an interim estimate prior to a detailed study, it sought expert guidance from the state Department of Environment, Water and Natural Resources (DEWNR).

Prior to undertaking this project, the probable pre-European percentage estimate vegetation cover for 23 NVIS Major Vegetation Subgroups (MVS) for Eyre Peninsula had been calculated. However, for the purpose of the estimates, Eyre Peninsula was defined as that part of the Eyre-Yorke Block Interim Biogeographic Region (IBRA), an unsuitable scale for this exercise.

Experts at DEWNR developed estimates at the required regional scale based on literature research pertinent to the peninsula, previous scientific work, biological surveys and ground truthing. They also based the resultant maps on on-ground expert knowledge developed over 25 years of extensive field work on the peninsula and two broad maps of the peninsula's vegetation communities.

In order to collect extent data for the year 2012, field experience, literature, survey quadrats, current and historical vegetation mapping were combined to digitise polygons for the 23 MVSs (using Arcmap at 1:50,000 scale). The polygons were drawn on a satellite imagery background, and at times coloured aerial photography, where vegetation definition was less clear.

The total area of the Eyre Peninsula IBRA region was calculated using the ArcMap program and the area of the individual polygons for each MVS was also totaled and calculated as a percentage of the total IBRA region.

The NRM region identified that a soil map is required for a more detailed estimate of pre-European vegetation to be modeled.

Regional Scale Datasets

In many cases, state/territory governments produce datasets of native vegetation for regional scales. For example, Corangamite and North Central Catchment Management Authorities use datasets provided by the Victorian Government's Department of Environment and Primary Industries based on the EnSym environmental systems modeling platform, whereby a pre-1750 extent and condition ("habitat hectares" (Parkes *et al.* 2003)) had been determined for each ecological vegetation class.

Where a regional body does not have access to up to date, regional scale mapping of extant vegetation from which to derive extent data, relevant data for foliage projective cover (representing tree canopy cover) can be downloaded from the TERN Portal AusCover archive (http://www.tern.org.au/AusCover-pg17728.html). Care needs to be exercised to ensure that these data are understood by the spatial analyst and fit for the desired purpose.

Examples of baseline regional scale national datasets which are relevant to assessing change in extent relative to the reference state include: interim national baseline 2004 native vegetation extent (Thackway *et al.* 2010), and the Persistent Green dataset, a median foliage projective coverage of the woody component of the spectral signal of the vegetation http://www.auscover.org.au/xwiki/bin/view/Product+pages/Persistent+Green-Vegetation+Fraction.

Several multi-temporal spatial data archives are also available, which may provide relevant datasets for monitoring of changes in extent over time. Examples include: the Queensland Statewide Landcover and Trees Study (SLATS) program, which generates datasets across Queensland's forests and woodlands to assess vegetation extent and clearing activities, https://www.qld.gov.au/environment/land/vegetation/mapping/slats-explained/ (Department of Environment and Resource Management Queensland 2012), the Terrestrial Ecosystem Research Network's Auscover Facility (Terrestrial Ecosystem Research Network Auscover Facility n.d.) and the National Carbon Accounting System (NCAS). Geoscience Australia's datacube project is being used to test vegetation condition metrics such as those developed for the SLATS program to generate national coverages www.ga.gov.au/corporate_data/76780/Rec2013_037.docx. These multi-temporal spatial datasets must be used advisedly because most have not been validated to assess whether they are fit for particular purposes.

National Scale Datasets

Where a regional body does not have access to detailed mapping of the extent of native vegetation, continental scale estimates of pre-1750 and current extent datasets are available for the 33 Major Vegetation Groups (MVGs) and 85 Major Vegetation Subgroups (MVSs) www.environment.gov.au/erin/nvis/index.html. Available products include a geographic information system raster dataset, tables and maps of the extent datasets for MVG and MVS distributions (**Figure 3**).

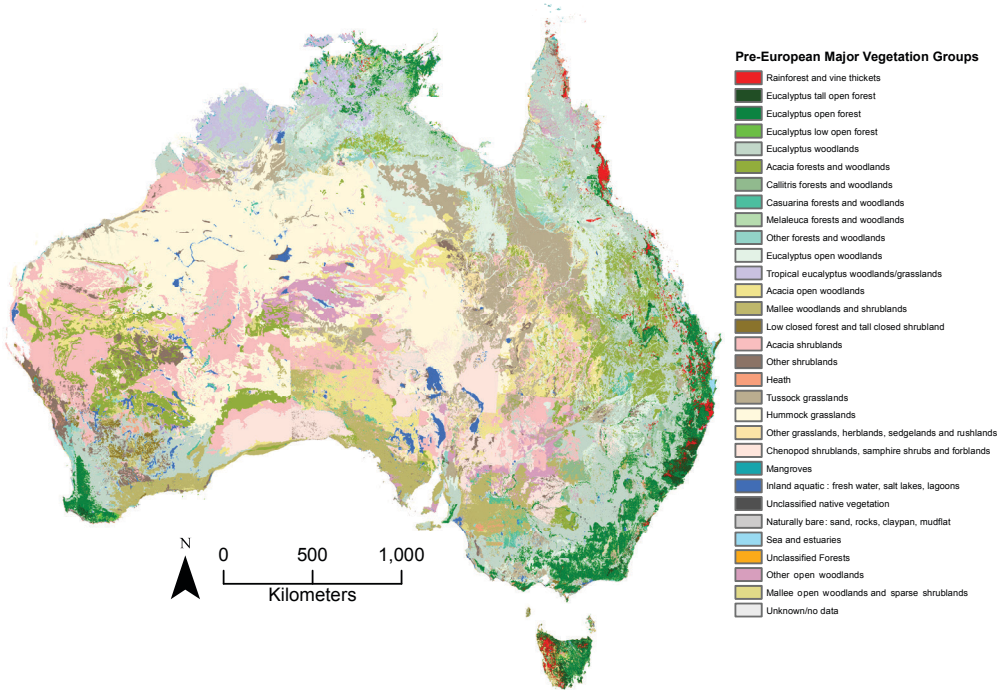


Figure 3: Estimated pre-1750 (left) and current (early 2000s) (right) distribution of Major Vegetation Groups in Australia (State of the Environment Committee 2011)

Data for Assessing Change in Composition

Guidelines

Composition refers to the functional and structural integrity of the native vegetation asset. It also refers to landscape complexity (eg invasive native scrub and succession in fire-dominated landscapes).

Populating indicators of composition requires in situ sampling/assessments. A statistically rigorous sampling design must be developed to aid in the selection of representative sites for each native vegetation type across the region. Where an existing sampling design is not available, statistical expertise should be sought to ensure the survey results are not confounded by factors such as high levels of natural variation around composition indicators within particular vegetation types.

If statistical advice is not available and cannot be acquired, random samples should be collected for at least 10 sites of each vegetation type in each region. Expert advice should be sought for the case of rare vegetation types, where ten sites may not be available.

Indicators chosen to contribute to a composition measure will depend on regional characteristics of native vegetation and the pressures upon them. Examples of indicators of native vegetation composition include: measures of species diversity or richness, vertical height profile/number of strata, foliage projective cover of the overstorey strata, structural diversity (ie age classes) of the overstorey strata, level of disease or pest damage and numbers of local indigenous plant species compared to non-indigenous plant species (examples of indicators can be found in Figure 4 and Table 2).

Regional scale assessments of changes in composition measures require an analysis of ground-truthed, or reference attributes at the plot-scale, that are then interpolated at larger scales to provide spatial models of condition indices. Vegetation condition can be assessed in the context of threatening processes that affect condition and the plot-based information must provide categorical or continuous metrics that quantify the level of impact of threats for each plot, in conjunction with the elements of vegetation that define its condition. While pressures are often included in condition measures to assist managers in detecting causes of changes in condition, it is not, however, appropriate to measure condition based solely on threats or pressures.

Methods for generating regional scale data for populating indicators of composition of (and structure within) each native vegetation community generally rely on plot-scale native vegetation surveys, but there is an increasing potential to utilise advances in the development of vegetation condition metrics derived from multi-temporal satellite images and from environmental models.

Since the early 1980s, satellite remote sensing has played an important role in mapping and monitoring of vegetation (extent, fragmentation and change in composition) as it is cost-effective and relatively quick to analyse over large areas. Recent improvements in the pixel size of satellite borne sensors such as SPOT, Ikonos and Quickbird mean they can now provide resolutions down to metres (5m to 0.6m respectively) making mapping at local scales, or in more fragmented landscapes (eg mapping riparian corridors or scattered paddock trees) feasible. Despite this, analysis of metrics derived from satellite imagery is currently not sufficiently mature to measure all elements of composition confidently. Most multi-temporal image archives, except for Landsat, have pixel resolutions which are too coarse for use in regional accounts. For example, of 22 indicators which underpin the assessment of vegetation condition using the Vegetation Assets States and Transitions-2 (VAST-2) system relating to the function, composition and structure of native vegetation, only eight (numbers 1-2 relating to 'vegetation function', and 13-18 relating to 'vegetation structure'), can currently be populated using metrics derived from satellite imagery. The remaining indicators can be populated using environmental models and expert assessments (or expert developed guidelines). See Table 2. (Richard Thackway pers. comm.)

While improvements have been made accessing archives based on SPOT, Ikonos and Quickbird, these archives do not contain long times series datasets equivalent to the Landsat archives established by Geoscience Australia and by the Joint Remote Sensing Research Program (JRSRP) in Brisbane. There are aspects of satellite imagery under investigation that can assist with measuring changes to composition from year to year. Examples of this include the Normalised Difference Vegetation Index (NDVI), which measures aspects of vigour as the level of 'greenness'. Provided the NDVI can be differentiated into vegetation types (perhaps by overlaying existing vegetation maps), in the future it may be possible to use NDVI to assess native vegetation quality at a regional scale on a more regular basis via the Landsat archives. When using the NDVI or other approaches to populate indicators of composition, there is a requisite need for concurrent vegetation composition maps and sufficiently mature ecological understanding to interpret and use such data correctly to determine quality reference benchmarks (see *Ecological Restoration and Management* (2006) Volume 7, Special Issue 1, for a detailed treatment of this issue).

Landscape Complexity

Mosaic pattern measures demonstrate how continuous and complex the landscape is in relation to dominant ecological processes. Mosaic patterns dominate certain landscapes, such as invasive native scrub in western NSW (GHD and Cummings 2009) and fire in the northern Australian savannahs (Andersen *et al.* 2005). Incorporating condition indicators of mosaic landscapes involves the use of specific accounting techniques.

Examples of Approaches

Two frameworks have been proposed for assessing and reporting the composition of native vegetation:

1. Jurisdictional Assessment Programs

Jurisdictional (state/territory or region-based) assessment programs may initially form the basis on which to report the regional condition of native vegetation. **Figure 4** provides an example of the methodology developed by the Conservation Council of South Australia (Croft *et al.* 2005), used by Natural Resources Eyre Peninsula to survey the composition of the 23 vegetation communities in their region. **Table 7** in the Appendix outlines an extensive number of programs used by state and territory agencies and NRM regions, and the corresponding indicators of composition.

Australia's native fauna and flora have evolved with fire. As such, fire is an important driver of change in native vegetation condition as inappropriate fire regimes have a major effect on composition indicators. Every vegetation type has a natural fire regime. This is the regime whereby the diversity of native fauna and flora would thrive. Hence the appropriate fire regime is vegetation type- and region-specific. Fire can markedly change the structure and composition of native vegetation through its extent (area burnt), frequency, distribution, intensity (strength of the fire) and patchiness (number of distinct areas burnt at any one time) (McDonald *et al.* 2014). A method was developed for the regional environmental accounts (McDonald *et al.* 2014) trial and a methods paper provides some guidance in this matter. The methods have been tested by Northern Gulf Resource Management Group for the Northern Gulf and Cape York Peninsula regions and provide some initial direction for the inclusion of fire in composition assessments.

An application for incorporating invasive native scrub as a landscape condition indicator into the regional environmental accounts is under investigation. See **Box 2** for more on this matter.

2. Vegetation Assets States and Transitions-2 (VAST-2) System

This system provides a structured way to record observed, measured responses of native plant communities against historic and contemporary land use and land management practices relative to a reference state. **Table 2** provides a list of 22 indicators linked to 10 criteria and three components. The focus of the system is premised on the idea that the disturbance history strongly influences the resilience of a site assessed using the criteria and indicators of regenerative capacity and therefore opportunities for improvements in vegetation condition. The disturbance history of every site will be different, although some sites are expected to share histories at the bioregional level.

It is noted that fire regime has been identified as a key criterion in the VAST-2 system and two indicators have been defined: 1) Area/size of fire foot prints (burnt area) and 2) Interval between fire starts (frequency) (Thackway 2014). Note that in some cases fire is absent eg mangrove, tropical rainforest and samphire.

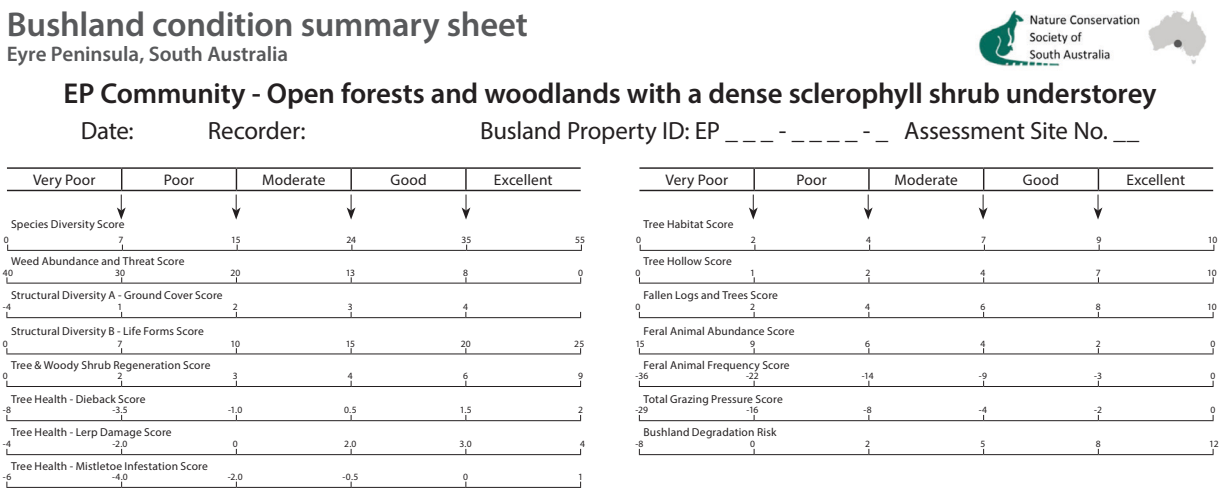


Figure 4: Excerpt of the bushland condition monitoring manual (Croft *et al.* 2005)

Table 2: VAST ecological criteria, performance indicators and diagnostic components (Thackway 2014)

Key functional, structural and composition criteria	Key indicators	VAST diagnostic components
1. Fire regime	1. Area/size of fire footprints	Regenerative capacity
	2. Interval between fire starts	
2. Soil hydrology	3. Plant available water holding capacity	
	4. Ground water dynamics	
3. Soil physical state	5. Effective rooting depth of the soil profile	
	6. Bulk density of the soil through changes to soil structure or soil removal	
4. Soil nutrient state	7. Nutrient stress – rundown (deficiency) relative to reference soil fertility	
	8. Nutrient stress – excess (toxicity) relative to reference soil fertility	
5. Soil biological state	9. Organisms responsible for maintaining soil porosity and nutrient recycling	
	10. Surface organic matter, soil crusts	
6. Reproductive potential	11. Reproductive potential of overstorey structuring species	
	12. Reproductive potential of understorey structuring species	
7. Overstorey structure	13. Overstorey top height (mean) of the plant community	Vegetation structure
	14. Overstorey foliage projective cover (mean) of the plant community	
	15. Overstorey structural diversity (ie a diversity of age classes) of the stand	
8. Understorey structure	16. Understorey top height (mean) of the plant community	
	17. Understorey ground cover (mean) of the plant community	
	18. Understorey structural diversity (ie a diversity of age classes) of the plant	
9. Overstorey composition	19. Densities of overstorey species functional groups	Species composition
	22. Richness – the number of indigenous overstorey species relative to the number of exotic species	
10. Understorey composition	21. Densities of understorey species functional groups	
	22. Richness – the number of indigenous understorey species relative to the number of exotic species	

Box 2 Invasive native species

Before European settlement, western and central NSW were most likely a mosaic of open grasslands, open woodlands and areas of thick scrub. Since the 1800s, changes in fire and grazing patterns have resulted in widespread thickening and encroachment of woody vegetation across large areas of New South Wales. This has had major impacts on both the natural environment and farm viability (Central West and Western CMAs 2010).

The term 'invasive native species (INS)' is applied depending upon the behaviour and location of the plant rather than referring to particular species. Species that can occur invasively vary from woody weeds (eg Turpentine and Budda) which are endemic in the western rangelands of NSW, to dense growth-locked cypress pine and localised stands of dense eucalypt regeneration (eg Poplar Box) in central regions.

Figure 5 shows paddock-based management of invasive native scrub by mechanical pulling of trees (ie thinning of the overstorey). This practice is designed to encourage the reestablishment of the locally indigenous species and a more diverse understorey ie structure and composition. Such management interventions must be accompanied by total grazing management of the main herbivores including sheep, pigs, kangaroos and goats, otherwise the same problem will reoccur with the invasion of woody shrub and tree species.

Figure 5: Management of Invasive Native Scrub (thinning). Photo Credit: Sue Briggs

For example, in the Central West of NSW, Poplar Box is identified as invasive native species (INS), and is described as having three recognisable forms: dense scrub, open scrubland and open woodland. Each of the forms provided habitat for a unique suite of native bird species (Doerr *et al.* 2009). To maintain habitat for the bird species, it was determined that the best possible condition for these vegetation communities is for each form to be in equal amounts across the landscape: ie a ratio of 1/3 dense scrub, one-third open scrubland and one-third open woodland. This ratio is therefore set as the reference benchmark.

A proposed method for accounting for the condition of invasive native scrub mosaic is determined by measuring the deviation of each native vegetation type from the reference state (H Possingham pers. comm.). Some general guidance is provided below.

Using the example of Poplar Box in Central West CMA, a formula that gives a statistical measure of diversity is required. Simpson's Diversity Index, for example, measures the probability that any two randomly selected points are the same habitat type. Hypothetically, if the ratio of the three forms of Poplar Box were found to be 0.30: 0.30: 0.40, the Condition Score for configuration of that vegetation type would be 66. If all the vegetation had thickened to become open woodland (0.00; 0.00; 1.00), then the condition score would be 0 (**Table 3**).

Table 3: Examples of *Econd* scores for invasive native scrub.

	Proportion (p_i)	*Econd*
Community 1		
Dense scrub	0.3	66
Open scrub	0.3	
Open woodland	0.4	
Community 2		
Dense scrub	0.6	54
Open scrub	0.3	
Open woodland	0.1	
Community 3		
Dense scrub	1.0	0
Open scrub	0.0	
Open woodland	0.0	

Data for Assessing Change in Configuration

Configuration is an important element of function, population viability, seed dispersal, and habitat suitability. It comprises aspects of fragmentation and connectivity.

Guidelines

The natural state for some native vegetation communities shows their distribution is associated with specific environmental conditions (for example, vegetation communities found only in cast landscapes, alpine areas or ground water fed areas). However, in highly cleared or fragmented landscapes, the additional effects of fragmentation are detrimental to the structure and composition of native vegetation (McIntyre and Hobbs 1999; Mutendeudzi and Thackway 2008).

Fragmentation refers to the breaking apart of habitat and not to habitat loss itself (Fahrig 2003). Jaeger (2000) describes fragmentation as consisting of a series of phases of habitat division and reduction (Figure 6). Fragmentation is often measured through indicators such as connectivity and patch metrics.

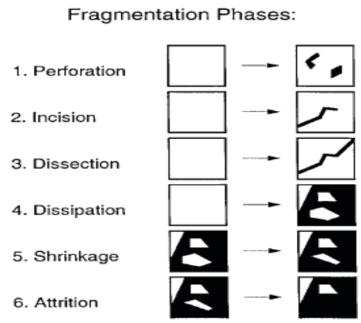


Figure 6: Fragmentation consists of a series of phases of habitat division and reduction (white areas are habitat) (Jaeger 2000)

Examples of Approaches

Connectivity measures the degree of structural fragmentation of native vegetation patches (both across all native vegetation types and within specific vegetation types, eg mangroves) and commonly is measured with indicators such as mean nearest neighbour and neighbourhood. Such metrics are embedded in certain composition indices, such as the Victorian Habitat Hectares (Parkes *et al.* 2003) and Biometric in NSW (Gibbons *et al.* 2009). Lindenmayer and Fisher (2007) and SKM (2009) recommend some simple metrics, such as the E=MC3C cost surface connectivity modelling methods, providing a useful first pass of connectivity. Summerell *et al.* (2011) provide a more detailed method using vegetation assessments based on concentric circles.

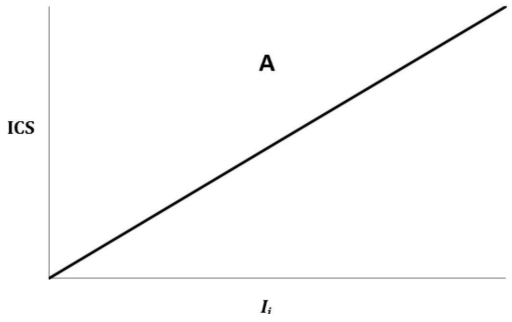
Patch metrics measure the size of native vegetation patches and structural complexity across the landscape. Indicators used in patch metrics include patch size, number of patches and distance to core area.

Configuration involves a GIS analysis of mapped vegetation types and their extents across a region using fragmentation statistics. GIS software and associated statistical tools, such as FRAGSTATS, are often used to calculate various configuration metrics such as mean nearest neighbour and patch sizes, based on available extent and reference extent maps as well as any subsequent time series data sets.

Step 5: Calculate Indicator Condition Scores

Indicator condition scores (ICS) are calculated by measuring the level of departure of the measured indicator from the reference benchmark and are calculated for each indicator, by vegetation type.

The *Quick Guide (Sbrocchi 2013)* states that an indicator condition score is a number between 0 and 100, where 100 is the reference benchmark for each indicator, and 0 indicates system function is absent (modified from Cosier and McDonald 2010). For some indicators, such as extent, the relationship between reference condition and a current score is linear, and the following formula A is suitable.



Formula A:

$$ICS = \left(\frac{I_i}{I_0}\right) * 100$$

where:

I_i = *Environmental indicator measure at 'i' point in time*

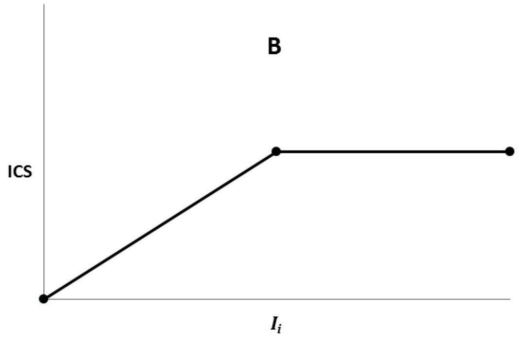
I_0 = *the reference benchmark for that indicator*

For example, in arid and semi-arid acacia low open woodlands (MVG 22) in the Eyre Peninsula region (**Table 5**), the ICS for extent is calculated as:

ICS (MVG 22) = (165246/186558)*100 = 89

However for other indicators, non-linear relationships between measures of extent and reference measures may be observed. In such cases, expert statistical advice should be sought. For example, if volume of leaf litter is used as an indicator of composition, both too little and too much leaf litter might be indicative of poor condition relative to an intermediate, reference benchmark volume of leaf litter in that vegetation type.

The theoretical basis for nonlinear relationships could be described as B or C or there may even be others, but the simplest approach is for the expert to provide their opinion as a score out of 100 for each of the assessed indicators. Formulas B and C are described below.



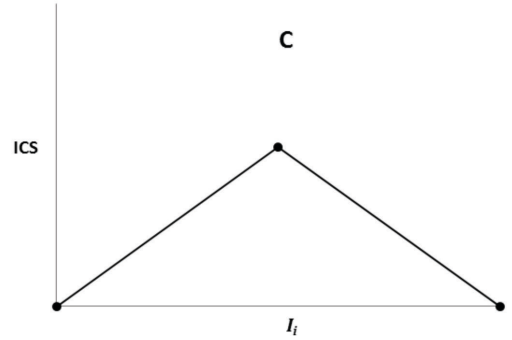
Formula B:

$$ICS = min\left(\frac{I_i}{I_0}, 1\right) * 100$$

where:

I_i = *Environmental indicator measure at 'i' point in time*

I_0 = *Reference benchmark for that indicator*



Formula C:

$$ICS = 1 - max\left(0, \frac{I_i}{I_0}\right) * 100$$

where:

I_i = *Environmental indicator measure at 'i' point in time*

I_0 = *Reference benchmark for that indicator*

Generating Indices for Composition or Configuration

In many cases with jurisdictional native vegetation assessment programs, multiple indicators are combined to describe one of the overarching indicator themes. An example of this is when the vegetation structure, regenerative capacity' and species composition are combined to create an indicator condition score (index) for a composition measure. Relative weightings may be accorded to reflect the contributions of the indicators to the ICS. Examples of this include the Bushland Condition Monitoring program in South Australia (Croft *et al.* 2005), Habitat Hectares in Victoria (Parkes *et al.* 2003) and VAST-2 (Thackway and Specht 2015), where weightings for different indicators are used when calculating an overall condition score.

Reporting Indicator Condition Scores and Related Data

The reference benchmark and current data underpinning each indicator should be provided as part of the native vegetation account as well as reporting the overall indicator condition score (index) for composition or configuration. The native vegetation account should include relevant data tables (see **Table 4**), which are used to store and calculate data for specific indicators and indices (separate tables for extent, composition and configuration datasets). The accounts should also include an asset table (see **Table 5**), which includes information compiled for each native vegetation type and indicator which make up the regional account. For more information on compiling data and asset tables, see the *Quick Guide (Sbrocchi 2013)*. Templates for the asset and data tables are also available from www.nrmregionsaustralia.org. In addition, methods used to combine the indicators into an indicator condition score for composition and configuration must be recorded in an Information Statement.

Table 4: Example extract from one of several data tables submitted for native vegetation condition in the Eyre Peninsula (Poole and Wiebkin 2013)

Easting	Northing	Benchmark Vegetation Type Code	MVS	Vegetation Description	Date	Native Species Diversity - Scaled	Native Species Diversity - Raw	Native Species Diversity - Weighting	Native Species Structural Diversity A - Scaled	Native Species Structural Diversity A - Raw	Native Species Structural Diversity A - Weighting	Fallen Trees and Logs - Scaled	Fallen Trees and Logs - Raw	Fallen Trees and Logs - Weighting	Overall
567712	6183480	EP1	8	Eucalyptus cladocalyx Woodland	06/02/2008	38	14	25	40	2	5	86	10	5	47
568194	6183330	EP1	8	Eucalyptus cladocalyx Open woodland	06/02/2008	44	17	25	20	1	5	70	7	5	50
565257	6165916	EP1	8	Eucalyptus cladocalyx Eucalyptus petiolaris Open forest	20/04/2009	78	34	25	80	4	5	30	3	5	59
475185	6323270	EP11.2	55	Eucalyptus diversifolia ssp. diversifolia, +/- Eucalyptus phenax ssp. +/- Eucalyptus yalatensis, Mallee	05/10/2010	85	40	25	60	3	5	95	12	5	46
457634	6328427	EP11.2	55	Eucalyptus diversifolia ssp. diversifolia, Open low mallee	25/05/2009	64	26	25	33	1	5	0	0	5	27
484360	6279045	EP12.1	36	Triodia compacta, +/- Goodenia ovata Low shrubland	05/05/2010	100	19	42	80	3	8	0	0	0	89
471220	6320805	EP12.1	36	Leucophyta brownii, +/- Isolepis nodosa +/- Dianella revoluta var. Low shrubland	13/08/2009	100	17	42	60	2	8	0	0	0	82
426303	6349974	EP8.1	55	Eucalyptus phenax ssp. phenax, Open mallee	16/11/2010	53	14	25	40	2	5	82	4	5	49

Table 5: Example of a completed native vegetation asset table

Asset *(See Step 1)* | Reference Benchmark *(See Step 3)* | Indicator Condition Score *(See Step 5)*

Indicator *(See Step 2)* | Data *(See Step 4)* | ***Econd*** *(See Step 6)*

NATIVE VEGETATION ASSET ACCOUNT - EYRE PENINSULA, SOUTH AUSTRALIA - 2012

Government of South Australia
Eyre Peninsula Natural Resources Management Board

Asset Category	Indicator of Asset Condition (Unit of Measure)	Reference Benchmark	Condition Measure	Indicator Condition Score	***Econd***
Eyre Peninsula Region		5,130,353			250
Arid & semi-arid acacia low open woodlands & shrublands with chenopods					
	Extent (Ha)	186,558	165,245	89	
	Composition (index)	100	66	66	
	Configuration (index)	100	74	74	
Arid & semi-arid hummock grasslands					11
	Extent (Ha)	23,320	5,012	21	
	Composition (index)	100	60	60	
	Configuration (index)	100	47	47	
Callitris forests & woodland					42
	Extent (Ha)	23,320	17,594	75	
	Composition (index)	100	63	63	
	Configuration (index)	100	48	48	
Casuarina & Allocasuarina forests & woodlands					7
	Extent (Ha)	233,198	30,910	13	
	Composition (index)	100	54	54	
	Configuration (index)	100	51	51	
Chenopod shrublands					52
	Extent (Ha)	233,198	190,627	82	
	Composition (index)	100	61	61	
	Configuration (index)	100	66	66	
Eucalyptus low open woodlands with tussock grass					0
	Extent (Ha)	46,640	147	0	
	Composition (index)	100	56	56	
	Configuration (index)	100	32	32	
Eucalyptus forests & woodlands with grassy understorey					9
	Extent (Ha)	46,640	8,130	17	
	Composition (index)	100	70	70	
	Configuration (index)	100	35	35	
Eucalyptus woodlands with shrubby understorey					15
	Extent (Ha)	46,640	13,111	28	
	Composition (index)	100	70	70	
	Configuration (index)	100	35	35	

Step 6: Calculate the Native Vegetation *Econd*

The *Econd* is calculated by combining the indicator condition scores (ICS) in a meaningful way to provide a representation of the condition of the asset as a whole. The purpose of the *Econd* is to measure relative change to the condition of the asset (in this case native vegetation).

An *Econd* can only be calculated for a native vegetation type where the account includes, at minimum, a measure of quantity (extent) and a measure of quality (composition and, if available, configuration).

Calculating the *Econd* for Each Native Vegetation Type

Formula:

Vegetation type *Econd* = Quantity * Quality

The logic is this: if the area of a pristine forest is reduced by 50% its condition has been halved, and its *Econd* is therefore 50. If the remaining 50% is degraded (eg by weed invasion, grazing of understorey, etc.), then the condition of the forest has been reduced to 25% (50% of 50%) and its *Econd* is therefore 25.

Using the previous example (**Table 5**), the *Econd* for arid and semi-arid acacia low open woodlands is calculated as follows:

Vegetation type *Econd* = Extent * (composition + configuration/2)

In this example, the composition ICS and configuration ICS are averaged to produce the measure of quality ((66+74)/2). This is multiplied by the ICS for extent (89), to give an *Econd* of 62.

Relative weightings for the components of the quality indicators may vary between vegetation assessment programs. Expert opinion should be obtained to accord the different measures of composition and configuration relative weightings. For example, as seen above, Natural Resources Eyre Peninsula used equal weights of 50% for both composition and configuration, the Habitat Hectares approach in Victoria weights composition with 75% and configuration as 25% of the score, and VAST approaches, used by SEQ Catchments, weights composition with 100% and configuration as 0%.

Calculating the Regional *Econd* for Native Vegetation

The regional *Econd* for native vegetation is the weighted average of the *Econds* of each vegetation type, scaled by their proportional extent at reference. Extent at reference (rather than current extent) is used in order to obtain a representative measure of condition across the entire region.

The regional *Econd* = $[\sum E_n*(A_0/A_{total})]/Z$

Where:

E_n = *Econd for native vegetation type 'n'*

A_0 = *spatial extent at the reference benchmark*

A_{total} = *total spatial extent of native vegetation at the reference benchmark*

Z = *total number of native vegetation types*

In the Eyre Peninsula (**Table 3**), this would be calculated as:

Regional *Econd* = [(62*(186558/5130353)) + (11*(23320/5130353)) + …+ (34*(1399187/5130353))]/11 = 25

The resulting *Econds* calculated for each vegetation type can be presented visually as a bar graph (**Figure 7**), or colour coded regional map (**Figure 8**).

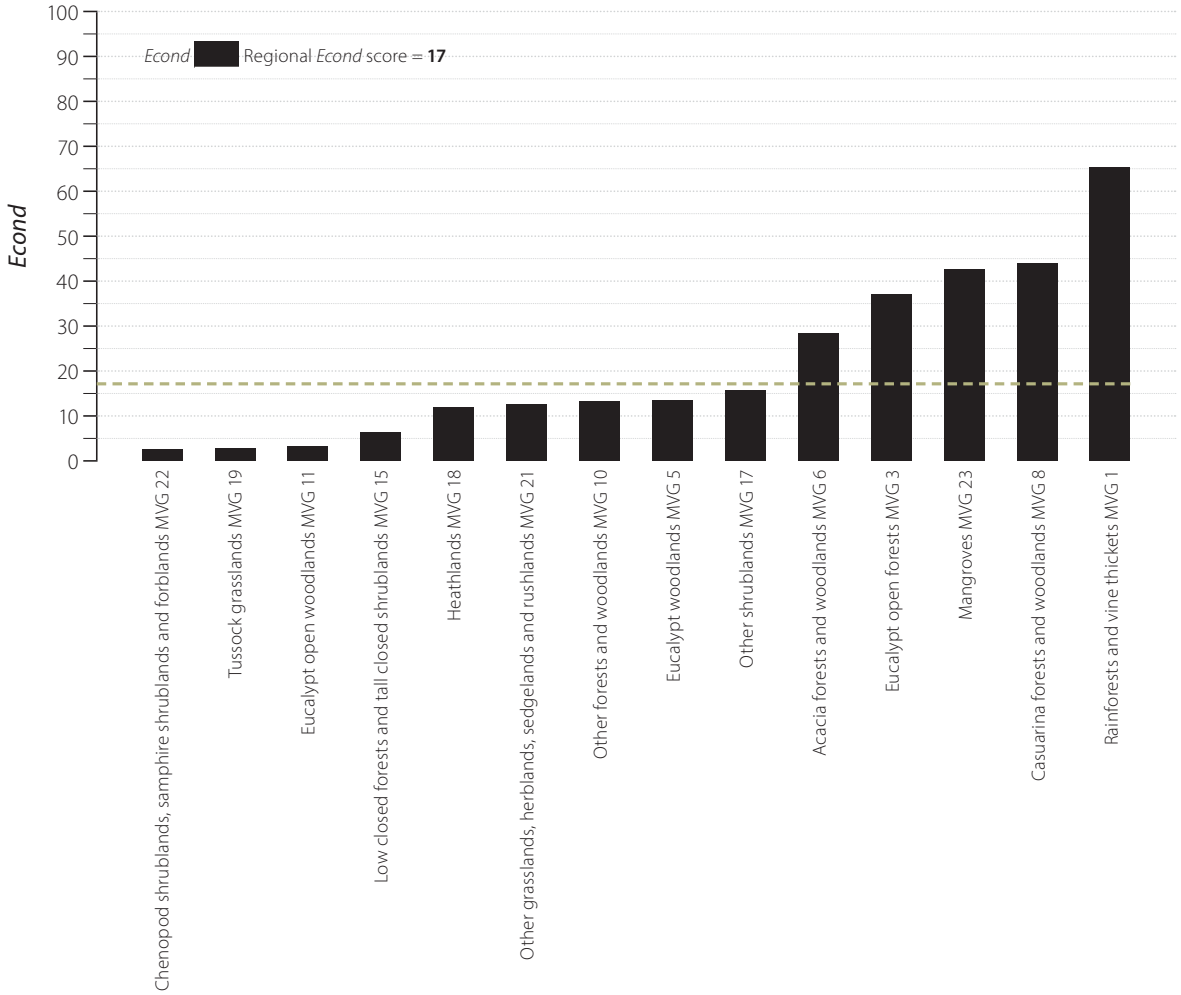


Figure 7: *Econds* for native vegetation types (MVS) of Natural Resources Eyre Peninsula region, South Australia

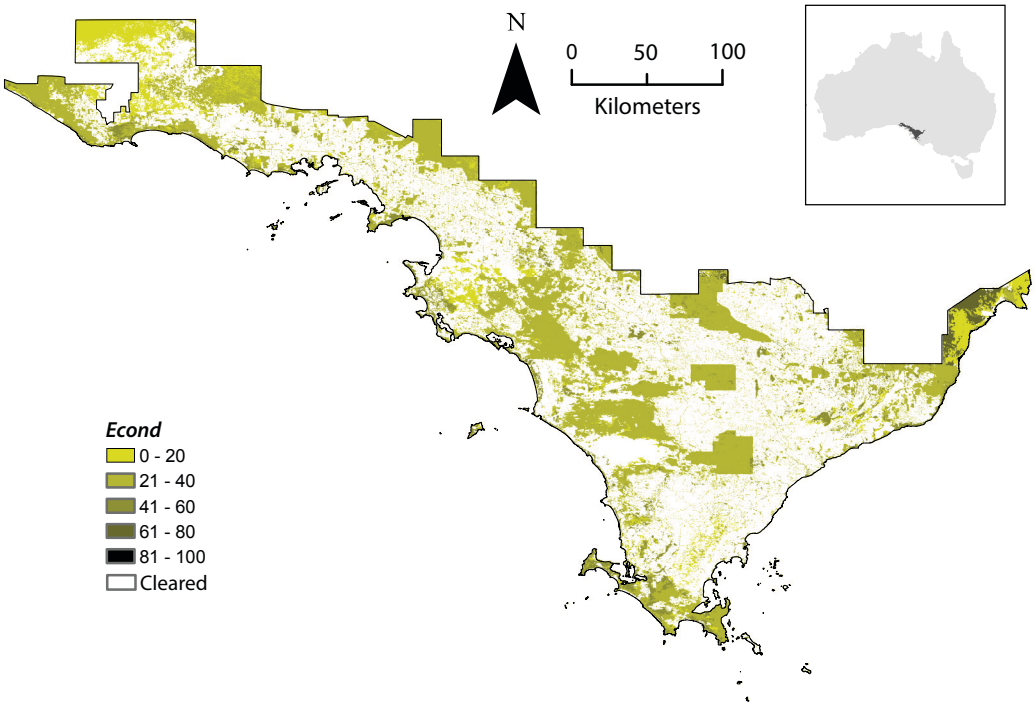


Figure 8: *Econds* of remaining native vegetation in Natural Resources Eyre Peninsula region, South Australia, mapped by major vegetation subgroup (MVS)

The value of combining extent, composition and configuration ICSs into a single *Econd* for each vegetation type is made clear in **Figure 9**. For many vegetation types there are large discrepancies between the values of the quantity (extent) versus quality (composition and configuration), which, if considered in isolation, would provide a distorted representation of the overall condition. Together with the asset *Econds,* the indicator condition scores assist with interpreting the drivers of change in a region ie whether the primary contributor to the overall condition is more likely a low score in the extent, composition or configuration indicators, and in which native vegetation type.

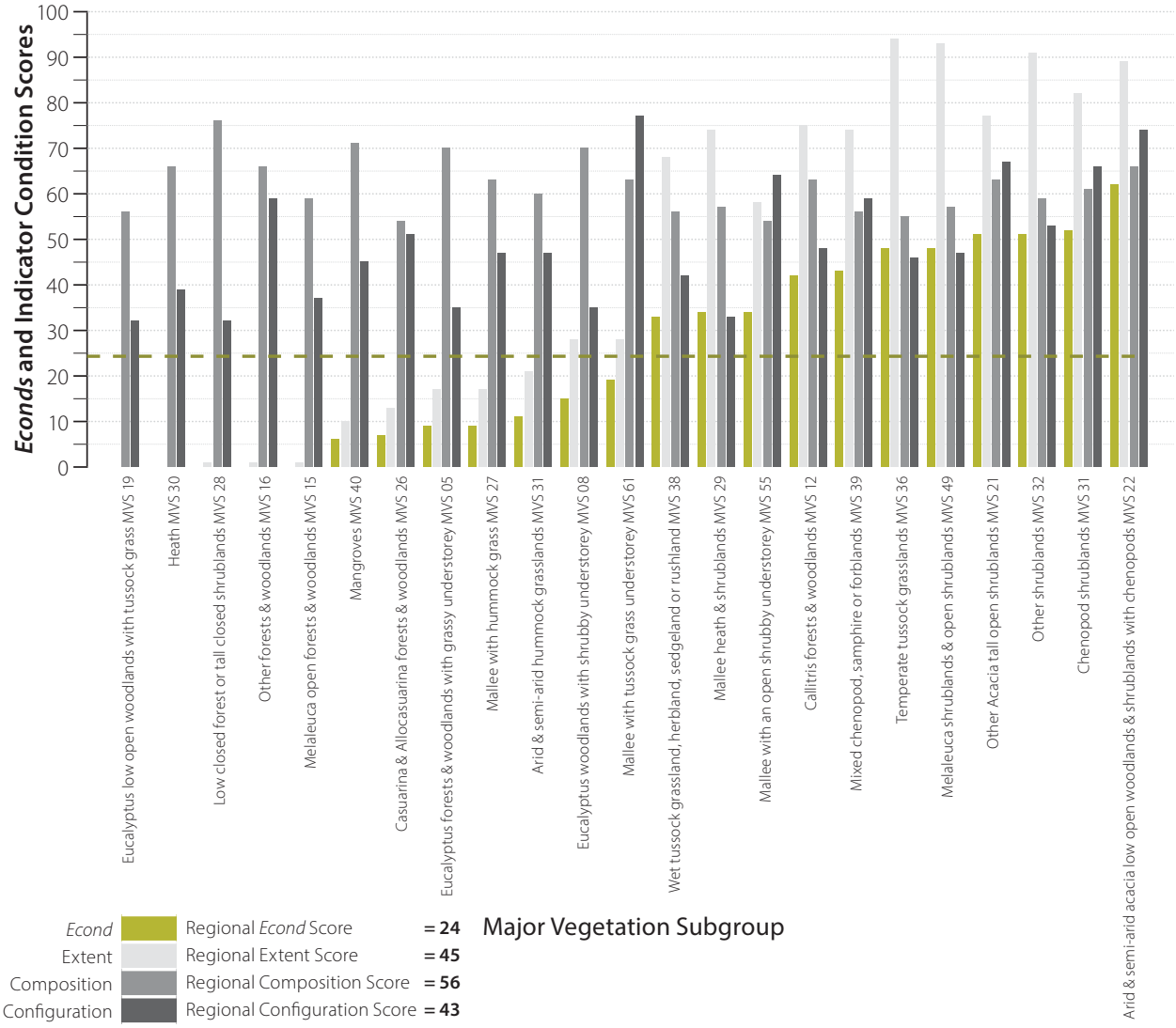


Figure 9: *Econds* and Indicator Condition Scores for native vegetation assets in the Natural Resources Eyre Peninsula region. Green bars represents the *Econd* of each native vegetation type within the region, darkest grey bars are the extent scores for each, and darker and light grey bars represent the quality indicators.

Step 7: Submit the Account for Accreditation

The completed native vegetation account should be submitted to the Scientific Standards and Accreditation Committee, as per the *Quick Guide (Sbrocchi 2013)*, which assesses the account against a set of Accreditation Standards including a Draft Indicator Data Standard (**Table 6**).

An Information Statement should be used to document the actions taken to populate each of the steps in the Guidelines, staged in this protocol. The statement, which accompanies an account, provides information on the rationale behind selection of assets, choice of indicators, the origins of the data, the analysis and treatment of data and construction of the *Econd.* A template can be found at www.nrmregionsaustralia.org.

Table 6: Draft accreditation standard for native vegetation condition indicators and data quality.

Accreditation Grade	Native Vegetation Extent	Native Vegetation Composition	Native Vegetation Configuration
5 Comprehensive	An annual extent measure is provided for each regional native vegetation type and Major Vegetation Group; and →	The composition of each vegetation community has been determined by an annual random site survey of flora composition using a suitable number of sites per vegetation type as determined by a statistical power analysis*; and →	The configuration of each vegetation community incorporates an appropriate measure
4 Substantial	An annual extent measure is provided for each regional native vegetation type; and →	The composition of each vegetation community has been determined by a regular** site survey of flora composition using a suitable number of sites per vegetation type as determined by a statistical power analysis*; and →	The configuration of each vegetation community incorporates an appropriate measure
3 Good	Extent measures are provided for each regional native vegetation type; and →	The composition of each vegetation community has been determined by a random site survey of flora composition using a suitable number of sites per vegetation type as determined by a statistical power analysis*; and →	The configuration of each vegetation community incorporates an appropriate measure
2 Reasonable	Extent measures are provided for each regional native vegetation type; and →	Expert judgment has been used to estimate the composition of each vegetation type^^, and →	The configuration of each vegetation community incorporates an appropriate measure
1 Acceptable	Extent measures are provided for each Major Vegetation Group; and →	Expert judgment has been used to estimate the composition of each Major Vegetation Group^^.	
0 Not accredited	Measures of Native Vegetation extent only where: • Woody vegetation communities are known to be degraded by clearing of understorey, grazing or weed invasion; • Grassland (non woody) vegetation communities are known to be significantly degraded by grazing or weed invasion (including grasslands dominated by improved pastures); or • Vegetation communities are known to have been significantly altered by changed fire regimes (*e.g* invasive native scrub in western NSW or northern Australian savannahs).		

** For the trial, 10 sites were assumed to be sufficient following expert advice. This is a general guide and does not replace the need for statistical power to be demonstrated.*

*** "Regular" – a consistent time period that is not annual (eg biannual to five-yearly surveys) and/or annual surveys in those vegetation classes that show/are likely to show change over a short period of time.*

^^ "Contemporary time period" – assessment applies to contemporary change/s observed in the 10 years.

Discussion

Proposed Implementation of the Protocol

NRM regions, with the support of the state and territory agencies, have developed a proposed set of indicators of vegetation composition and configuration to be used in native vegetation condition accounts, generally based on state or territory assessment programs (**Appendix 1**).

The NVIS attribute framework has been variously implemented by all jurisdictions (Thackway *et al.* 2008; Hnatiuk *et al.* 2009). It is noted that each jurisdiction uses and maintains specific classification and mapping systems (**Table 1**). At present, Queensland has the closest native vegetation attribute framework to the NVIS attribute framework. Other jurisdictions including South Australia, Northern Territory, Tasmania and Western Australia have variously implemented the NVIS framework within their statewide survey, classification and mapping programs (Thackway *et al.* 2008). New South Wales is currently remapping the whole state using a new mapping approach which closely matches the NVIS attribute framework. Victoria continues to enhance its Ecological Vegetation Classes and supplies the Australian Government with native vegetation maps consistent with the NVIS attribute framework by integrating its Ecological Vegetation Classes and other vegetation datasets. In addition, regions may use other classification systems depending on the alignment between the level of detail of the classification and the scale required to make policy and investment decisions (**Figure 2**). It should be noted that these other classifications may or may not relate to the NVIS framework, making the task of inter- and intra- region comparisons difficult to reconcile, eg classification and map differences arise because no national system has been used.

Towards Multiyear Accounting to Report Trends

Understanding the health of an environmental asset not only requires an understanding of the condition of an asset at a particular point in time: the direction and rate of change are of equal significance in environmental management.

A common failing of condition reports is the reliance on compiling the current status of vegetation type and extent, expressed as datasets and maps. Such reporting has a major deficiency in that data and maps, which have been compiled over different reporting cycles, cannot be compared because the methods used to compile each status report are not the same between each reporting cycle. A case in point is reporting on changes in the extent of Australia's forests in the State of the Forests Reports (SOFR) (National Forest Inventory 1998), SOFR 2003 (National Forest Inventory 2003), SOFR 2008 (Montreal Process Implementation Group 2008), and SOFR 2013 (Montreal Process Implementation Group for Australia & National Forest Inventory Steering Committee 2013). This issue was resolved in the SOFR 2013 report (Montreal Process Implementation Group for Australia & National Forest Inventory Steering Committee 2013) by benchmarking the relative extents of forest areas found in the four SOFR reports over the period 1998-2013 to the areas of forest reported for the same period in the NCAS dataset.

Changes in quantity and quality should therefore be repeated regularly to create trend datasets. In addition, as more data or methodologies become available, new or improved indicators should be incorporated into the accounts. Expert advice should be sought to ensure that as the accounts evolve, the ability to compare condition scores across years (the advantage of using reference condition) is not lost.

Historical information can be used to establish a reliable estimate of trend in condition accounting. For example, Central West Catchment Management Authority in NSW tested the utility of the tree cover database developed for the national carbon account (NCAS) for regional environmental asset condition accounting (Greenhalgh 2012). The database used epochs of Landsat satellite imagery dating back to the 1970s, and can be used to construct trend data on changes in vegetation extent. ABARES also used the NCAS time series dataset to report regional level trends in the extent of revegetation and rehabilitation across Australia by looking for pixels that were observed to be non-woody in 1980 and woody in 1990 and subsequent epochs (Richard Thackway pers. comm.).

Other methodologies, based on expert assessment of historical information, have been developed to provide ways to track change and trends. *Tracking the Transformation of Vegetated Landscapes* (Thackway 2012a) provides a structured way to record observed, measured responses of native plant communities against historic and contemporary land use and land management practices relative to a reference state.

The framework utilises information on observed and/or measured changes in land use and land management practices and their impacts on vegetation structure, species composition and regenerative capacity over time. Fundamental to

the approach is access to credible published sources of information that describe where, when, and what changes in land use and land management practices were used to manage the vegetation.

The sources of this information are multidisciplinary, including land use histories, remote sensing, and several branches of ecological science: landscape, vegetation and restoration. Much of the historic information is qualitative, compared to contemporary information, which is mostly quantitative.

Trend data can be used to track progress and the effectiveness of different management approaches or programs. Such data can be used by decision makers to ascertain the regions or assets which are in decline, and the reasons for changes in condition across the landscape.

When condition is visually displayed relative to a reference state, as in **Figure 10**, it makes it easy for managers to think about the current condition of an asset in relation to the optimal condition, and assists in the setting of realistic targets for management outcomes.

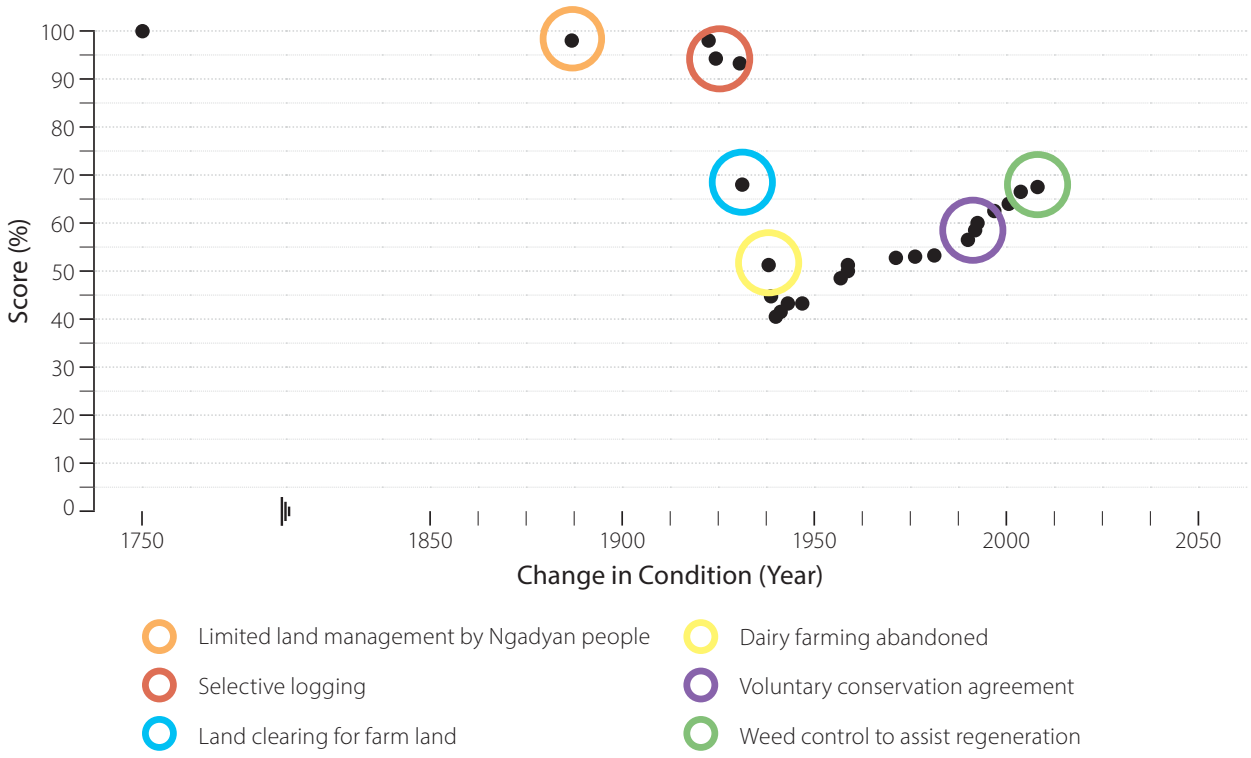


Figure 10: Condition change in native vegetation at Wooroonooran Nature Reserve, QLD, 1750-2010. Image courtesy Richard Thackway (Thackway 2012b).

Conclusions

Numerous national reports including State of the Environment reports (Department of the Environment 2009; State of the Environment Committee 2011) have identified the benefits of systematic collection, analysis and reporting of long-term natural resources data, particularly native vegetation. Despite these observations over 15 years, public and private investment in designing, establishing and maintaining such information systems has been limited.

To address this deficiency, this protocol for multiyear reporting on the condition of native vegetation assets at the regional scale supplies a methodology to consistently account for changes in condition through time. Completion of regional scale native vegetation accounts for each NRM region, using this protocol, will represent a significant advance in understanding the condition of native vegetation types (assets).

Despite the fact that the NVIS framework has been used to back-engineer a consistent national classification and map of Australia's native vegetation, ie MVGs and MVSs, these MVGs and MVSs continue to reflect the different methods used by each state and territory to survey, classify and map the native vegetation in their jurisdictions. For this reason, regional and state-based native vegetation classification systems are often not directly comparable within and between states, making it difficult to compare the status of native vegetation across state/territory borders.

Use of this protocol provides commonality between the regional accounts as data is used to populate indicators of extent, composition and configuration of native vegetation types.

Ongoing and regular data collection is essential for measuring changes in the condition of native vegetation. Challenges with regular data collection may be addressed by:

- exploring opportunities to utilise appropriate regional-scale, metric-based datasets, derived from validated satellite imagery. These datasets offer significant opportunities to incorporate higher spatial resolutions and multi-temporal sampling across the whole landscape;
- incorporating elements of community participation or citizen science into field assessments; and
- developing partnerships between NRM regions and state/territory agencies for the supply of relevant data to populate the indicators.

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Appendix 1 – Indicators of Composition and Configuration

Table 7: Summary of the proposed indicators of vegetation composition and configuration for use in the respective regional native vegetation condition accounts.

Region	NACC (WA)	Northern Gulf (NT)	QMDC (QLD)	SEQ Catchments (QLD)	Namoi (NSw)	Central West CMA (NSW)	Corangamite (VIC)	North central (VIC)	NRM North (TAS)	Eyre Peninsula (SA)
Pre-existing methodology used	Expert opinion based on existing surveys in region	None	Biocondition - context and connection	Expert opinion based on VAST methodology	ELA (based on biometric, biocondition and habitat hectares)	Biometric	Habitat hectares	Habitat hectares	none	A version of the bushland condition monitoring methods
Sampling unit (number of classes)	Beard's class (1:250,000)	BVG			BVG		Ecological Vegetation Class (EVC)	Ecological Vegetation Class (EVC) (50)		
Frequency of sampling (last year)	No comprehensive sampling in region	n/a	2009	No comprehensive sampling in region	Keith class (50m x 20m)	No comprehensive sampling in region	1989 - 2005	1989 - 2005	n/a	2012
Vegetation composition	Vegetation structure		Recruitment of woody perrenials	Vegetation structure (overstorey)	2011	Indigenous plant species richness	Large trees	Large trees		Indicators varied depending on vegetation type, but included:
	Understorey		Native plant species richness	Vegetation structure (understorey)	Canopy species	Native overstorey cover	Tree canopy cover	Tree canopy cover		Structure
	Overstorey		Tree canopy cover (%)	Species composition (overstorey)	Large trees	Native midstorey cover	Understorey	Understorey		Diversity
	Species diversity		Tree canopy height	Species composition (understorey)	Trees with hollows	Native ground cover (grasses)	Lack of weeds	Lack of weeds		Weed
	Regenerative capacity		Shrub layer cover (%)	Regenerative capacity (fire)	Dead fallen timber (length)	Native ground cover (shrubs)	Recruitment	Recruitment		Regeneration
	Fallen timber		Native perennial grass cover (%)	Regenerative capacity (reproductive potential)	Canopy health	Native ground cover (other)	Organic litter	Organic litter		Dieback
	Soil disturbance		Native perennial forb and non-grass cover (%)	Regenerative capacity (soil structure)	Native shrub & small tree species	Number of tree hollows	Logs	Logs		Habitat
	% Cryptogams		Native annual grass, forb and non-grass cover (%)	Regenerative capacity (soil chemistry)	Native groundcover species	Regeneration				Nativeness
	% Weed cover		Large trees	Regenerative capacity (soil biology)	Exotic plant cover	Total length of fallen logs				Mangrove seedling

Region	NACC (WA)	Northern Gulf (NT)	QMDC (QLD)	SEQ Catchments (QLD)	Namoi (NSW)	Central West CMA (NSW)	Corangamite (VIC)	North Central (VIC)	NRM North (TAS)	Eyre Peninsula (SA)
	% Litter cover		Fallen woody material	Regenerative capacity (soil hydrology)	Native canopy (% cover)					
	Bird presence		Weed cover		Native midstorey (% cover)					
	Slope		Litter cover		Weeds (ground cover canpoy & midstorey)					
	% Bare ground				Mosses & lichens (groundcover %)					
					Organic litter (groundcover %)					
					Rock/bare ground (groundcover %)					

Appendix 2 – Glossary

Accreditation – certification of competence in a specified subject or areas of expertise, and of the integrity of an agency, firm, group, or person, awarded by a duly recognised and respected accrediting organisation (Business Dictionary 2015)

Account – a compiled set of information about the behaviour of institutional units and the activities in which they engage. Key elements of an account are entities engaging in activities, beneficiaries of the activities, and the transactions between them (adapted from European Commission *et al.* 2009).

Accounting – the process of identifying, measuring, recording and communicating economic transactions (Dictionary of Accounting 2010).

Asset – items of value to society (Australian Bureau of Statistics 2005).

Asset table – the second level of data in the environmental account spreadsheet below the Summary table, showing regional *Econds* dissected into individual asset classes. *Econds* and Indicator Condition Scores are reported for each asset class, with their corresponding reference benchmarks and measures.

Capacity – the ability of a given environmental asset to generate a set of ecosystem services in a sustainable way into the future (United Nations *et al.* 2013).

Composite Index – also 'composite indicator'; a group of indicators combined and standardised into an index (a number between 0-100). In the *Accounting for Nature* model, the *Econd* is a composite index formed from multiple indicators of condition.

Composition - the functional and structural integrity of the native vegetation asset. It provides information about the various components which make up that vegetation type (such as key species, vertical structure, proportion of weedy or endemic plants, etc).

Condition – the scientific description of the quality or 'state' of an environmental asset (Stoddard *et al.* 2006; Tierney *et al.* 2009; Bunn *et al.* 2010). Condition is measured through the use of indicators relating to the asset's vigour (level of productivity), organisation (structure and interactions) and resilience (ability to rebound from a shock) against a reference condition (Rapport *et al.* 1998). Condition underpins the assessment of the capacity of an environmental asset to provide goods and services that are of value to people, now and into the future. In the *Accounting for Nature* model, condition is represented by the composite index, the *Econd*.

Configuration - the spatial arrangement of plant communities across the landscape which serve an important function in population viability, population connectivity, seed dispersal, and habitat suitability.

Data table - the third level of data in the environmental account spreadsheet below the Summary and Asset tables, showing specific indicators and the measures used to construct the Indicator Condition Scores for each asset class.

Degradation – considers changes in the capacity of environmental assets to deliver a broad range of ecosystem services and the extent to which this capacity may be reduced through the action of economic units, including households (United Nations *et al.* 2012).

Econd *(Environmental Condition Index)* – describes the relative condition of any environmental asset as composite index, where 100 indicates the condition of an asset in the absence of significant post-industrial human alteration, and 0 indicates system function is absent (Cosier and McDonald 2010)

Environmental account – an account for one or multiple aspects of the biophysical environment.

Environmental asset – the naturally occurring living and non-living components of the earth, together comprising the biophysical environment, that may provide benefits to humanity (United Nations *et al.* 2013).

Environmental asset class – overarching themes used to describe the environment which incorporates sets of environmental assets. In the Australian State of the Environment reports, recognised environmental asset classes include land, water, coast, marine and atmosphere (State of the Environment 2011).

Environmental Asset Condition Accounts – A set of tables that document the condition of an environmental asset which measure the change in quality and quantity of the asset. In the *Accounting for Nature* model, these accounts use the *Econd* as the unit of measure of change.

Index – a method of combining a set of indicator measures to produce a number on a scale between 0-1 (or 0-100).

Indicator – environmental indicators are quantifiable and transparent measures – which can be physical, chemical, or biological – of the characteristics of the ecosystem that can be used to detect change.

Indicator condition score – within the *Accounting for Nature* model, the indicator condition score is a standardised raw value of the indicator measure against the reference benchmark. In some cases, the indicator condition score may also act as an intermediate index, comprising multiple indicators of a similar type (eg water quality indicators combined to form a water quality index). Within the index 100 represents the reference benchmark for each indicator and 0 indicates system function is absent (modified from Cosier and McDonald 2010). Also called a theme index or theme score.

Indicator theme – an overarching description of a group of indicators that, together, provide a measure of an aspect of an asset's condition. For example, indicators of pH, turbidity, dissolved oxygen and salinity may comprise a Water Quality indicator theme for rivers assets.

Information statement – a document describing the rationale behind selection of assets, choice of indicators, origins of the data, the analysis and treatment of data, and construction of the *Econds*.

Quantity – amount or measure (Macquarie Dictionary 2005).

Quality – the standard of something as measured against other things of a similar kind; the degree of excellence of something (Oxford Dictionary 2015).

Reference benchmark - a measure of the asset's reference condition which can be a fixed point in time (for example, an estimate of its condition prior to industrial development) (Hughes *et al.* 1998; Norris and Thoms 1999, Wallin *et al.* 2003); observed at reference sites (Reynoldson *et al.* 1997); or a scientifically accredited model that estimates the condition of the biota in the absence of significant post-industrial human alteration (Karr 2006).

Reference condition – a scientific estimate of the condition of an ecosystem in the absence of significant post-industrial human alteration (Stoddard *et al.* 2006).

Summary table – the first and highest level of data in the environmental account spreadsheet, showing *Econds* and indicator condition scores for the entire region at each time period.

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