Regional-scale method to monitor vegetation condition using condition models and expert elicitation

DOCUMENT DETAILS

Method Name: Regional-scale method to monitor vegetation condition using condition models and expert elicitation

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Relevant Environmental Asset Class: Native Vegetation

Confidence Levels: Level 3

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1. Introduction

Vegetation in Australia has been significantly modified since European Settlement. Land-use change has been a major driver of this modification, with clearing for pasture responsible for at least 70% of cleared vegetation over the last 40 years (Evans, 2016). In 1995, Graetz et al. (1995) estimated that ~52% of Australia's intensive land-use areas had been cleared or intensely modified for agricultural, urban, and industrial expansion.

As a result of land-use intensification and clearing, much of Australia's remaining forest, shrubland, grassland and open woodland ecosystems have become degraded or fragmented (Tulloch et al. 2015, Evans 2016). However, many regional land management groups are trying to improve vegetation condition within their regions. Therefore, it is important to monitor vegetation condition consistently and cost-effectively within a region to understand how it changes over time in response to management activities and land-use change.

The Commonwealth Scientific and Industrial Research Organisation have developed a national-scale vegetation 'composition' condition model, called the Habitat Condition Assessment System (HCAS). The HCAS model uses remote sensing, spatial ecological modelling, and sparse data from on-ground condition assessments to generate a national view of 'composition' condition on a scale of 0 to 100, where 0 represents areas that are completely degraded, and 100 represents areas that are in 'best-on-offer' or 'reference' condition (Williams, 2020). The model does this by comparing the remote-sensed 'signals' of areas identified to be at either 0 or 100 condition (identified through modelling or on-ground condition data) with all other areas across Australia. HCAS has been developed at the national scale with 250 m resolution and therefore requires a level of verification for use at the regional scale.

This Method uses this national-scale HCAS model as the basis for the composition condition assessment. The outputs of the model are verified for the specific accounting region through a prescribed expert elicitation process using the IDEA Protocol (see Step 4). Various state governments within Australia are also working on their own state-wide condition assessment frameworks, similar to HCAS, which, when available, will be able to be substituted for HCAS within this Method.

1.1. Aim and Scope of this Method

This Method has been developed to help regional land managers (such as Natural Resource Managers and Local Governments) better understand how the condition of vegetation and the extent of different land-uses are changing over time within their region. The outputs of this Method can assist regional land managers with understanding the impacts of their management activities, help with environmental decision making and reporting for the region and ultimately lead to improved and targeted vegetation management.

This Method outlines how to build a regional scale Environmental Account in a robust, repeatable and transparent way and in accordance with the *Accounting for Nature ® Standard*. Accounts developed with this Method will produce credible and verifiable vegetation condition scores that can support public claims at the regional scale. This Method is not intended for use at the project or property scale (areas nominally less than ~250,000 ha), nor should the final condition scores be interrogated to infer the condition of individual or groups of properties or projects.

This Method aims to be practical, and time and cost efficient to implement at such a large scale. The Method assesses condition continuously across the landscape by breaking the entire landscape down into unique assessment units that are defined by combinations of land-use (e.g. grazing, cropping, conservation, etc.), and land-cover classes (e.g. remnant, non-remnant woody, non-remnant herbaceous etc.). Instead of requiring traditional field surveys to determine condition for each assessment unit (which are often extremely costly when considering such a large area), the Method instead generates average condition scores using a combination of the national-scale HCAS modelling (or state-wide condition modelling, where available) and expert elicitation to provide robust condition estimates for application at the regional-scale.

This means that the whole accounting area (broken down into unique classes) is assessed for native vegetation condition; some areas will receive very low condition scores, such as built-up areas, infrastructure, and intensive cropping, while other areas will receive high scores, such as remnant or regrowth vegetation areas. This is approach enables the overall regional vegetation condition score to be influenced by the condition of all areas within the accounting region, including degraded non-remnant areas, remnant areas, restoration plantings, grazing paddocks etc., not just areas traditionally considered ‘native vegetation’.

This classification of the entire region into unique land-use and land-cover classes is also beneficial in that it enables regional trends in vegetation condition to be inferred from changes in land-use and land-cover (e.g. changes in intensity of agriculture or restoration/planting projects) within the region, rather than requiring intense and costly time series surveys.

The Method generates a Vegetation Condition map that can be interrogated and summarised in different ways, including: an average Econd® for each land-use/land-cover class, an average Econd® score for each vegetation type within the region; as well as an overall summary Econd® score. contained within the accounting region. Under the *AfN Standard*, the Econd® is an index between 0 and 100, where 100 describes the ‘undegraded’ or ‘best possible’ condition of an environmental asset, and 0 indicates that the asset is completely degraded. The Econd® is generated by comparing the current observed or modelled condition of native vegetation to the expected undegraded Reference Condition (which would achieve an Econd® of 100).

1.2. Overview

Purpose	To assist regional land-managers understand the condition and change in condition of vegetation within their region.
Application	Australia wide
Scale	Regional (>~250,000 ha) This Method is not suitable for use at the project or property scale (areas nominally less than ~250,000 ha), nor can the final condition scores be interrogated to infer the condition of individual or groups of properties or projects.
Scope	To assess and monitor change in condition over time.
Target Audience	This Method has a diverse target audience. It is targeted to be implemented by regional land managers such as Natural Resource Management Groups, with audience being the decision makers of those groups, as well as residents living within the region.
Decisions to inform	This Method aims to help understanding of the condition of native vegetation at a regional scale and change over time. The outcomes of the assessment may therefore help to target management and investment to areas that could be improved, and assist with environmental decision making and reporting.
Confidence Level/s	Level 3
Expertise required to implement the Method	- AfN Accredited Expert (Category 1 – Native Vegetation) with knowledge of vegetation and land-uses within the region it is being applied - GIS skills to stratify the accounting region into unique and relevant land-use/land-cover classes and vegetation types - Expert elicitation specialist to run the expert elicitation process

1.3. Justification of Confidence Level

This Method has a Level 3 Confidence Level. Whist the condition scoring is based on a national scale condition model, this baseline information is then verified or modified through a structured expert elicitation process.

The Method calculates the average composition condition for land-use/landcover segments of the region using the HCAS Model, or similar product(e.g. state-based condition models), as the input. This approach of averaging the HCAS data across the different land-use/landcover segments results in a higher level of confidence of the composition score compared to relying on the accuracy of the condition estimate for each pixel within the HCAS Model. It also enables the development of time series and trend data for regional vegetation condition without requiring condition products to be based on short-term remote sensing inputs. For example, the Method underpinning the best condition estimate from HCAS uses an 18-year 'epoch' of remote sensing data. The long timeframe enables the HCAS algorithm to use information about trends and variability in the remote sensing signals in estimating vegetation condition for a specific location. Using short-term remote sensing data, such as a single seasonal snapshot, or even data from across a single year, can make it more difficult to separate the influence of weather and other seasonal changes, which should generally have minimal impact on condition, from the impacts of management that directly affect condition. The average condition of large areas, such as the assessment units used in this Method, is not expected to change rapidly from year to year.

1.4. What an Environmental Account looks like

The *Accounting for Nature®* Framework requires accounts to be comprised of three key components for them to be certified:

1. An **Environmental Account Summary** – a public document that summarises the results of the environmental account in a form that is readily communicated to the public.
2. An **Information Statement** – describes in detail the method used and the actions taken to address each of the eight steps under the framework including rationale behind asset selection, choice of indicators, Method used, analysis and management of data and calculation of the Econd®.
3. The **Environmental Account** – a database (such as an excel file) that contains all the data described in Asset Tables, Data Tables, and Balance Sheets.
4. An **Audit Report** (for 'certified' Accounts) or **AfN Technical Assessment** (for 'self-verified' Accounts)– an independent report that is completed by an AfN Accredited Auditor or AfN, that verifies the Account was prepared in accordance with the approved Methods, the *AfN Standard* and AfN Audit rules.

Upon certification of the account, the Environmental Account Summary and Information Statement will be published on the AfN Environmental Account Certification Registry.

1.5. Overview of Process

This method includes the following six steps:

Step 1.	Define purpose, scope and accounting region
Step 2.	Compile existing data
Step 3.	Stratify accounting region into assessment units
Step 4.	Assess composition within assessment units
Step 5.	Expert verification of composition condition
Step 6.	Assess configuration condition
Step 6.	Step 7. Calculate the Econd®

2. Creating the Environmental Account

Step 1. Define purpose, scope, and accounting region

The preliminary step to developing an Environmental Account is to **describe** the Environmental Account through defining its intended **purpose**, **type,** and **accounting region.**

Purpose:	Describe the specific purpose of the account.
Account Type:	Describe the type of the account. Include consideration of whether specific condition estimates will be generated for each pre-clearing vegetation class (recommended), or whether vegetation classes will be intersected with generic condition classes (simpler but less informative). This choice should be discussed as part of the expert elicitation process and answered based on the account purpose and the confidence among experts that condition variation across vegetation types is well-enough known to be confidently represented. *Change over time* – an ongoing assessment of the change of environmental condition through time. How frequently will the account be updated? Consider expected frequency of updates to land use and landcover data. For example, land use data may be updated every 3-5 years while landcover data may be released annually. Annual or biannual updates may be useful (eg in areas where land clearing rates are high), or an update every 5 years may be sufficient. More information on updating the account/repeating the assessment is provided in Section 3.
Accounting region:	Describe the accounting region (include location and size details, remember a region should be larger than ~250000 ha). Provide a map of the accounting region that shows location and size information. NB. The accounting region must stay the same for the lifespan of the account. If the accounting region changes (such as a new area added, or an area removed), then a new account must be developed, or the account, 're-set' and started again with the new accounting region. To model connectivity it may be necessary to work with data that extends slightly beyond the spatial boundary of the account. For example, the example condition account presented in Appendix 1 applied a 50km buffer to the region of interest to accommodate connectivity assessment across the region.

Output of Step A

- A description of the accounting region including **location** and **size**
- A table describing the **purpose** and **type** of account
- A **map** showing the accounting region

Step 2. Compile existing data

Data collation

The following data layers need to be compiled (if newer versions of the datasets are available, it is recommended you use those, and keep track of the specific version of each dataset that is used):

Dataset	Data type	Source
HCAS v2.1	GeoTIFF	9 arcsecond gridded HCAS 2.1 (2001-2018) base model estimation of habitat condition for terrestrial biodiversity, 18-year trend and 2010-2015 epoch change for continental Australia https://data.csiro.au/collection/csiro%3A44610v7
Catchment scale land use of Australia - Update December 2020	GeoTIFF or Shapefile	https://www.awe.gov.au/abares/aclump/catchment-scale-land-use-of-australia-update-december-2020
Geoscience Australia Landsat Land Cover Calendar Year Collection 2.0	GeoTIFF	Geoscience Australia Landsat Land Cover Calendar Year Collection 2.0 https://explorer.prod.dea.ga.gov.au/products/ga_ls_landcover_class_cyear_2

In addition to the above datasets, the most up-to date **pre-clear/pre-1750** and **remnant** vegetation mapping for the region must be acquired (e.g. Broad Vegetation Groups in QLD, or Major Vegetation Sub-Groups for NVIS Mapping for all of Australia). All layers that are vectors should be translated to 25 m rasters aligned with the landcover data (which uses the Australian Albers Equal Area datum (EPSG: 3577)) to complete the spatial analysis.

Output of Step 2

- All required data sources along with a table summarising each dataset (and version) that was used.

Step 3. Stratify the accounting region into assessment units

Stratify the accounting region

The region of interest (i.e. the accounting region) must be segmented into assessment units that differentiate broad condition classes. This is done using the Land-use and Land-cover data identified in step 2, however a simple intersection of these two types of data would result in far too many strata to be practical, so both maps require a level of grouping prior to them being combined to create a map with a discrete and manageable number of assessment units (keeping in mind the purpose of the account). The assessment unit classifications/groupings are to stay the same for the lifetime of the account (noting however that the extent of each assessment unit might change between updates).

Land-use

The Land-use Map is based on Version 8 of the Australian Land Use and Management Classification System (ALUM) (ABARES, 2016), which describes Australian Land Use and Management types with a tiered hierarchical system. There are 6 Primary Classes, 32 Secondary Classes, and 191 Tertiary Classes across Australia, however each region that the Method can be applied to might only have a subset of these. The classes are broadly structured by the potential degree of modification and the impact on the 'natural state' of the land.

These class tiers don't necessarily translate to the purpose of producing a regional Environmental Account, and therefore it is recommended that the Land-use be reclassified into groups most relevant to the goal of assessing regional vegetation condition.

This can be done by reclassifying land-uses into groups based on how land-use affects native vegetation condition within the region. When grouping the classes, it is important to consider the percent of area that each land-use contributes to the region and how much it is expected to affect native vegetation condition. This reclassification can be conducted using a staged approach where the tertiary ALUM classes are first categorised into broad similar groups (e.g. nature conservation, other natural areas, cropping etc, recommendation for about ~30 groups) and then those groups further categorised into final groups (recommend around ~10 groups) that directly relate to the purpose of the environmental account and focus on the most extensive land-uses within the specific region.

Land-cover

Currently in draft form, the new Geosciences Australia Land Cover Classification System (LCCS) has been developed for Australia at 25 m resolution with defined FAO land cover classes and will be updated on an annual basis. The LCCS takes a modular approach to land cover classification that allows the product to be enhanced over time as new granular data is added. (https://www.transparency.gov.au/annual-reports/geoscience-australia/reporting-year/2019-20-20).

The Land-cover classifications map is used to further divide the final land-use groups into the type of cover each pixel within a given land-use contains – a unique combination of artificial, cultivated, or natural, and woody, herbaceous, bare, or water. Combining the land-cover and final land-use groups, results in a matrix of assessment unit groupings. When determining the final groupings it is again important to consider the purpose of the environmental account and how the land-covers are anticipated to relate to vegetation condition. Mapped remnant vegetation should be considered as a separate landcover class.

It should be noted that this approach can be agnostic of sub-asset or vegetation type in generating condition estimates. That is, vegetation classes can be intersected with the condition estimates generated for the assessment unit based on land use and landcover to yield the account.

An alternative and preferred approach would be to intersect the land use and landcover segments with the pre-clearing vegetation classes to produce assessment units specific to vegetation types. This approach would be necessary to generate accounts to higher confidence levels and should be considered as part of the expert elicitation. Hybrid approaches, for example where remnant vegetation assessment units are further subdivided into assessment units based on vegetation types, but non-remnant assessment units are not subdivided based on vegetation types, should also be considered.

An important benefit of the stratification developed for this method is that it can be relatively easily checked for errors and correct where necessary when applying the resulting condition data at sub-regional scales. Conceptually, the stratification step is arguably unnecessary. A regional account could be generated simply by summarising the HCAS data for the underlying vegetation classes. However, the estimates of condition from the HCAS model unavoidably include an error component, like all model predictions. The simple land use and landcover classes used to develop the stratification in this method can readily be checked using imagery and/or field observations to make relatively straightforward assessments of apparent land use and landcover. Where the land use and landcover data applied in the stratification are found to be wrong, it is not complicated to identify the appropriate correct value. Whereas direct use of a condition model output, such as HCAS, makes it less straightforward to identify errors with confidence and would also require more detailed re-assessment to find appropriate corrections for apparent errors. The 25m grid resolution to which the assessment units can be mapped is also finer scale than the 250m resolution of the HCAS product. These 'useability' benefits, plus the opportunity to use changes to land use and landcover to establish time series accounts from condition products with inputs from long remote sensing epochs, are the main reasons for including this stratification step in this regional method.

Output of Step 3

- A map (raster 25 m resolution) and table summarising the assessment units identified within the accounting region

Example:

The Burnett Mary Region in Queensland contains 154 Tertiary ALUM Land-uses. According to the dominant land-uses within the region and what most impact or change vegetation condition, the ALUM land-uses could be grouped in the following way: into 26 Broad groups, which are then categorised into 9 final groups, summarised in the below table.

Final Group	Percent area
Grazing Native Vegetation	64.2
Native Forestry or managed resource protection	14.1
Nature Conservation	7.9
Crops (irrigated or not)	6.2
Residential and farm infrastructure	2.4
Plantation Forests	2.2
Other	1.4
River, marsh/wetland	1.2
Modified Pasture	0.5

The Burnet Mary Region was assigned nine final land-use groups. The land-cover mapping revealed 45 land cover classes, this resulted in 405 independent land-use/land-cover combinations. However, when grouped into assessment units resulted in 25 assessment units summarising the land-use and land cover within the region to provide relevant context and precision for the regional account.

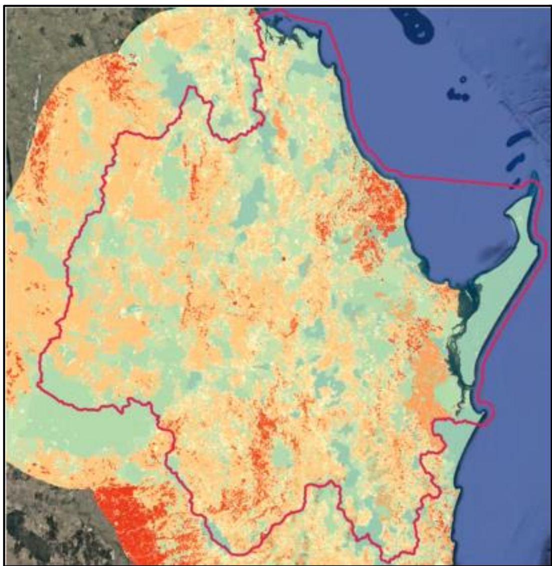
Assessment Unit	Landcover	Land-use	Percent Area
1	Mapped Remnant	Outside conservation and forestry	20.7
2	Woody Non-remnant	Grazing	11.8
3	Herbaceous Non-remnant	Grazing	33.2
4	Bare	Grazing	0.5
5	Woody Non-remnant	Forestry or Resource Protection	0.8
6	Herbaceous Non-remnant	Forestry or Resource Protection	0.4
7	Bare	Forestry or Resource Protection	0.0
8	Woody Non-remnant	Cropping	0.7
9	Herbaceous Non-remnant	Cropping	4.1
10	Bare	Cropping	1.5
11	Woody Non-remnant	Conservation	0.1
12	Herbaceous Non-remnant	Conservation	0.1
13	Woody Non-remnant	Residential	0.8
14	Herbaceous Non-remnant	Residential	1.2
15	Woody Non-remnant	Plantation	1.9
16	Herbaceous Non-remnant	Plantation	0.3
17	Woody Non-remnant	Modified Grazing	0.1
18	Herbaceous Non-remnant	Modified Grazing	0.4
19	Mapped Remnant	Conservation Land	7.6
20	Woody Non-remnant	River/marsh/wetland	0.1
21	Herbaceous Non-remnant	River/marsh/wetland	0.0
22	Mapped Remnant	Forestry and managed resource protection lands	13.0
23	Woody Non-remnant	Other	0.3
24	Herbaceous Non-remnant	Other	0.6
25	Water > 3 months	-	0.1

Step 4. Estimate Composition within Assessment Units

Native Vegetation Composition describes the structure, function, and species assemblage of vegetation (Butler 2020). These three key components of Composition are all included in the various condition assessment frameworks (HCAS or relevant state- based models, refer to Appendix C for more information), and therefore these condition assessment frameworks can be directly used as the Composition estimate following expert verification.

The average composition score for native vegetation within each land use/land cover assessment unit in this method is measured in the following way:

1. Calculate the mean composition condition score (using the relevant condition assessment framework, e.g. HCAS) for each assessment unit (generated in Step 3) using zonal statistics in a spatial analysis tool, such as RStudio, QGIS, or ArcGIS.
2. The mean composition condition score for each assessment unit is then verified or adjusted as necessary through an expert elicitation process.



Segment	short description	HCAS mean
1	Mapped native veg outside conservation and forestry	0.69
2	Woody non-rem, grazing	0.58
3	Herbaceous cover, grazing	0.44
4	Bare/sparse cover, grazing	0.28
5	Woody non-rem, forestry or resource protection	0.64
6	Herbaceous cover, forestry or resource protection	0.51
7	Bare/sparse, forestry or resource protection	0.26
8	Woody natural cover, cropping landuse	0.23
9	Herbaceous or cultivated woody, cropping landuse	0.20
10	Bare/sparse cover, cropping land use	0.11
11	Woody non-remnant, nature conservation lands	0.63
12	Herbaceous or bare cover, conservation lands	0.49
13	Woody non-rem, residential	0.54
14	Herbaceous or bare, residential	0.39
15	Woody non-rem, plantation landuse	0.68
16	Herbaceous non-remnant, plantation landuse	0.64
17	Woody, non-rem, modified grazing	0.22
18	Herbaceous or bare, modified grazing	0.25
19	Mapped remnant veg, conservation land	0.75
20	Woody non-remnant, river/marsh/wetland	0.41
21	Herbaceous or bare non-remnant, river/marsh/wetland	0.39
22	Mapped remnant veg, forestry and managed resource protection lands	0.78
23	Woody non-remnant, all other landuses	0.41
24	Herbaceous non-remnant, all other landuses	0.30
25	Water >3months	0.34

Figure 2. An example map and table output of vegetation composition condition that is presented to the Experts.

Output of Step 4

- A spatial layer (25 m resolution), map and summary table showing the composition condition scores for each assessment unit.

Step 5. Expert Verification of Composition Condition

The various condition assessment frameworks have recognised limitations, and therefore the condition scores for each assessment unit must be verified using expert elicitation. AFN recommends project proponents engage a specialist to help design and facilitate the expert elicitation process and assist with specific wording of questions relevant to the region being assessed. To maintain consistency between assessments, we recommend using the IDEA Protocol (Figure 1), described in detail by Hemming et al (2017).

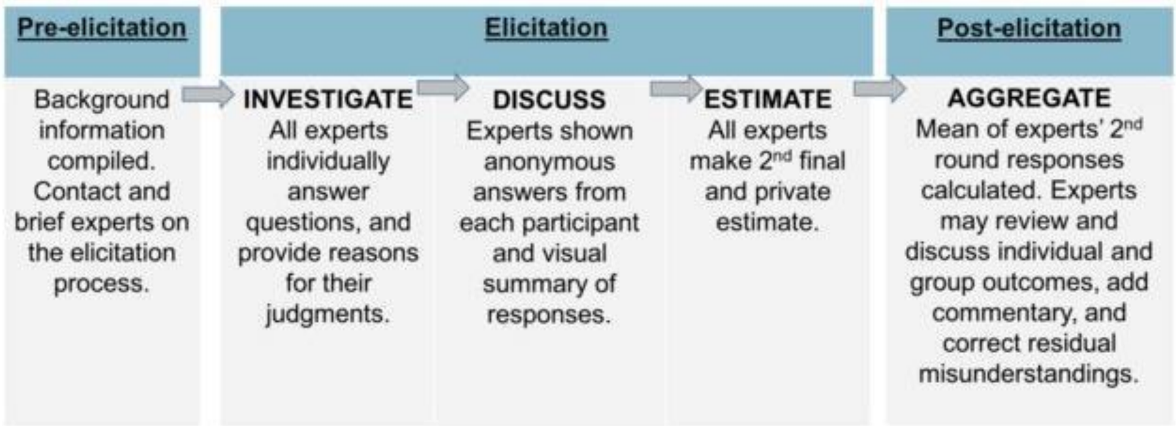


Figure 1. IDEA Protocol expert elicitation workflow, from Hemming et al 2017

The elicitation process may be run via in-person or remote workshops. A diverse group of experts who are familiar with the vegetation condition in the region and represent diverse knowledge of the region are invited to participate in the elicitation process. To help with selecting experts, it is recommended to establish relevant knowledge criteria (Hemming et al. 2017). Relevant experts might include, state government representatives, local NRM group representatives, local scientists, or consultants, for example. A preliminary invitation to experts introduces the project, explains the expert elicitation process, and provides an opportunity for experts to discuss the topic and clarify any information or aspects of the elicitation process with the project team.

1. Pre-elicitation information package

Prior to conducting the expert elicitation the following information should be compiled into an information package to aid the panel of experts in their decision-making process and provide essential background and context to the project:

- An overview of the elicitation procedure, following the guidelines of the IDEA Protocol
- This Method
- An explanation of the context and location of the regional assessment. Additional relevant and region-specific background information may also be provided to help guide experts with their decision-making process such as data on recent bushfires, rainfall, droughts, etc (or anything that may impact vegetation condition within the region).
- A clear explanation of what condition means. For example: Condition describes the structure, function, and species assemblage and connectivity of vegetation. Condition is commonly measured in the field with either all, or a sub-set of the following indicators: large trees, tree canopy height, recruitment of canopy species, tree canopy cover, shrub canopy cover, coarse woody debris, native plant species richness, non-native plant cover, native perennial grass cover, and litter cover. Configuration or connectivity is usually measured using remote sensing

analyses. Condition is scored on a scale of 0 to 100, where 0 means that the condition is completely degraded, and 100 means that the vegetation is in the best possible condition.

- A clear summary of the Composition Condition Model outputs and an explanation of how they were generated.
- The output of the model and a summary table (e.g. Figure 2).

2. Condition Score Estimation via Online Survey

Following the preliminary recruitment process, each expert is given two weeks (if possible) to individually verify the output of the model, i.e. the average composition condition score for each assessment unit, via an online survey. Experts are asked to draw on their relevant experience and knowledge as well as information provided in the information pack.

At a minimum, the following themes should be incorporated in the expert elicitation questions, however additional questions may be asked, and the questions may be reworded where appropriate. AfN strongly encourages Proponents consult with an expert elicitation specialist to help with designing the questions (the same question set are to be used every time the expert elicitation is repeated, so it is important to ensure they are appropriate and comprehensive). For each assessment unit:

- The experts should be asked if they think the average condition score output by the model accurately represents the current condition of the entire assessment unit.
- If they think it is not, the expert should provide a considered assessment of the current average composition condition score for the entire assessment unit and provide assessments of the upper and lower bounds that they think the true current average condition score of the entire assessment unit might sit within. Providing upper and lower bounds helps to document the degree of uncertainty and helps guide the following group discussion.

3. Group Discussion Workshop

Once everyone has completed their assessment for every assessment unit, the results are summarised. Results are then presented to the group and discussed at a second workshop. Where there is disagreement or high uncertainty for an assessment unit, these assessment units are reviewed and reasons for conflicting assessments are identified and discussed.

4. Condition Score re-estimation

Experts then have an opportunity to revise their assessment via the online survey, based on the group discussion, again within a timeframe of 2 weeks, if possible.

5. Data Aggregation

The results are summarised and used to assign new scores for each assessment unit and each vegetation sub-asset, wherever those results have been adjusted by the group.

6. Composition Condition Layer Adjustment (Optional)

The results from the final workshop may be used to assign new scores for each assessment unit in the composition spatial layer, where relevant. The final composition condition score will contribute 80% to the final Econd® scores.

Output of Step 5

- A spatial layer (25 m resolution), map and summary table showing the final composition condition scores for each assessment unit (Note: these may not have changed from step 4).

Step 6. Calculate Configuration Condition Scores

Configuration describes how vegetation is distributed across the landscape (Butler, 2020). Configuration in this method is measured using the 'neighbourhood habitat value' metric (Drielsma, Ferrier & Manion, 2007) and will be referred to as 'neighbourhood context.' Neighbourhood context will be calculated for every pixel (25 m x 25 m) within the accounting region.

Neighbourhood context describes how well ecological processes such as pollination and dispersal can function at a given location considering the condition of its neighbourhood (OEH, 2019). In this case, a neighbourhood is the area around a given location (pixel) defined by a specified radius.

This approach estimates neighbourhood context using a network of 'least cost paths' between the pixel and all surrounding pixels within a specified radius (it's neighbourhood). To construct the least cost Paths the 'permeability' of the surrounding pixels must be determined. The 'permeability' describes the expected ease or difficulty of a species (plant or animal) to disperse through (refer to Appendix F. for the model used) and is modelled using the composition condition layer. In general, pixels with high condition are more permeable compared to pixels with low condition.

The resulting neighbourhood context is modelled for each pixel over a range of defined radii to consider the range of ecological processes that occur within an environment (i.e. from local to landscape). The final neighbourhood context value describes 'connectivity' of the pixel. For example, of a pixel in surrounded by remnant vegetation will have a larger neighbourhood context score compared to a pixel surrounded by a cropping field, this is because the remnant vegetation is more permeable, and therefore has higher connectivity value.

To transform the neighbourhood context score into an index (0 to 100), each pixel score is to be divided by the maximum neighbourhood context score for the region.

The indexed neighbourhood context score for each pixel contributes 20% to the overall Econd® score. Areas outside the project area are assumed to not change in base condition apart from the context change effected by the project.

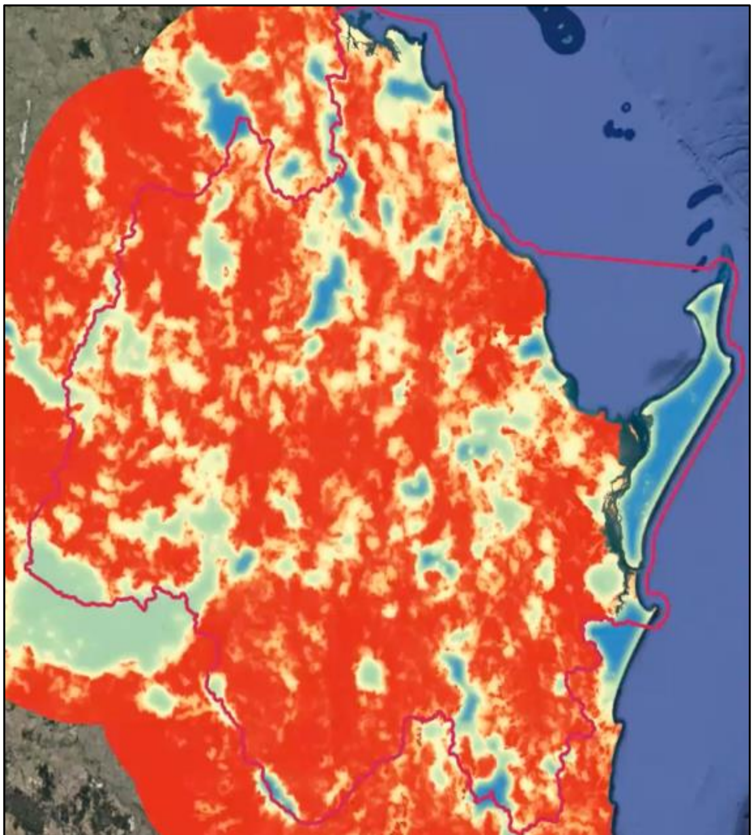


Figure 3. An example output of the neighbourhood context Score – where blue indicates high connectivty and red indicates low connectivity.

Output of Step 6

- A map (25 m resolution) displaying the neighbourhood context scores for each 25 m pixel within the region

Step 7. Calculate the Econd®

The Econd® is an index between 0 and 100, where 100 describes the 'undegraded' or 'best possible' reference condition of an environmental asset, and 0 indicates the asset is completely degraded. The Econd® can be summarised in different ways for the accounting region: assessment unit, sub-asset, and overall.

The **Econd®** is firstly calculated for **each pixel** within the accounting region in accordance with the below equation:

Econd® = (Composition x 0.8) + (Configuration x 0.2)

The **assessment unit Econd®** is then calculated as the average of all pixel Econd® scores within each assessment unit, using zonal statistics

The **sub-asset Econd®** score for the different vegetation types within the region is calculated as the average of all pixel Econd® scores within each pre-clearing vegetation types (for example NVIS Major Vegetation Sub-groups), using zonal statistics. (Note this approach is limited, in that sub-assets were not identified in the initial stratification step and therefore rely on the average condition of the assessment unit)

The **overall Econd®** is then calculated as the area weighted average of the assessment unit Econd® scores.

Output of Step 6

- A **data table** (e.g. a spreadsheet) containing all the raw data for each indicator for each sample, including the calculations for the ICS and Econd®.
- A **summary table** showing the Econd® scores.

3. Compile Environmental Account and submit for certification

Steps two to six should be repeated at regular intervals (a minimum of every five years or where Base Year recalculation is required, as specified under the *Accounting for Nature*® Framework) to establish a trend over time, noting however that assessment unit classifications remain the same for the life of the account – but their relative extent may change over time. Also, unless a new HCAS or state-based condition model has been released, the assessment units may be given the same HCAS score – but this should be reverified through the expert elicitation process. When repeating the elicitation, it is important to use the same approach, the same experts, same questions, the same information pack (with updated information) etc. to ensure the results are consistent and comparable.

An Environmental Account may incorporate multiple Environmental Assets, and always needs to include the following information:

- Information Statement and Environmental Account Summary,
- Environmental Account (including raw data tables), and;
- An Audit Report or Self Verification Report that verifies the Account was prepared in accordance with the approved Methods, the *AfN Standard* and *AfN Audit rules*.
    - An Audit Report is completed by an AfN Accredited Auditor and is required if you are seeking to have your account "Certified" (Tier 1); OR
    - A Self-verification Report contains the results of your self-verification assessment and AfN's Technical Assessment and is required if you are seeking to have your account "Self-verified" (Tier 2).

If you wish for your account to be 'certified,' it must be verified in accordance with the *Accounting for Nature®* Standard, which outlines the criteria that must be satisfied. The benefit of having an account certified is that AfN allows you to display the Certified Account logo and you are able to make public claims about your account. AfN Certified accounts require the Environmental Account Summary and Information Statement to be made publicly available.

4. References

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Appendix A – Worked Example of an account developed for the Burnett-Mary NRM Region

Step 1.

Purpose: To develop a regional account for the native vegetation condition of lands within pre-clearing vegetation classes in the Burnett-Mary NRM region to inform relative ecosystem priorities for biodiversity benefit scoring in evaluating investments into environmental planting projects.

Scope: A one-off account, generated without the benefit of structured expert elicitation, for major vegetation sub-groups form the National Vegetation Information System (NVIS MVS)

Region: The Burnett-Mary NRM region. Note that spatial data were generated for the region plus a 50km buffer to accommodate modelling of connectivity.

Step 2.
Data compiled for this example account were:

- Land use – "Queensland land use current 2019" downloaded from http://qldspatial.information.qld.gov.au/catalogue/custom/search.page?q=%22Land use mapping - 1999 to Current – Queensland%22 – accessed May 2021
- Landcover - DEA Land Cover v1.0.0 for 2015 – note that these data are a beta version of a product being designed for public release in 2022
- Vegetation – NVIS Version 6.0 - Australia - Estimated Pre1750 Vegetation (QLD) Major Vegetation Subgroups – downloaded from https://www.awe.gov.au/agriculture-land/land/native-vegetation/national-vegetation-information-system/data-products (note these data require combination of spatial data with details of classification from a flat table)
- Condition model – CSIRO HCAS v2.1 – note that these data were made available prior to their planned public release in 2022
- NRM region boundary - NRM regions of Australia 2020 downloaded from http://www.environment.gov.au/fed/catalog/search/resource/downloadData.page?uuid=%7BAB80DA43-CB00-455D-8A3C-70162EB8D964%7D

Step 3.

Land use classes were aggregated from 154 Tertiary landuses mapped in the region to 26 initial groups (identified using 'Out code' in table A1 below), and then into the 9 broad classes listed in the example box under step 2 and as columns in Table A2.

Table A 1First stage reclassification of land use data into amalgamated land use codes (right hand column)

QLUMP Code	ALUM Code	Primary	Secondary	Tertiary	Extent (ha)	Out code
2	1.1.1	Conservation and natural environments	Nature conservation	Strict nature reserves	535	1100
4	1.1.3	Conservation and natural environments	Nature conservation	National park	700736	1100

QLUMP Code	ALUM Code	Primary	Secondary	Tertiary	Extent (ha)	Out code
5	1.1.4	Conservation and natural environments	Nature conservation	Natural feature protection	21490	1100
6	1.1.5	Conservation and natural environments	Nature conservation	Habitat/species management area	134	1100
7	1.1.6	Conservation and natural environments	Nature conservation	Protected landscape	93	1100
8	1.1.7	Conservation and natural environments	Nature conservation	Other conserved area	26639	1100
9	1.2.0	Conservation and natural environments	Managed resource protection	Managed resource protection	51239	1200
11	1.2.2	Conservation and natural environments	Managed resource protection	Surface water supply	2129	1200
15	1.3.0	Conservation and natural environments	Other minimal use	Other minimal use	25354	1200
16	1.3.1	Conservation and natural environments	Other minimal use	Defence	18923	1200
17	1.3.2	Conservation and natural environments	Other minimal use	Stock route	14	1200
18	1.3.3	Conservation and natural environments	Other minimal use	Residual native cover	221214	1200
19	1.3.4	Conservation and natural environments	Other minimal use	Rehabilitation	746	1200
20	2.1.0	Production from relatively natural environments	Grazing native vegetation	Grazing native vegetation	6118344	2100
21	2.2.0	Production from relatively natural environments	Production native forests	Production native forests	1019085	2200
22	2.2.1	Production from relatively natural environments	Production native forests	Wood production forestry	10	2200
24	3.1.0	Production from dryland agriculture and plantations	Plantation forests	Plantation forests	61594	3100
25	3.1.1	Production from dryland agriculture and plantations	Plantation forests	Hardwood plantation forestry	21827	3100
26	3.1.2	Production from dryland agriculture and plantations	Plantation forests	Softwood plantation forestry	124955	3100
27	3.1.3	Production from dryland agriculture and plantations	Plantation forests	Other forest plantation	60	3100
28	3.1.4	Production from dryland agriculture and plantations	Plantation forests	Environmental forest plantation	25	3100
29	3.2.0	Production from dryland agriculture and plantations	Grazing modified pastures	Grazing modified pastures	6991	3200

QLUMP Code	ALUM Code	Primary	Secondary	Tertiary	Extent (ha)	Out code
31	3.2.2	Production from dryland agriculture and plantations	Grazing modified pastures	Woody fodder plants	29335	3200
36	3.3.0	Production from dryland agriculture and plantations	Cropping	Cropping	389966	3300
37	3.3.1	Production from dryland agriculture and plantations	Cropping	Cereals	1892	3300
38	3.3.2	Production from dryland agriculture and plantations	Cropping	Beverage & spice crops	11	3300
39	3.3.3	Production from dryland agriculture and plantations	Cropping	Hay and silage	485	3300
40	3.3.4	Production from dryland agriculture and plantations	Cropping	Oilseeds	800	3300
41	3.3.5	Production from dryland agriculture and plantations	Cropping	Sugar	3562	3300
42	3.3.6	Production from dryland agriculture and plantations	Cropping	Cotton	11730	3300
45	3.4.0	Production from dryland agriculture and plantations	Perennial horticulture	Perennial horticulture	3885	3300
46	3.4.1	Production from dryland agriculture and plantations	Perennial horticulture	Tree fruits	1987	3300
47	3.4.2	Production from dryland agriculture and plantations	Perennial horticulture	Olives	170	3300
48	3.4.3	Production from dryland agriculture and plantations	Perennial horticulture	Tree nuts	691	3300
49	3.4.4	Production from dryland agriculture and plantations	Perennial horticulture	Vine fruits	41	3300
50	3.4.5	Production from dryland agriculture and plantations	Perennial horticulture	Shrub berries and fruits	1864	3300
51	3.4.6	Production from dryland agriculture and plantations	Perennial horticulture	Perennial flowers and bulbs	3	3300
53	3.4.8	Production from dryland agriculture and plantations	Perennial horticulture	Citrus	26	3300
55	3.5.0	Production from dryland agriculture and plantations	Seasonal horticulture	Seasonal horticulture	9	3300
59	3.5.3	Production from dryland agriculture and plantations	Seasonal horticulture	Seasonal vegetables and herbs	3	3300
60	3.6.0	Production from dryland agriculture and plantations	Land in transition	Land in transition	6125	3600
62	3.6.2	Production from dryland agriculture and plantations	Land in transition	Abandoned land	2013	3600

QLUMP Code	ALUM Code	Primary	Secondary	Tertiary	Extent (ha)	Out code
63	3.6.3	Production from dryland agriculture and plantations	Land in transition	Land under rehabilitation	15	3600
65	3.6.5	Production from dryland agriculture and plantations	Land in transition	Abandoned perennial horticulture	81	3600
67	4.1.1	Production from irrigated agriculture and plantations	Irrigated plantation forests	Irrigated hardwood plantation forestry	511	4100
69	4.1.3	Production from irrigated agriculture and plantations	Irrigated plantation forests	Irrigated other forest plantation	82	4100
71	4.2.0	Production from irrigated agriculture and plantations	Grazing irrigated modified pastures	Grazing irrigated modified pastures	8599	4200
72	4.2.1	Production from irrigated agriculture and plantations	Grazing irrigated modified pastures	Irrigated woody fodder plants	449	4200
77	4.3.0	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated cropping	55108	4300
78	4.3.1	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated cereals	294	4300
79	4.3.2	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated beverage and spice crops	264	
80	4.3.3	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated hay and silage	426	4300
81	4.3.4	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated oilseeds	239	4300
82	4.3.5	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated sugar	67260	4300
83	4.3.6	Production from irrigated agriculture and plantations	Irrigated cropping	Irrigated cotton	13320	4300
87	4.4.0	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated perennial horticulture	3215	4300
88	4.4.1	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated tree fruits	6420	4300
89	4.4.2	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated olives	197	4300
90	4.4.3	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated tree nuts	11595	4300
91	4.4.4	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated vine fruits	484	4300
92	4.4.5	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated shrub berries and fruits	1942	4300
93	4.4.6	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated perennial flowers and bulbs	10	4300

QLUMP Code	ALUM Code	Primary	Secondary	Tertiary	Extent (ha)	Out code
94	4.4.7	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated perennial vegetables and herbs	41	4300
95	4.4.8	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated citrus	4359	4300
96	4.4.9	Production from irrigated agriculture and plantations	Irrigated perennial horticulture	Irrigated grapes	526	4300
97	4.5.0	Production from irrigated agriculture and plantations	Irrigated seasonal horticulture	Irrigated seasonal horticulture	7148	4300
98	4.5.1	Production from irrigated agriculture and plantations	Irrigated seasonal horticulture	Irrigated seasonal fruits	218	4300
100	4.5.2	Production from irrigated agriculture and plantations	Irrigated seasonal horticulture	Irrigated seasonal flowers and bulbs	38	4300
101	4.5.3	Production from irrigated agriculture and plantations	Irrigated seasonal horticulture	Irrigated seasonal vegetables and herbs	2500	4300
102	4.5.4	Production from irrigated agriculture and plantations	Irrigated seasonal horticulture	Irrigated turf farming	775	4300
103	4.6.0	Production from irrigated agriculture and plantations	Irrigated land in transition	Irrigated land in transition	691	4300
104	4.6.1	Production from irrigated agriculture and plantations	Irrigated land in transition	Degraded irrigated land	105	4300
105	4.6.2	Production from irrigated agriculture and plantations	Irrigated land in transition	Abandoned irrigated land	188	4300
107	4.6.4	Production from irrigated agriculture and plantations	Irrigated land in transition	No defined use - irrigation	28	4300
108	4.6.5	Production from irrigated agriculture and plantations	Irrigated land in transition	Abandoned irrigated perennial horticulture	133	4300
109	5.1.0	Intensive uses	Intensive horticulture	Intensive horticulture	485	5100
110	5.1.2	Intensive uses	Intensive horticulture	Shadehouses	165	5100
111	5.1.3	Intensive uses	Intensive horticulture	Glasshouses	91	5100
112	5.1.4	Intensive uses	Intensive horticulture	Glasshouses (hydroponic)	4	5100
113	5.1.5	Intensive uses	Intensive horticulture	Abandoned intensive horticulture	4	5100
114	5.2.0	Intensive uses	Intensive animal production	Intensive animal production	106	5200
115	5.2.1	Intensive uses	Intensive animal production	Dairy sheds and yards	648	5200
116	5.2.2	Intensive uses	Intensive animal production	Feedlots	926	5200
117	5.1.1	Intensive uses	Intensive horticulture	Production nurseries	96	5100
118	5.2.3	Intensive uses	Intensive animal production	Poultry farms	370	5200
119	5.2.4	Intensive uses	Intensive animal production	Piggeries	496	5200
120	5.2.5	Intensive uses	Intensive animal production	Aquaculture	946	5200

QLUMP Code	ALUM Code	Primary	Secondary	Tertiary	Extent (ha)	Out code
121	5.2.6	Intensive uses	Intensive animal production	Horse studs	1588	5200
122	5.2.7	Intensive uses	Intensive animal production	Saleyards/stockyards	141	5200
123	5.2.8	Intensive uses	Intensive animal production	Abandoned intensive animal husbandry	53	5200
124	5.3.0	Intensive uses	Manufacturing and industrial	Manufacturing and industrial	5014	5300
125	5.3.1	Intensive uses	Manufacturing and industrial	General purpose factory	4	5300
126	5.3.2	Intensive uses	Manufacturing and industrial	Food processing factory	314	5300
127	5.3.3	Intensive uses	Manufacturing and industrial	Major industrial complex	1638	5300
128	5.3.4	Intensive uses	Manufacturing and industrial	Bulk grain storage	46	5300
129	5.3.5	Intensive uses	Manufacturing and industrial	Abattoirs	123	5300
130	5.3.6	Intensive uses	Manufacturing and industrial	Oil refinery	41	5300
131	5.3.7	Intensive uses	Manufacturing and industrial	Sawmill	405	5300
132	5.3.8	Intensive uses	Manufacturing and industrial	Abandoned manufacturing and industrial	68	5300
133	5.4.0	Intensive uses	Residential and farm infrastructure	Residential and farm infrastructure	308	5400
134	5.4.1	Intensive uses	Residential and farm infrastructure	Urban residential	35025	5400
135	5.4.2	Intensive uses	Residential and farm infrastructure	Rural residential with agriculture	11871	5400
136	5.4.3	Intensive uses	Residential and farm infrastructure	Rural residential without agriculture	170697	5400
137	5.4.4	Intensive uses	Residential and farm infrastructure	Remote communities	69	5400
138	5.4.5	Intensive uses	Residential and farm infrastructure	Farm buildings/infrastructure	8817	5400
139	5.5.0	Intensive uses	Services	Services	83	5500
140	5.5.1	Intensive uses	Services	Commercial services	2923	5500
141	5.5.2	Intensive uses	Services	Public services	3960	5500
142	5.5.3	Intensive uses	Services	Recreation and culture	18563	5500
143	5.5.4	Intensive uses	Services	Defence facilities - urban	29	5500
144	5.5.5	Intensive uses	Services	Research facilities	458	5500
146	5.6.1	Intensive uses	Utilities	Fuel powered electricity generation	412	5500
149	5.6.5	Intensive uses	Utilities	Electricity substations and transmission	467	5500
150	5.6.6	Intensive uses	Utilities	Gas treatment, storage and transmission	715	5500
151	5.6.7	Intensive uses	Utilities	Water extraction and transmission	237	5500
152	5.7.0	Intensive uses	Transport and communication	Transport and communication	2598	5700
153	5.7.1	Intensive uses	Transport and communication	Airports/aerodromes	2266	5700
154	5.7.2	Intensive uses	Transport and communication	Roads	14854	5700
155	5.7.3	Intensive uses	Transport and communication	Railways	538	5700

QLUMP Code	ALUM Code	Primary	Secondary	Tertiary	Extent (ha)	Out code
156	5.7.4	Intensive uses	Transport and communication	Ports and water transport	131	5700
157	5.7.5	Intensive uses	Transport and communication	Navigation and communication	63	5700
158	5.8.0	Intensive uses	Mining	Mining	2734	5800
159	5.8.1	Intensive uses	Mining	Mines	4996	5800
160	5.8.2	Intensive uses	Mining	Quarries	3101	5800
161	5.8.3	Intensive uses	Mining	Tailings	797	5800
162	5.8.4	Intensive uses	Mining	Extractive industry not in use	528	5800
163	5.9.0	Intensive uses	Waste treatment and disposal	Waste treatment and disposal	380	5900
164	5.9.1	Intensive uses	Waste treatment and disposal	Effluent pond	92	5900
165	5.9.2	Intensive uses	Waste treatment and disposal	Landfill	158	5900
166	5.9.3	Intensive uses	Waste treatment and disposal	Solid garbage	545	5900
168	5.9.5	Intensive uses	Waste treatment and disposal	Sewage	264	5900
169	6.1.0	Water	Lake	Lake	1022	6100
170	6.1.1	Water	Lake	Lake - conservation	3503	6100
174	6.2.0	Water	Reservoir/dam	Reservoir/dam	3808	6200
175	6.2.1	Water	Reservoir/dam	Reservoir	35586	6200
176	6.2.2	Water	Reservoir/dam	Water storage - intensive use/farm dams	14965	6200
177	6.2.3	Water	Reservoir/dam	Evaporation basin	898	6200
178	6.3.0	Water	River	River	33536	6300
179	6.3.1	Water	River	River - conservation	442	6300
181	6.3.3	Water	River	River - intensive use	566	6300
182	6.4.0	Water	Channel/aqueduct	Channel/aqueduct	324	6400
183	6.4.1	Water	Channel/aqueduct	Supply channel/aqueduct	299	6400
184	6.4.2	Water	Channel/aqueduct	Drainage channel/aqueduct	22	6400
185	6.4.3	Water	Channel/aqueduct	Stormwater	20	6400
186	6.5.0	Water	Marsh/wetland	Marsh/wetland	13530	6500
187	6.5.1	Water	Marsh/wetland	Marsh/wetland - conservation	3174	6500
188	6.5.2	Water	Marsh/wetland	Marsh/wetland - production	5524	6500
189	6.5.3	Water	Marsh/wetland	Marsh/wetland - intensive use	78	6500
190	6.5.4	Water	Marsh/wetland	Marsh/wetland - saline	45978	6500
191	6.6.0	Water	Estuary/coastal waters	Estuary/coastal waters	7066	6600
192	6.6.1	Water	Estuary/coastal waters	Estuary/coastal waters - conservation	106	6600
194	6.6.3	Water	Estuary/coastal waters	Estuary/coastal waters - intensive use	153	6600
196	5.6.4	Intensive uses	Utilities	Solar electricity generation	2	5500

The 'final groups' from the land use reclassification were intersected with landcover values to create 25 assessment unit 'segments' as detailed in Table A2 and mapped in Figures A1 and A2.

Table A 2 Combinations of amalgamated land use classes (columns) with land cover codes (rows) to produce assessment units (land use and landcover segments)

Land cover code	Land Cover Description	Grazing native vegetation	Native forestry or managed resource protection	Crops or horticulture	Nature conservation	Residential and farm infrastructure	Plantation forests	Grazing modified pastures	River, marsh or wetland	All other landuses
	Mapped remnant native vegetation	1	22	1	19	1	1	1	1	1
4	Cultivated Terrestrial Vegetated: Woody Closed (> 65 %)	2	5	9	11	13	15	18	20	23
5	Cultivated Terrestrial Vegetated: Woody Open (40 to 65 %)	2	5	9	11	13	15	18	20	23
6	Cultivated Terrestrial Vegetated: Woody Open (15 to 40 %)	2	5	9	11	13	15	18	20	23
7	Cultivated Terrestrial Vegetated: Woody Sparse (4 to 15 %)	2	5	9	11	13	15	18	20	23
8	Cultivated Terrestrial Vegetated: Woody Scattered (1 to 4 %)	3	6	9	12	14	16	18	21	24
9	Cultivated Terrestrial Vegetated: Herbaceous Closed (> 65 %)	3	6	9	12	14	16	18	21	24
10	Cultivated Terrestrial Vegetated: Herbaceous Open (40 to 65 %)	3	6	9	12	14	16	18	21	24
11	Cultivated Terrestrial Vegetated: Herbaceous Open (15 to 40 %)	3	6	9	12	14	16	18	21	24
12	Cultivated Terrestrial Vegetated: Herbaceous Sparse (4 to 15 %)	4	7	10	12	14	16	18	21	24
13	Cultivated Terrestrial Vegetated: Herbaceous Scattered (1 to 4 %)	4	7	10	12	14	16	18	21	24
17	Natural Terrestrial Vegetated: Woody Closed (> 65 %)	2	5	8	11	13	15	17	20	23
18	Natural Terrestrial Vegetated: Woody Open (40 to 65 %)	2	5	8	11	13	15	17	20	23
19	Natural Terrestrial Vegetated: Woody Open (15 to 40 %)	2	5	8	11	13	15	17	20	23
20	Natural Terrestrial Vegetated: Woody Sparse (4 to 15 %)	2	5	8	11	13	15	17	20	23
21	Natural Terrestrial Vegetated: Woody Scattered (1 to 4 %)	3	6	9	11	13	15	17	20	23
22	Natural Terrestrial Vegetated: Herbaceous Closed (> 65 %)	3	6	9	12	14	16	18	20	24
23	Natural Terrestrial Vegetated: Herbaceous Open (40 to 65 %)	3	6	9	12	14	16	18	20	24
24	Natural Terrestrial Vegetated: Herbaceous Open (15 to 40 %)	3	6	9	12	14	16	18	20	24
25	Natural Terrestrial Vegetated: Herbaceous Sparse (4 to 15 %)	4	7	10	12	14	16	18	21	24
26	Natural Terrestrial Vegetated: Herbaceous Scattered (1 to 4 %)	4	7	10	12	14	16	18	21	24
41	Natural Aquatic Vegetated: Woody	2	5	8	11	13	15	17	20	23
42	Natural Aquatic Vegetated: Herbaceous	3	6	9	12	14	16	18	20	24
45	Natural Aquatic Vegetated: Woody Closed (> 65 %) Water < 3 months (temporary or seasonal)	2	5	8	11	13	15	17	20	23
48	Natural Aquatic Vegetated: Woody Open (40 to 65 %) Water < 3 months (temporary or seasonal)	2	5	8	11	13	15	17	20	23
51	Natural Aquatic Vegetated: Woody Open (15 to 40 %) Water < 3 months (temporary or seasonal)	2	5	8	11	13	15	17	20	23
54	Natural Aquatic Vegetated: Woody Sparse (4 to 15 %) Water < 3 months (temporary or seasonal)	2	5	8	11	13	15	17	20	23
57	Natural Aquatic Vegetated: Woody Scattered (1 to 4 %) Water < 3 months (temporary or seasonal)	3	6	9	11	13	15	17	20	23
60	Natural Aquatic Vegetated: Herbaceous Closed (> 65 %) Water < 3 months (temporary or seasonal)	3	6	9	11	13	15	17	20	23
63	Natural Aquatic Vegetated: Herbaceous Open (40 to 65 %) Water < 3 months (temporary or seasonal)	3	6	9	12	14	16	18	20	24

Land cover code	Land Cover Description	Grazing native vegetation	Native forestry or managed resource protection	Crops or horticulture	Nature conservation	Residential and farm infrastructure	Plantation forests	Grazing modified pastures	River, marsh or wetland	All other landuses
66	Natural Aquatic Vegetated: Herbaceous Open (15 to 40 %) Water < 3 months (temporary or seasonal)	3	6	9	12	14	16	18	20	24
69	Natural Aquatic Vegetated: Herbaceous Sparse (4 to 15 %) Water < 3 months (temporary or seasonal)	3	6	9	12	14	16	18	20	24
72	Natural Aquatic Vegetated: Herbaceous Scattered (1 to 4 %) Water < 3 months (temporary or seasonal)	4	7	10	12	14	16	18	20	24
73	Artificial Surface	4	7	10	12	14	16	18	21	24
74	Natural Surface	4	7	10	12	14	16	18	21	24
75	Natural Surface: Sparsely vegetated	4	7	10	12	14	16	18	21	24
76	Natural Surface: Very sparsely vegetated	4	7	10	12	14	16	18	21	24
77	"Natural Surface: Bare areas	4	7	10	12	14	16	18	21	24
78	Water	25	25	25	25	25	25	25	20	25
79	Water: (Water)	25	25	25	25	25	25	25	20	25
80	Water: (Water) Perennial (> 9 months)	25	25	25	25	25	25	25	20	25
81	Water: (Water) Tidal area	25	25	25	25	25	25	25	20	25
82	Water: (Water) Non-perennial (7 to 9 months)	25	25	25	25	25	25	25	20	25
83	Water: (Water) Non-perennial (4 to 6 months)	25	25	25	25	25	25	25	20	25
84	Water: (Water) Non-perennial (1 to 3 months)	2	6	9	11	13	15	18	20	24

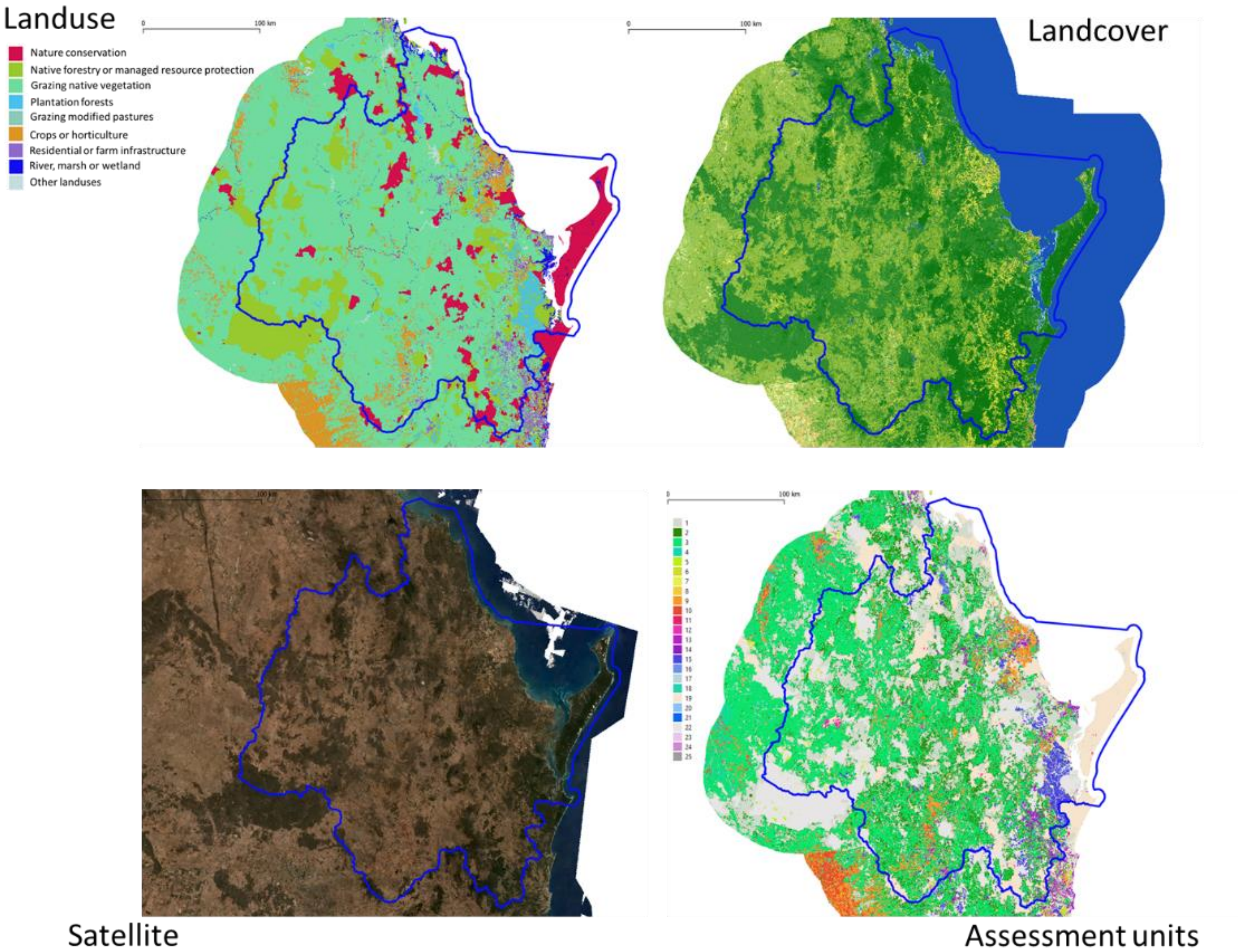


Figure A 1 Regional overview of land use and land cover inputs to stratification and the output assessment units

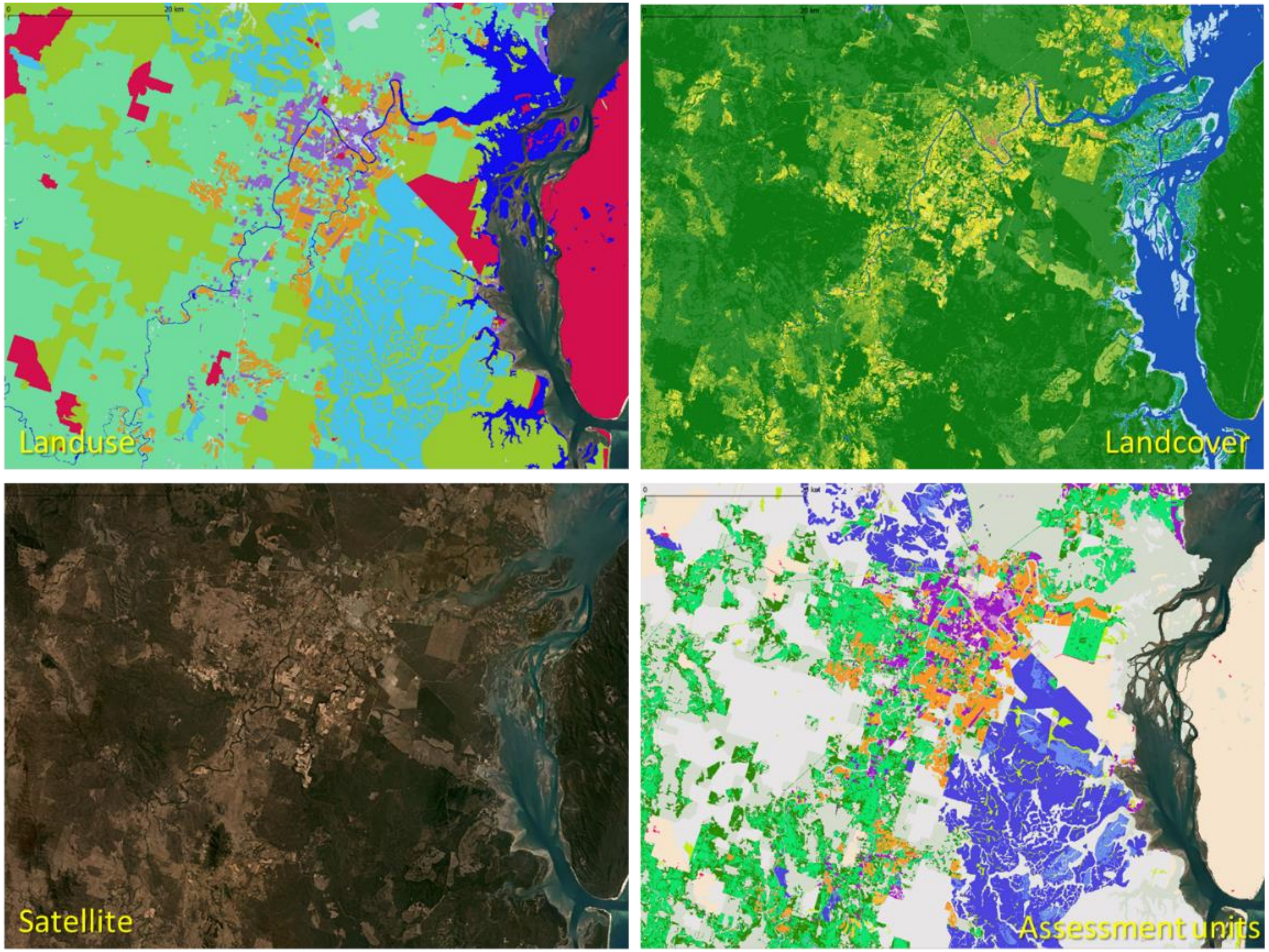


Figure A 2 Local scale view stratification components and resultant assessment units

Step 4. Estimate average condition of assessment units

For the purpose of this example account, the average composition condition scores for assessment units involved a first pass estimate from the HCAS 2.1 data, followed by application of expert opinion to modify the HCAS average and arrive at a final average score. Table A3 details the results, which are mapped in Figure A4. The main differences between the HCAS scores and assigned scores was for assessment units representing highly modified systems, for which the HCAS average consistently appeared to over-estimate the plausible composition condition score (based on the expert opinion). Application of the structured expert elicitation approach described for this method will strengthen this step and to help understand where and why condition differs to the HCAS average.

Table A 3 Summary of composition condition value assignment to assessment units

Assessment unit code	Landcover	Land-use	% of region area	Average HCAS value	Assigned average condition
1	Mapped Remnant	Outside conservation and forestry	20.7	0.69	0.7
2	Woody Non-remnant	Grazing	11.8	0.58	0.5
3	Herbaceous Non-remnant	Grazing	33.2	0.44	0.3
4	Bare	Grazing	0.5	0.28	0.2
5	Woody Non-remnant	Forestry or Resource Protection	0.8	0.64	0.6
6	Herbaceous Non-remnant	Forestry or Resource Protection	0.4	0.51	0.5
7	Bare	Forestry or Resource Protection	0.0	0.26	0.2
8	Woody Non-remnant	Cropping	0.7	0.23	0.2
9	Herbaceous Non-remnant	Cropping	4.1	0.20	0.05
10	Bare	Cropping	1.5	0.11	0.01
11	Woody Non-remnant	Conservation	0.1	0.63	0.6
12	Herbaceous Non-remnant	Conservation	0.1	0.49	0.5
13	Woody Non-remnant	Residential	0.8	0.54	0.4
14	Herbaceous Non-remnant	Residential	1.2	0.39	0.2
15	Woody Non-remnant	Plantation	1.9	0.68	0.2
16	Herbaceous Non-remnant	Plantation	0.3	0.64	0.2
17	Woody Non-remnant	Modified Grazing	0.1	0.22	0.25
18	Herbaceous Non-remnant	Modified Grazing	0.4	0.25	0.1
19	Mapped Remnant	Conservation Land	7.6	0.75	0.8
20	Woody Non-remnant	River/marsh/wetland	0.1	0.41	0.4
21	Herbaceous Non-remnant	River/marsh/wetland	0.0	0.39	0.4
22	Mapped Remnant	Forestry and managed resource protection lands	13.0	0.78	0.75
23	Woody Non-remnant	Other	0.3	0.41	0.3
24	Herbaceous Non-remnant	Other	0.6	0.30	0.01
25	Water > 3 months	-	0.1	0.34	0.4

The result of applying the assigned composition condition scores to the assessment units is presented in figure A3.

Step 5 Calculate configuration scores

Configuration scores were calculated by applying the neighbourhood habitat area tool developed by Jamie Love and Michael Drielsma for NSW (Drielsma et al 2007). The tool requires 'permeability' scores for each pixel in the analysis area, which were calculated as a function of assigned condition value for this example account. The value of 1/alpha in Figure A3 is the distance over which half of the value of a connection to habitat is lost. Links composed of higher condition habitat are more permeable than through land in low condition. Figures A4 and A5 show the configuration output alongside HCAS and assigned condition scores.

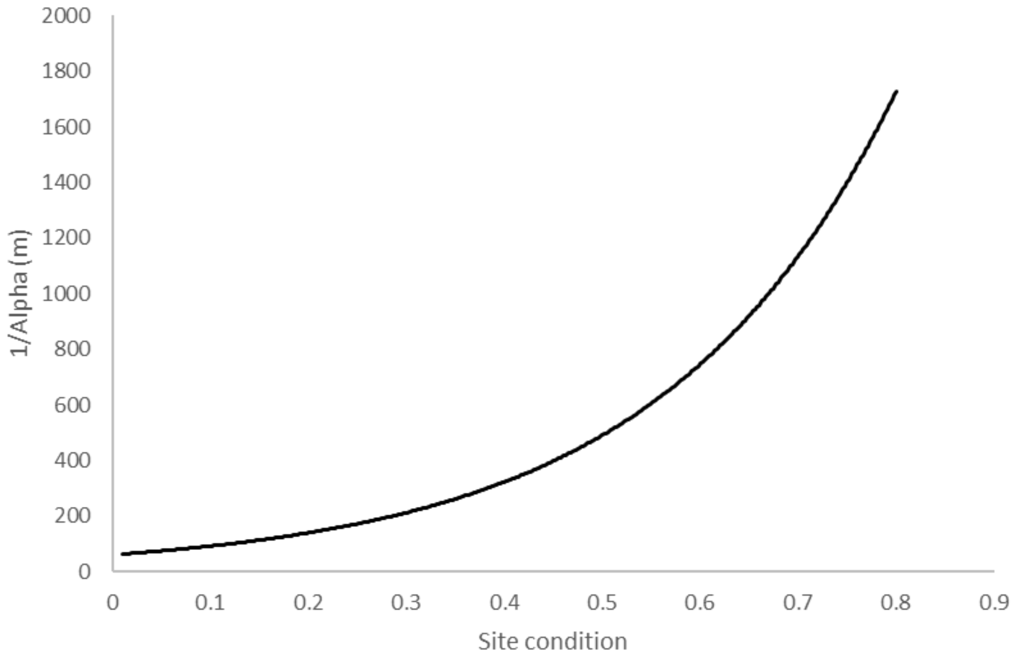


Figure A 3 Relationship between permeability parameter used to model connectivity (1/alpha) and habitat condition

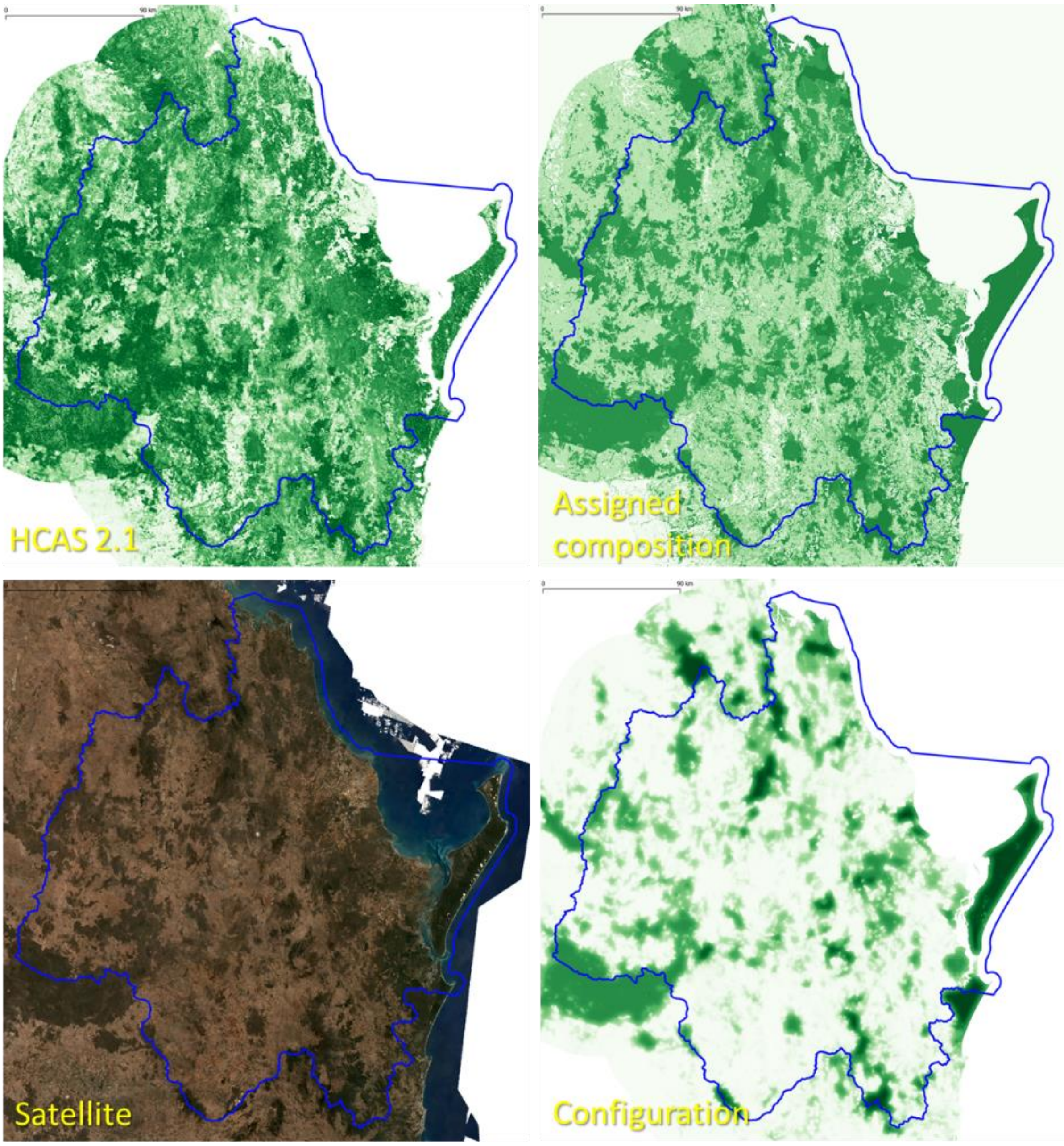


Figure A 4 Components of condition for the BMRG region.

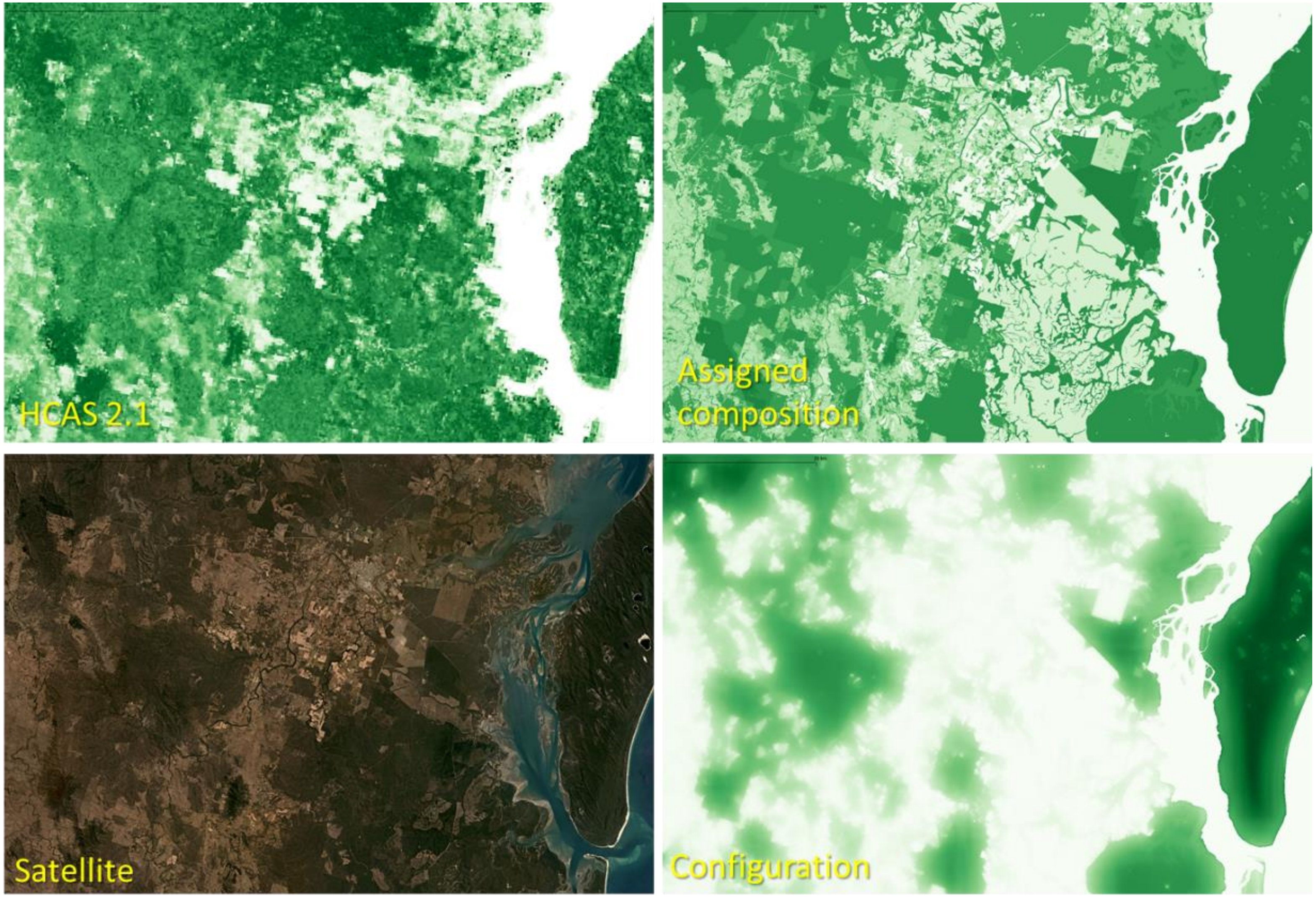


Figure A 5 Components of condition score for a landscape within the BMRG region

Step 6 Calculate Econd

For this example account, separate Econd scores were calculated for major vegetation subgroups within bioregions, as well as for the whole region. The regional Econd® of 45.7 is an area weighted average of the Econd® scores for the component MVS/IBRA vegetation classes.

Table A 4 Econd scores calculated for Major Vegetation Subgroups (NVIS) within the two bioregions that make up the Burnett-Mary NRM region. Excludes aquatic systems

IBRA_MVS	MVS Short description	Extent (ha)	Econd
SEQ_2	Tropical or sub-tropical rainforest	184812	51.3
SEQ_3	Eucalyptus (+/- tall) open forest with a dense broad-leaved and/or tree-fern understorey (wet sclerophyll)	20927	48.3
SEQ_4	Eucalyptus open forests with a shrubby understorey	28211	33.9
SEQ_5	Eucalyptus open forests with a grassy understorey	558686	49.8
SEQ_6	Warm Temperate Rainforest	391	26.6
SEQ_8	Eucalyptus woodlands with a shrubby understorey	250628	38.8
SEQ_9	Eucalyptus woodlands with a tussock grass understorey	1848476	44.6
SEQ_13	Brigalow (Acacia harpophylla) forests and woodlands	16224	27.1
SEQ_14	Other Acacia forests and woodlands	154	56.5
SEQ_15	Melaleuca open forests and woodlands	79786	51.6
SEQ_16	Other forests and woodlands	21974	57.3
SEQ_19	Eucalyptus low open woodlands with tussock grass	18604	43.3
SEQ_26	Casuarina and Allocasuarina forests and woodlands	18891	75.0
SEQ_30	Heathlands	15760	58.7
SEQ_32	Other shrublands	1791	71.9
SEQ_37	Other tussock grasslands	14124	63.7
SEQ_40	Mangroves	25423	65.3
SEQ_47	Eucalyptus open woodlands with shrubby understorey	10472	55.2
SEQ_50	Banksia woodlands	66419	77.1
SEQ_53	Eucalyptus low open woodlands with a shrubby understorey	25318	52.1
SEQ_54	Eucalyptus tall open forest with a fine-leaved shrubby understorey	7633	72.1
SEQ_59	Eucalyptus woodlands with ferns, herbs, sedges, rushes or wet tussock grassland	10	43.3
SEQ_60	Eucalyptus tall open forests and open forests with ferns, herbs, sedges, rushes or wet tussock grasses	112823	56.3
SEQ_62	Dry rainforest or vine thickets	146258	32.4
SEQ_63	Sedgelands, rushs or reeds	26532	60.0
SEQ_80	Other shrublands	28	67.8
BBS_2	Tropical or sub-tropical rainforest	31	65.0
BBS_4	Eucalyptus open forests with a shrubby understorey	20952	46.2
BBS_5	Eucalyptus open forests with a grassy understorey	123419	43.6
BBS_8	Eucalyptus woodlands with a shrubby understorey	618038	53.8

IBRA_MVS	MVS Short description	Extent (ha)	Econd
BBS_9	Eucalyptus woodlands with a tussock grass understorey	960524	40.4
BBS_12	Callitris forests and woodlands	17581	49.2
BBS_13	Brigalow (Acacia harpophylla) forests and woodlands	124308	27.3
BBS_14	Other Acacia forests and woodlands	3782	54.4
BBS_19	Eucalyptus low open woodlands with tussock grass	12133	33.0
BBS_32	Other shrublands	13809	60.5
BBS_35	Blue grass (Dichanthium) and tall bunch grass (Chrysopogon) tussock grasslands	221	21.7
BBS_47	Eucalyptus open woodlands with shrubby understorey	5291	65.5
BBS_59	Eucalyptus woodlands with ferns, herbs, sedges, rushes or wet tussock grassland	66852	33.2
BBS_60	Eucalyptus tall open forests and open forests with ferns, herbs, sedges, rushes or wet tussock grasses	2531	29.0
BBS_62	Dry rainforest or vine thickets	83816	30.5

Appendix B. Glossary

AfN Accredited Expert: are deemed to have the requisite skills to work with project Proponents to create Environmental Accounts and advise on key aspects of the AfN Standard. They are listed on the AfN Accredited Expert Register but are not qualified to conduct audits

Assessment Unit: refers to the unique combination of land-use, land-cover and optionally vegetation type. These are the smallest unit for which an Econd® is calculated.

Composition: describes the structure, function and the assemblage of species within an area of vegetation.

Configuration: refers to the positioning of a specific area of vegetation within the landscape with regard to its connectivity, context and patch size.

Econd®: is a composite index of environmental condition between 0 and 100 that describes the condition of the asset relative to its undegraded state (its reference benchmark). Econd® scores are constructed by averaging Indicator Condition Scores as per the formula described in AfN Approved Methods

GIS: refers to Geographic Information System, which is a mapping system.

HCAS: refers to the Habitat Condition Assessment System developed by the CSIRO – refer to Appendix C for more information.

Indicator Condition Score (ICS): are a measured score out of 100 that are calculated for each indicator for an Environmental Asset. Details of how to estimate or measure indicators and reference condition benchmarks and calculate Indicator Condition Scores are contained in AfN Approved Methods.

Information Statement: is a statement prepared by the Proponent that documents, in non-technical terms, the rationale for the selection of assets, choice of indicators, the origins of the data, the analysis and treatment of data and construction of the Econd® and account accreditation status. The Information Statement must contain a metadata statement and data quality statement.

Regional-scale: refers to a larger Environmental Accounting area, typically owned and managed by multiple different entities for a range of purposes, or in which multiple entities have rights of access and use, that has definable characteristics (if not fixed boundaries).

Appendix C. Summary of Current Vegetation Condition Models

This section will be updated as new Condition Models become available.

HCAS – Australia Wide

250 m resolution

HCAS version 2.1 is not yet publicly available (Williams, 2020). The HCAS model was developed for all of Australia using remote sensing which can provide large scale observations of the land over time, where no ground-based information is available, or feasible to collect. The HCAS approach to assessing habitat condition relies on proxy indicators that can be reliably detected via remote sensing, therefore rather than being a complete assessment, it is an indicative assessment of condition. To estimate condition, the model utilises reference benchmarking (which complies with AfN's definition of reference, i.e. undegraded), to assess ecological equivalency between a site and an equivalent 'undegraded' site. A key limitation of HCAS is that it appears to overestimate the condition of heavily degraded areas and this is why the HCAS condition scores are averaged for each assessment unit and then verified by an expert panel.

The remote sensing workflow is summarised below in Figure C1. The indicators include remotely sensed biotic data. For more information on HCAS please consult the further reading list below.

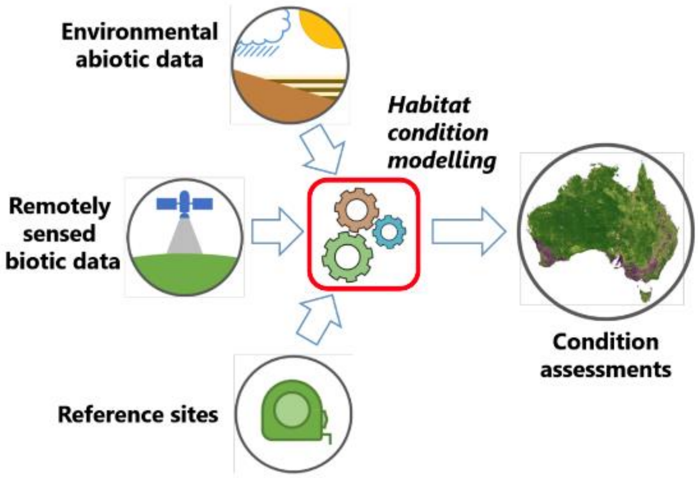


Figure C1. An overview of the HCAS Model (Lehman 2021).

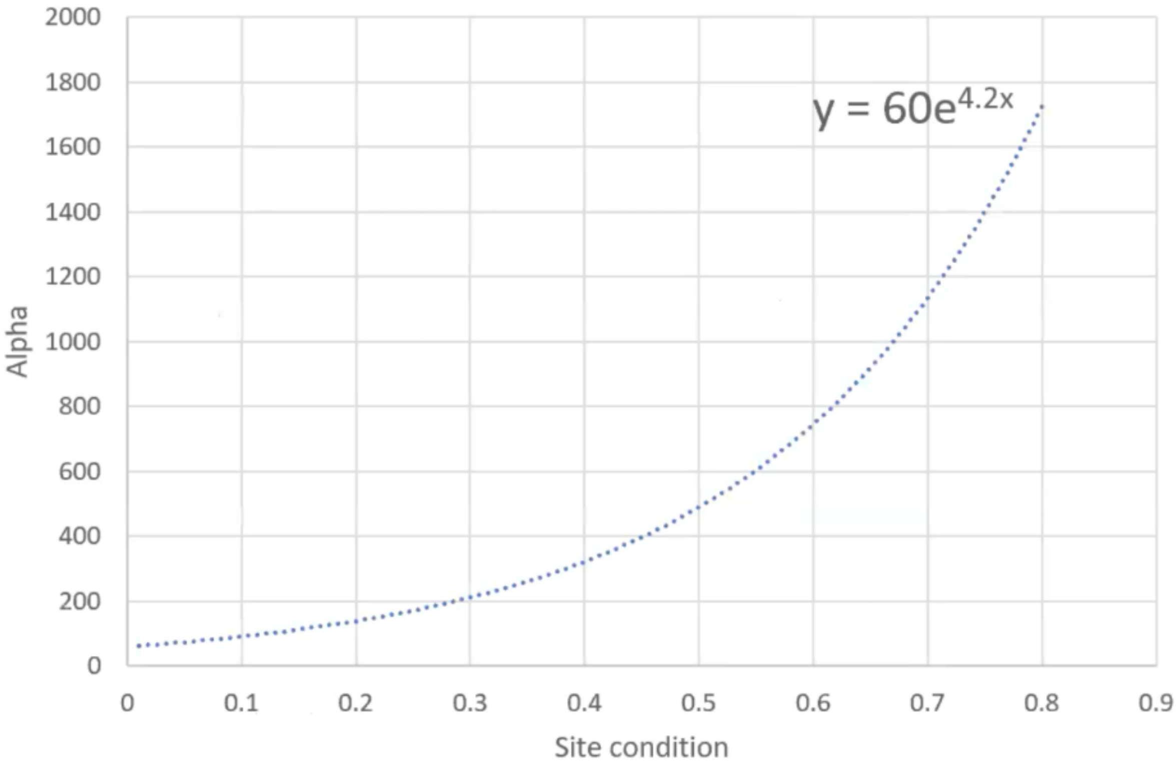
Further reading

Williams KJ*, Donohue RJ*, Harwood TD*, Lehmann EA*, Lyon P, Dickson F, Ware C, Richards AE, Gallant J, Storey RJL, Pinner L, Ozolins M, Austin J, White M, McVicar TR, Ferrier S (2020) Habitat Condition Assessment System: developing HCAS version 2.0 (beta). A revised method for mapping habitat condition across Australia. Publication number EP21001. CSIRO, Canberra, Australia.

Harwood, Tom; Donohue, Randall; Williams, Kristen; Ferrier, Simon; McVicar, Tim; Newell, Graham; White, Matt. HCAS: A new way to measure the condition of natural habitats for terrestrial biodiversity across whole regions using remote sensing data. Methods in Ecology and Evolution. 2016; 7:1050-1059. https://doi.org/10.1111/2041-210X.12579

Lehmann, Eric; Williams, Kristen; Harwood, Tom; Ferrier, Simon. A not-too-technical introduction to the HCAS v2.x mechanics: a revised method for mapping habitat condition across Australia. Canberra, ACT, Australia: CSIRO; 2021. https://doi.org/10.25919/ek91-wj41

Appendix D. Neighbourhood context



Appendix E. Overview of Method Workflow