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vegetation community maps
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Accuracy assessment of vegetation community maps generated by aerial photography interpretation: perspective from the tropical savanna, Australia

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Abstract. Aerial photography interpretation is the most common mapping technique in the world. However, unlike an algorithm-based classification of satellite imagery, accuracy of aerial photography interpretation generated maps is rarely assessed. Vegetation communities covering an area of 530 km² on Bullo River Station, Northern Territory, Australia, were mapped using an interpretation of 1:50,000 color aerial photography. Manual stereoscopic line-work was delineated at 1:10,000 and thematic maps generated at 1:25,000 and 1:100,000. Multi-variate and intuitive analysis techniques were employed to identify 22 vegetation communities within the study area. The accuracy assessment was based on 50% of a field dataset collected over a 4 year period (2006 to 2009) and the remaining 50% of sites were used for map attribution. The overall accuracy and Kappa coefficient for both thematic maps was 66.67% and 0.63, respectively, calculated from standard error matrices. Our findings highlight the need for appropriate scales of mapping and accuracy assessment of aerial photography interpretation generated vegetation community maps. © 2011 Society of Photo-Optical Instrumentation Engineers (SPIE). [DOI: [10.1117/1.3662885](https://doi.org/10.1117/1.3662885)]

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1 Introduction and Background

There is an increasing demand for current and reliable vegetation information at a range of spatial scales worldwide.¹⁻⁶ Vegetation communities across the globe have traditionally been mapped using aerial photography interpretation (API). The technique is labor intensive and expensive; however, it is accepted by government agencies and vegetation scientists as an accurate means of depicting vegetation communities at a point in time and space.⁷⁻¹² The use of aerial photography was anticipated to decrease as the capabilities of higher spatial resolution airborne and satellite sensors improved in the 1990s; however, it continues to be a universally accepted method for vegetation community mapping applications.^{13,14}

Insufficient coverage of finer spatial scale ($= <1:25,000$) vegetation community mapping across the Australian continent has been recognized for decades. This was made evident during the National Land and Water Resources Audit and National Vegetation Information System (NVIS) framework. The framework compiled vegetation mapping datasets from across the Australian states and territories ranging from 1:25,000 to 1:1,000,000.¹⁵ During the compilation,

significant gaps in the dataset became apparent, particularly in central and northern regions of Australia. Anecdotal evidence suggests 1:25,000 spatial scales are necessary for property and conservation management and 1:100,000 are feasible for regional reporting requirements and management. The loss of detail is largely dependent on the nature of the landscape, the interpretive base (spatial resolution), quality of field data, experience of the aerial photo interpreter, and the purpose of the mapping project.

Parallel to the need for finer spatial scale vegetation community maps is the requirement for positional and attribute map accuracy.^{16–21} Accuracy assessment of thematic maps generated from remotely sensed data is a fundamental component and there is no single or universal measure.^{16,18,22} Accuracy results are derived from confusion or error matrices in which overall accuracy, producers, and users accuracy and a Kappa coefficient can be calculated.^{17,18,20}

Many agencies, governments, and nongovernment organizations acknowledge accuracy assessment is an important component of vegetation community mapping; however, rarely do they conduct accuracy assessments. Maps generated by API continue to be used as baseline information for development assessments, conservation planning, land management, and various modeling applications. One key outcome of these assessments in Australia is often irreversible clearing of native vegetation to accommodate a growing population.

The complex nature, lack of resources, and limitation of reliable site data are the main reasons why accuracy assessment is rarely conducted. Literature indicates that approximately 50 samples (minimum 30 samples) per map class are required to adequately populate an error matrix.²³ For extensive and remote areas this is unrealistic. API is a subjective technique and is largely influenced by the interpreter, further justifying the need for quantitative accuracy assessment.^{7,24,25} Studies that have mapped vegetation communities across large and remote areas across the world highlight the financial and logistical difficulties of collecting additional field data for quantitative accuracy assessment. Accuracy assessment is compromised as site data are used partly (or solely) for map attribution. Conversely, studies that publish statistically valid accuracy assessment results cover relatively small, readily accessible areas.

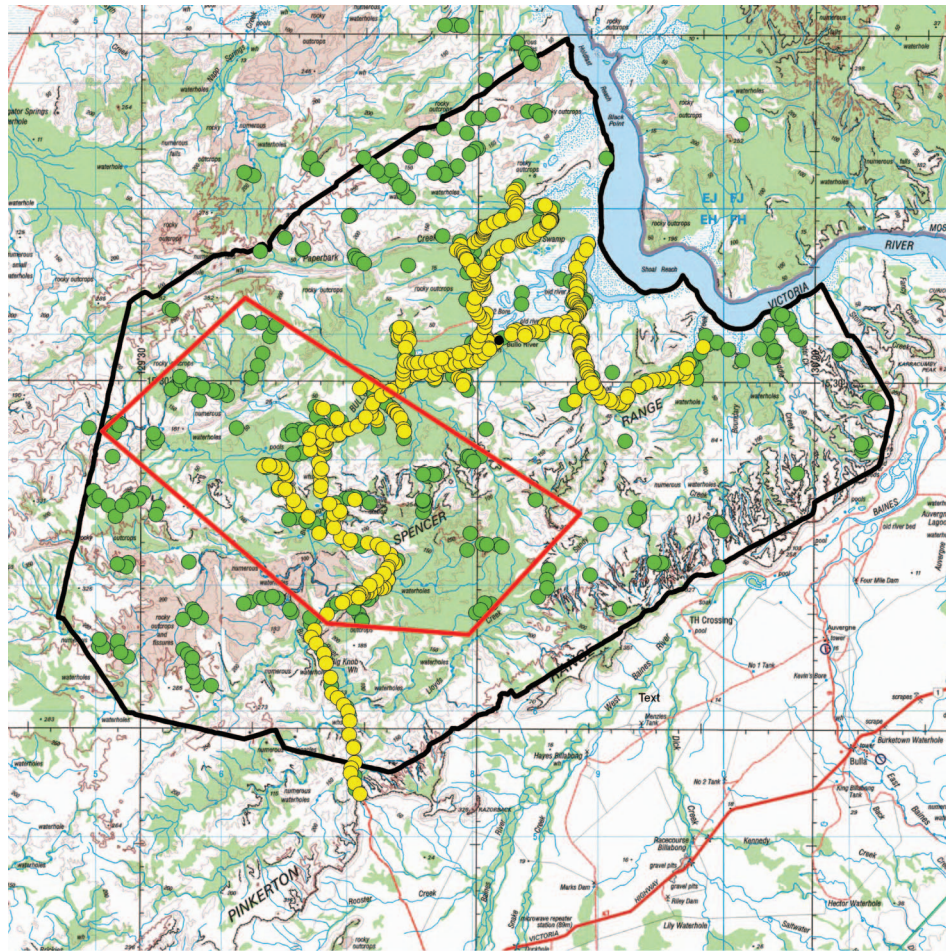
This study presents accuracy assessment results based on 50% of a field dataset. The study area also covered a large, remote area in northern Australia (where access was predominately by helicopter). It emphasizes the importance of site data for map attribution and accuracy assessment through an evaluation of API generated vegetation community maps at two spatial scales: property management (1:25,000) and regional (1:100,000). It identifies the loss of detail (polygons <4 ha minimum mapping unit) between the two spatial scales and highlights the importance of capturing data at a finer spatial scale for property management applications. The predicted difference between the two spatial scale maps is that there will be a loss of attribute and spatial detail of vegetation communities that have restricted distribution.

This study is a component of a broader research project to compare the accuracy of API, pixel-based, and object-based vegetation community maps at two spatial scales. The content covered here includes the results of the API component.

2 Data and Methodology

2.1 Study Area

The study area is located on Bullo River Station in the Victoria River District in north western Northern Territory, Australia (Fig. 1). The study area covers an area of 530 km² and is situated in the Bullo River catchment representing three broad landform types: rugged sandstone hills and escarpment; low hills, rises and plains; and alluvial plains toward the intertidal fringes of the Bullo and Victoria rivers. These landform types support a range of habitats typical of northern Australia tropical savannas, including a variety of eucalypt communities, riparian zones, paperbark swamps, mangrove communities, and saline coastal flats subject to tidal inundation.



Legend

- Bullo River Station -study area
- Road Note Sites
- Full Floristic Sites
- Bullo River Station

Topographic Map 1:250,000

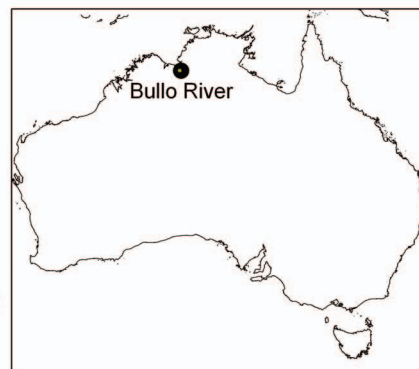
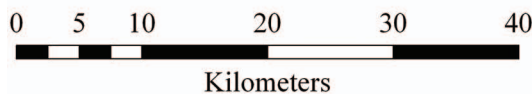


Fig. 1 Locality map showing the distribution of full floristic and road note sites across Bullo River Station and the study area.

2.2 Field Sampling

The field sampling was conducted over four years (2006 to 2009) and six sampling efforts where access was predominately by helicopter and four wheel drive vehicle. A systematic sampling approach was used to preselect sites covering the geographic and environmental range across the study area using a Geographic Information System (GIS). To represent the various vegetation

patterns, site selection was based on tonal variation, color, and texture of the aerial photography and SPOT5 imagery. Disturbed areas (i.e., recent fire and grazing) were avoided.

Across the study area two site types were sampled: 1. full floristic sites and 2. less detailed sites (road notes) (Fig. 1). The full floristic sites were used for multivariate analysis and extended beyond the study area boundary to Bullo River Station and included 392 sites. Within the study area, we sampled 137 full floristic sites and 104 road notes. We used 50% of the dataset to attribute the polygons on the map and the remaining 50% were reserved for the accuracy assessment. Sampling intensity was dependant on accessibility, funding, and resources.

At each full floristic site, all plant species present in a 20×20 m quadrat were recorded with associated structural information (cover, height, and growth form across three strata). Strata are layers of foliage and branches of measurable height.²⁶ For this study, we identified up to three strata: 1. upper strata (tree-layer), 2. mid-strata (shrub layer), and 3. ground strata (incorporating tussock grasses and/or hummock grasses, sedges, forbs, and low shrubs). Plants unable to be identified in the field were collected and identified at the Northern Territory Herbarium. Cover was estimated as canopy cover (crowns treated as opaque) for the upper strata and projective foliage cover (PFC,- vertical projection of foliage only) for the mid- and ground strata. Mean height and range were measured for species greater than 2 m tall and visually estimated for those less than 2 m (for species greater than 1% cover). Percentage ground cover (equating to 100%) was visually estimated for litter, bare earth, crust, exposed rocks, and vegetation. Landform pattern and element were also recorded according to Speight.²⁷

Road notes were qualitative and mainly recorded on vehicle-based field trips. Waypoints were saved for helicopter-based trips with a hand-held GPS. Road notes included a description of the dominant species and an estimate of the structural formation (including cover and height) for homogeneous vegetation patterns.

For strata, dominant growth form, canopy cover, PFC, average height, and height range were measured. This information was required to derive a structural formation for the vegetation community descriptions. This study adopted Australia's national standards for vegetation classification.^{26,28}

2.3 Field Data Analysis and Vegetation Classification

Multivariate routines were applied to 392 sites and 957 plant species. A subset of the full floristic dataset was used including the upper strata with species contributing less than 0.1% cover removed and a square root transformation applied.²⁹ The most commonly used similarity coefficient (Bray–Curtis) was conducted and multidimensional scaling plots used as a visual aid to remove 39 outlier sites. A combination of multivariate analysis and intuitive classification identified 22 discrete and mappable vegetation communities across the study area.²⁹ The similarity of percentages (SIMPER) procedure was used to discern species typical of the vegetation communities and species discriminating between groups. SIMPER was also used to rank species in order of their relative contributions to determine community patterns for each floristic group.

Vegetation attributes were summarized to construct vegetation community descriptions and were described using the NVIS Information Hierarchy Level VI—sub-association, the highest level of detail floristically and structurally.²⁸ Cover and height information was averaged across all full floristic sites for each stratum and modal growth forms were derived. To establish species dominance, frequencies of occurrence were calculated and up to five dominant species were described for each stratum. All sites were assigned a vegetation community number prior to map attribution.

2.4 Image Acquisition and Processing

Aerial photography for the study area was captured on May 28, 2006 at a scale of 1:50,000. Differential GPS centers, exterior orientation from Applanix (a provider of digital imaging technology), color contact prints, and photo scans at $15 \mu\text{m}$ resolution were sourced.

Every second digital image was ortho-rectified using an exterior orientation method. It was not necessary to ortho-rectify each photo due to overlapping stereo pairs. Data required for this method included 600 dpi raw images, camera calibration details, exterior orientation parameters including X , Y , Z coordinates in eastings/northings, attitude omega, phi, kappa, and a digital elevation model. Attitude omega, phi, and kappa, which were provided in degrees, had to be converted to radians for the exterior orientation set up. Eight fiducial points were selected with a root-mean-square error of below 0.10 units. The output coordinate system was Geocentric Datum of Australia (GDA94), Map Grid of Australia eastings/northings at a scale of 1:50,000 (0.00002), and cell size 2×2 m pixels using a nearest neighbor algorithm. The ortho-rectified aerial photos were mosaiced and color balanced with a blue haze filter.

2.5 Aerial Photography Interpretation

The aerial photography stereo pairs were examined under a stereoscope to delineate vegetation communities. Line-work was digitized as a polyline shapefile (GDA94, decimal degrees) using the mosaic as an interpretive base in a GIS. The spatial scale was set to 1:10,000 for line-work digitizing. The polyline dataset was smoothed using a smooth polylines algorithm and converted to a polygon shape file.

Preliminary map attributes were assigned to the polygons of the original 1:10,000 polyline dataset and updated once the final vegetation community groups were determined. Map attribution was a manual process conducted in a GIS. Polygons containing a site were attributed initially (76 full floristic sites and 50 road notes) and the remaining polygons attributed based on visual interpretation. Topography was also evaluated to define landform and land surface characteristics.

Polygons less than 0.25 ha were eliminated to create the 1:25,000 thematic map and 4 ha for 1:100,000.

2.6 Error and Accuracy Assessment

A systematic method was used to differentiate sites for map attribution and the accuracy assessment. Odd number sites were selected for map attribution and even number sites for the accuracy assessment.

Error matrices were derived for the two spatial scale vegetation community maps. Two sources of spatial information were quantitatively compared including 1. polygons generated from API and 2. point source data from half the field dataset (65 full floristic sites and 58 road notes). Four accuracy measures were calculated; overall accuracy, Kappa coefficient, producers, and users accuracy.³⁰

3 Results and Discussion

3.1 Vegetation Community Descriptions

Twenty-two vegetation communities were identified from 392 full floristic and structural sites and 957 plant species (Appendix A). The most common and widespread vegetation community was 1—*Eucalyptus tectifica* dominated low woodland. This community occurred across a range of landform patterns and substrates. The most extensive was on plains and rises and hill slopes of low hills and hills. Another vegetation community that intergraded on the plains, on imperfectly drained soils, typically adjacent to water courses was community 7—*Corymbia grandifolia* mid-open woodland. Canopies were more spaced on the aerial photography in comparison to community 1 and community 7 rarely occurred on hill slopes.

Community 22 was also extensive and characteristic of broken sandstone plateaux and hills. It was a very mixed community of *Acacia* spp., *Grevillea* spp., *Gardenia* spp., *Terminalia latipes*,

and *Buchanania obovata* tall sparse shrub land. It formed mosaic polygons with other communities including 2, 10, 27, and 31. The communities contributing to mosaics with community 22 (not mapped as discrete units) included 27 and 31. Community 27 was sporadic and characterized by *Eucalyptus brachyandra* low open woodland. Community 31 was also sporadic on the sandstone plateaux and common on broken sandstone dominated by *Corymbia cliftoniana* low open woodland. These two communities were not discernable on the aerial photography mosaic; therefore, they were mapped as mosaics. However, they were floristically discrete vegetation communities.

Communities 10 and 6 appeared similar in terms of aerial photography color and texture and occurred on plateaux. Community 10, dominated by *Eucalyptus phoenicea* low open woodland, was present on the plateaux and hills to the north of the study area. It was also common on rises and plains adjacent to the alluvial plains of the Bullo River. Community 2 was also common across similar landforms to communities 10 and 6; however, tree canopies were sparser on the aerial photography.

Community 6 was dominated by *Eucalyptus miniata* mid-open woodland. This community existed as three associations, an influence of substrate and landform. The typical form was on the plateaux, the second occurred on rugged sandstone hill slopes, and the third was on heavier soils adjacent to drainage lines on the alluvial plains.

Several communities were associated with stream channels, drainage depressions, and swamps. The stream channels on the plains and alluvial plains were usually mapped as mosaics dominated by community 21—*Melaleuca leucadendra* mid-woodland. This community also formed swamps not associated with stream channels. Community 4 also occurred on stream channels across plains, rises, low hills, hills, and plateaux, usually in association with community 21 differing in its landscape position and floristics. Other swamps were dominated by either tussock grasses or sedges and included communities 8 and 30, respectively.

On the drainage depressions, communities 11 and 20 were either discrete or intergraded. These communities were dominated by either *Corymbia polycarpa* or *Melaleuca viridiflora* and were typically adjacent to the relict levees of the Bullo River and its tributaries. Community 20—*Melaleuca viridiflora* was characterized by its fine pattern on the aerial photography in contrast to very sparse tree canopies of community 11—*Corymbia polycarpa*.

On the alluvial plains, relict levee systems were dominated by community 3—*Corymbia bella* mid-woodland. Adjacent to this community on the plains was community 18, dominated by a mix of *Corymbia foelscheana*, *Corymbia confertiflora*, *Corymbia grandifolia*, *Brachychiton diversifolius*, and *Bauhinia cunninghamii* mid-woodland. Community 5—*Eucalyptus pruinosa* low open woodland was quite common on the levee systems and plains.

Community 12 was restricted to the Victoria River fault line and very common on scarps and hill slopes of escarpments, plateaux, and hills. Also common on scarps and the heads of gullies on plateaux, escarpments and hills was community 28. This community was a dry vine thicket dominated by *Xanthostemon paradoxus*, *Pouteria sericea*, *Acacia lamprocarpa*, *Ziziphus quadrilocularis*, and *Alstonia spectabilis* mid-woodland.

Less extensive communities that occurred on hills and plateaux included communities 13, 15, and 16. Community 13—*Corymbia ptychocarpa* mid-woodland occurred in small pockets on permanent springs. Confined to the hills in the north-west corner of the study area were communities 15 and 16. Community 15 was represented by *Eucalyptus brevifolia* low open woodland and community 16 was dominated by *Melaleuca sericea* low open woodland.

3.2 Vegetation Community Maps

The study area was mapped at 1:10,000 and two thematic maps generated at 1:25,000 and 1:100,000 spatial scales. Five polygons were eliminated to produce the 1:25,000 map and 51 for the 1:100,000 map from a total of 700 polygons. Figure 2 illustrates the distribution of vegetation communities mapped at 1:25,000 and the polygons (<4 ha—minimum mapping unit) eliminated

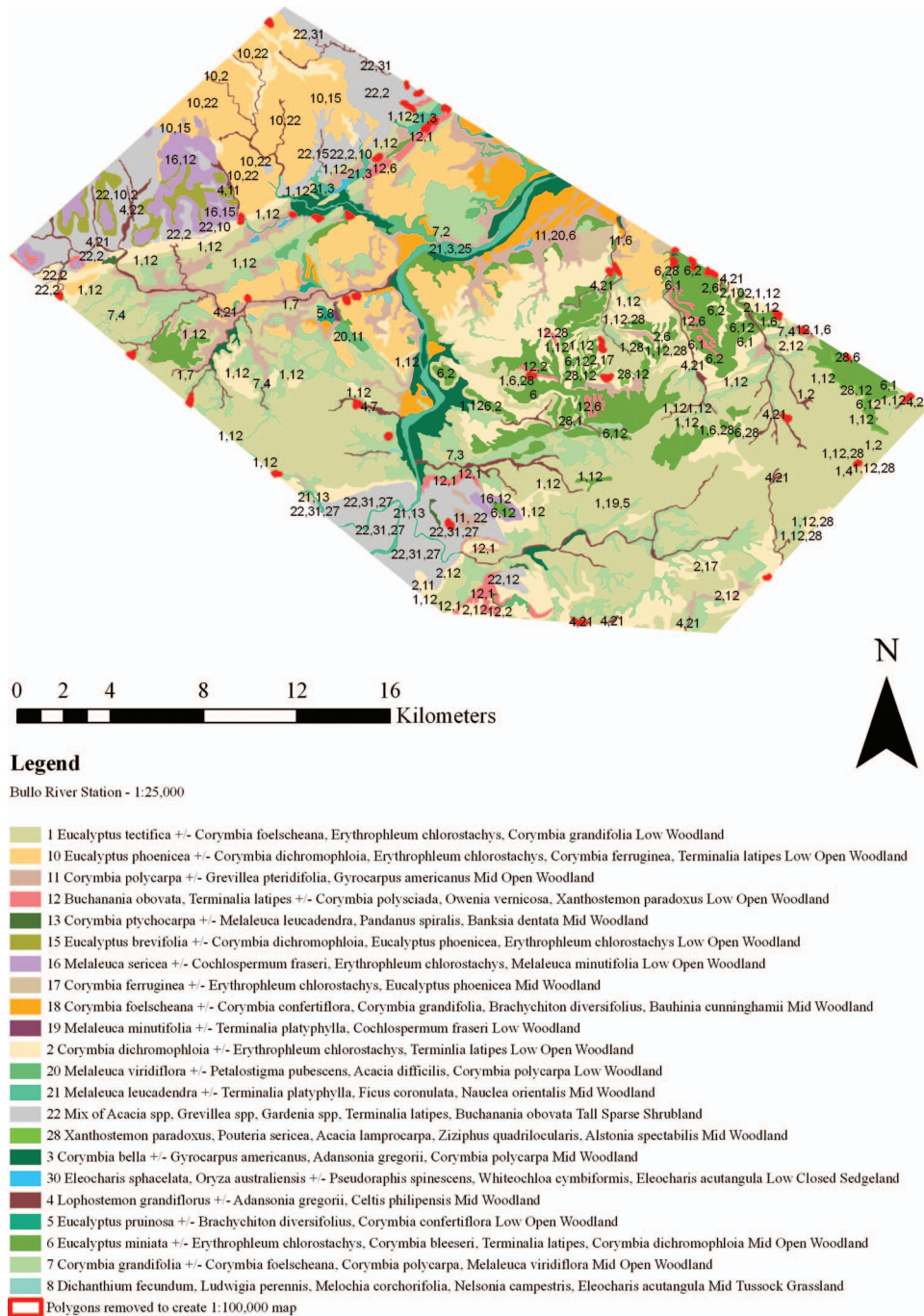


Fig. 2 Study area 1:25,000 vegetation community map, illustrating polygons removed for the 1:100,000 product highlighted in red.

to generate the 1:100,000 product. The 1:100,000 map lost attribute and spatial detail for two vegetation communities. All polygons were eliminated from the map for vegetation communities 13—*Corymbia ptychocarpa* dominated spring fed mid-woodland and 28, the dry vine thicket community confined to the heads of sandstone gullies and scarps mainly to the south of the study area. From a property management and biodiversity conservation perspective, the delineation of these communities is important for their future protection and management. This comparison of

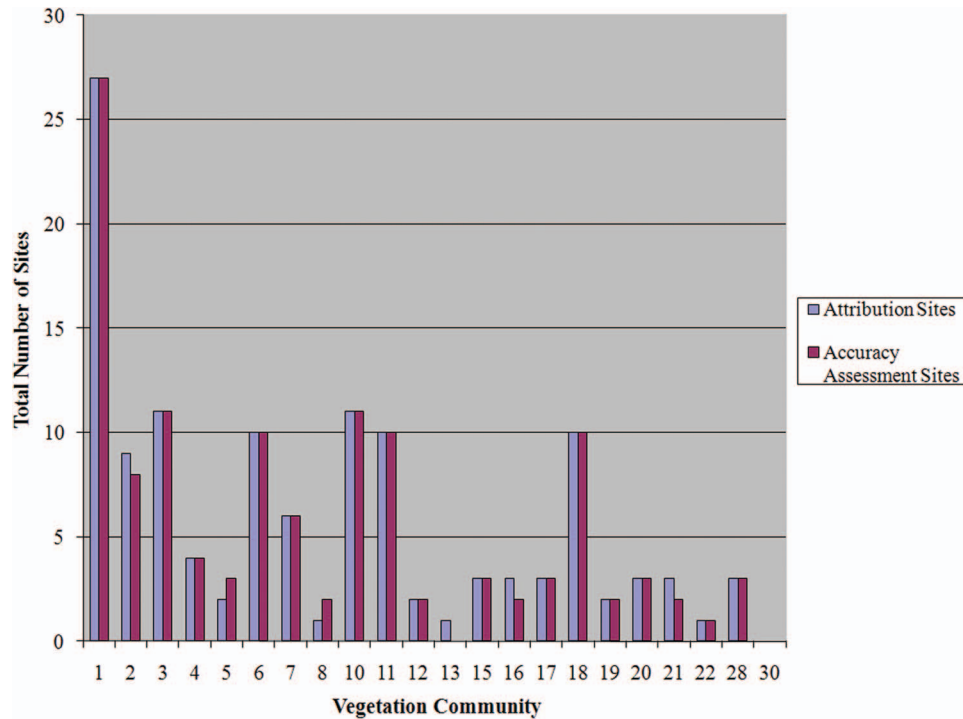


Fig. 3 The total number of samples per vegetation community for API map attribution and accuracy assessment.

map detail indicates that 1:25,000 or less is an appropriate spatial scale for property management and 1:100,000 for regional applications.

When compared to other studies in the region, the 1:25,000 map of the study area captured the highest level of attribute and spatial detail. An existing survey that mapped vine thicket vegetation (community 28) across the top end of the Northern Territory did not distinguish the full extent of this community, even though it was a targeted survey to classify and map the monsoon vine forest vegetation.³¹ This may have been a result of the interpretive base (various spatial resolutions of aerial photography). Similarly, community 13 confined to spring-fed pockets on rugged sandstone was not captured in existing datasets across the region. The datasets evaluated included the vegetation map of the Northern Territory mapped at 1:1,000,000 (Ref. 32) and the lands of the Ord-Victoria Area, Western Australia, and Northern Territory mapped at 1:250,000.³³

3.3 Accuracy Assessment

The number of sites selected for map attribution and accuracy assessment were comparable for the majority of vegetation communities. Three communities were mapped as mosaics (25, 27, and 31) and three did not contain sites for the accuracy assessment (13, 14, and 30). A total of 19 vegetation communities were used in the accuracy assessment from the 22 that were mapped (Fig. 3). The number of sites for the accuracy assessment ranged from 1 to 27 with an average of 6. Figure 1 illustrates the distribution of full floristic and road note sites for map attribution and accuracy assessment. The spatial distribution of sites shows the majority were confined to the main access track and nongazetted tracks. To sample the required number of sites for quantitative accuracy assessment, field sampling costs would double. The total cost of field sampling was \$120,000, including staff salaries, travel allowance, and vehicle costs. Helicopter hire (wet rate) alone exceeded \$28,000.

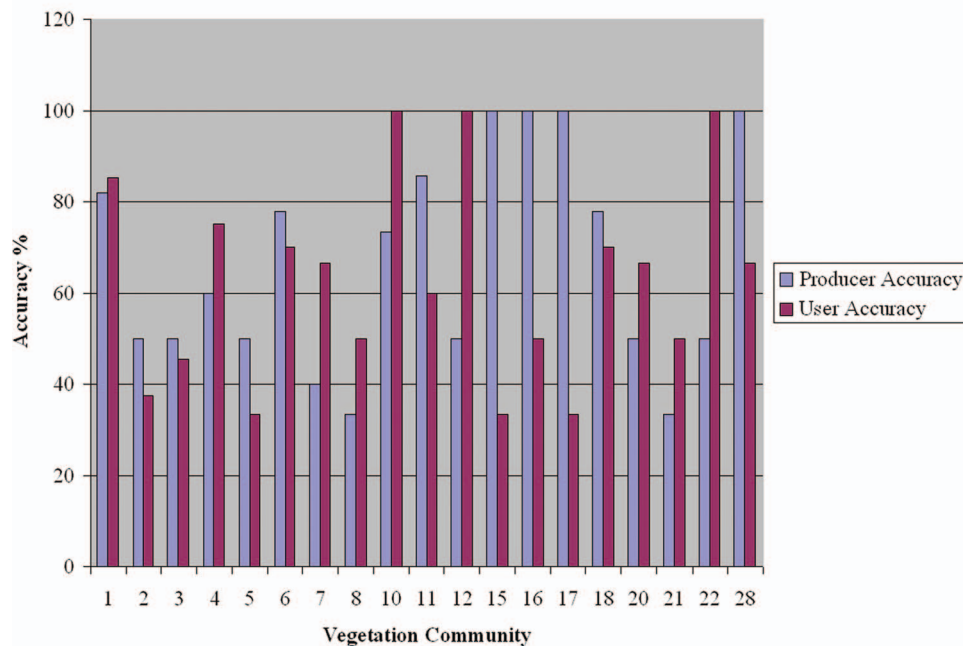


Fig. 4 Producer and user accuracies for the thematic vegetation community maps.

This study focused on a standard accuracy assessment approach of generating error matrices and reporting overall accuracy, Kappa coefficient, users, and producers accuracy. The results are not dissimilar to other international studies; however, the majority do focus on smaller areas, land cover, or land use mapping, mapping vegetation at the generic level, mapping at spatial scales greater than 1:50,000, and targeted surveys such as mapping riparian zones.³⁴⁻⁴⁰ Few studies conduct accuracy assessment on maps that capture the floristic and structural components of vegetation communities that are presented here.

The error matrix for the 1:25,000 and 1:100,000 thematic vegetation community maps is presented in Appendix B. The overall accuracy for the two maps was 66.67% and Kappa coefficient 0.63. The two maps generated the same accuracy as a result of the spatial distribution of the accuracy assessment sites and the polygons that were eliminated to create the 1:100,000 thematic map. Eliminated polygons did not have site data intersecting for accuracy assessment. If additional sites were sampled for the accuracy assessment, the result may be different, although not significantly given that 51 small polygons (<4 ha) were eliminated from a total of 700.

The producer and user accuracies were comparable for the two maps (Fig. 4). Communities that were extensive and dominant across the study area had a significant number of sites for map attribution and accuracy assessment including 1, 3, 6, 10, 11, and 18. These communities had the highest and comparable producer and user accuracies and were homogeneous floristically and structurally. The vegetation communities that had lower accuracies were heterogeneous and had the highest proportion of misclassified polygons based on the accuracy assessment sites. These communities included 2, 17, and 15 and were all similar based on color, tone, and textural characteristics of the aerial photography. Three vegetation communities had zero percentage producer and user accuracy and even though these were mapped, there were no accuracy assessment sites. Communities with 100% producer accuracy were typically undersampled, had a low number of polygons, and were located in areas difficult to access.

There are four possible sources of error according to Congalton and Green:³⁰ 1. errors in the reference data, 2. classification schemes, 3. remote sensing data used as the image base, and 4. mapping error. The sources of error in this study can be attributed to the mapping error and the multivariate analysis to define the floristic groups.

Quantitative accuracy assessment of API has been recognized since the 1950s including the use of error matrices.²¹ These techniques did not receive widespread attention until the mid-1970s for remotely sensed data. Accuracy assessment is increasingly acknowledged as an essential attribute to be provided with spatial data; however, it is not conducted as standard practice by government agencies or nongovernment organizations when producing maps from remotely sensed data.⁴¹ Even though there is a wide range of accuracy techniques, assessment of accuracy on vegetation community maps is rarely conducted in many situations. Qualitative visual checks on API generated vegetation community maps have been acceptable and in many organizations this continues to be the case.³⁰

Across the Australian states and territories, departmental agencies rarely conduct accuracy assessment irrespective of the importance documented in methodological reports^{42,43} and national guidelines.⁷ However, some national programs do enforce quantitative accuracy assessment, including the Australian Collaborative Land Use Mapping Program.⁴⁴ Several states have recently implemented the requirement of accuracy assessment on all vegetation community maps.⁴⁵ For example, the Queensland government approach states acceptable measures are 80%.⁴³ Keith and Simpson⁴⁶ highlight map accuracy is arguably the most important criterion for assessing vegetation maps which are often dependent on precision and currency of spatial data.

During the process of data compilation for NVIS to build a nationally consistent vegetation dataset from the Australian states and territories, it was apparent the majority of vegetation community datasets did not undertake accuracy assessment.¹⁵ The American National Vegetation Classification System for ecological community mapping suggests 80% is the standard, although a 50% to 70% accuracy range is commonly accepted in regional mapping programs.²⁵ It is important to note that overall accuracy is not the sole measure of accuracy. Producers and users accuracy may be of greater value to depict the accuracy of particular classes. For example, the overall accuracy of a vegetation community map may be high; however, users accuracy for a rare community may be low.⁴¹

There are parallels with recent work conducted by Roelfsema and Phinn⁴⁷ on seagrass and coral reef mapping. The research found that few studies rarely conduct accuracy assessment, especially using operational datasets. Operational data refers to data used by government agencies and nongovernment organizations for decision making purposes. The study assessed over 80 peer-reviewed papers and found no studies provided repeatable accuracy assessment methods.

Vegetation scientists continue to use API to generate vegetation community maps, often without any form of qualitative or quantitative accuracy assessment.⁴⁸ Time constraints, stringent deadlines, lack of available resources, logistics, and the cost of acquiring field data are the most obvious contributing factors why accuracy assessment is not conducted.

4 Conclusions and Future Work

The use of aerial photography and API remains a common approach for vegetation community mapping despite recent advances in commercial satellite imagery and semiautomated techniques. This work demonstrates that vegetation community mapping across Australia and worldwide rarely conduct accuracy assessments and report on it. Researchers, land managers, and developers continue to use API generated vegetation community maps to inform management decisions without any knowledge of the spatial and attribute accuracy. Vegetation communities are compromised due to unsuitable spatial scales and by low (or known) map accuracies. Population growth inevitably places increasing pressure on native vegetation; therefore, it is essential that accurate maps are being used to inform decision making and policy. Even though land clearing guidelines and legislation are in place in many Australian jurisdictions, the data quality of vegetation community maps remains to be addressed.

We have highlighted that finer spatial scale vegetation community maps are required to depict discrete vegetation patterns at appropriate spatial scales for property management and conservation planning. This is apparent across large expanses of the tropical savanna of northern

Australia and the world, where finer spatial scale vegetation community maps do not exist and land clearing applications are increasing. The spatial scale of mapping has a significant influence on the end product, and, where polygons are removed (<4 ha minimum mapping unit), attribute and spatial detail of a thematic map are eliminated unless they are captured as mosaic communities.

This study demonstrates the inherent importance of field data collection for map attribution and accuracy assessment. Further work is required to trial other methods for conducting accuracy assessment where funds and resources are insufficient. This may include withholding a lower number of samples for accuracy assessment. Is half the field dataset excessive and what is an acceptable percentage of samples to reserve for quantitative accuracy assessment? Fuzzy accuracy assessment techniques should also be explored for future vegetation community maps—especially across heterogeneous areas. The fuzzy error matrix approach is a technique that allows an analyst to compensate for heterogeneous situations by applying a set of fuzzy rules to the same classification.³⁰

We believe there is a requirement for comparative studies on different sources of remotely sensed imagery and mapping techniques, due to the increase of commercially available satellite imagery and improved image processing software. The accuracy of semiautomated techniques such as pixel and object-based image classification applied across the same study area would be valuable as a comparison to API. Prospective techniques could present cost and time effective methods for vegetation community mapping across large tropical savanna regions, at fine spatial scales and acceptable degrees of accuracy.

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Appendix A: Vegetation community descriptions and areas of the 1:25,000 and 1:100,000 vegetation community maps

| Vegetation community ID | 1:25K Area (km ²) | 1:100K Area (km ²) | Vegetation community description NVIS subassociation |
|-------------------------|-------------------------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | 152.62 | 152.41 | <i>Eucalyptus tectifica</i> +/- <i>Corymbia foelscheana</i> , <i>Erythrophleum chlorostachys</i> , <i>Corymbia grandifolia</i> Low Woodland over <i>Cochlospermum fraseri</i> , <i>Terminalia canescens</i> , <i>Brachychiton tuberculatus</i> Tall Sparse Shrubland over <i>Eriachne obtusa</i> , <i>Heteropogon contortus</i> , <i>Sehima nervosum</i> , <i>Ampelocissus frutescens</i> , <i>Waltheria indica</i> Mid Tussock Grassland |

(Continued.)

| | | | |
|----|-------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2 | 63.78 | 63.71 | <i>Corymbia dichromophloia</i> +/- <i>Erythrophleum chlorostachys</i> , <i>Terminalia latipes</i> Medium Low Open Woodland over <i>Cochlospermum fraseri</i> +/- <i>Croton arnhemicus</i> , <i>Terminalia canescens</i> , <i>Corymbia dichromophloia</i> Tall Sparse Shrubland over <i>Triodia bitextura</i> , <i>Eriachne ciliata</i> , <i>Eriachne obtusa</i> , <i>Stackhousia intermedia</i> , <i>Phyllanthus exilis</i> Mid Open Hummock Grassland |
| 3 | 11.21 | 11.13 | <i>Corymbia bella</i> +/- <i>Gyrocarpus americanus</i> , <i>Adansonia gregorii</i> , <i>Corymbia polycarpa</i> Mid Woodland over <i>Bauhinia cunninghamii</i> , <i>Acacia holosericea</i> , <i>Ficus aculeata</i> , <i>Flueggea virosa</i> Low Open Woodland over <i>Heteropogon contortus</i> , <i>Mnesithea rottboelioides</i> , <i>Hyptis suaveolens</i> , <i>Grewia retusifolia</i> , <i>Sida acuta</i> Very Tall Tussock Grassland |
| 4 | 10.59 | 10.66 | <i>Lophostemon grandiflorus</i> +/- <i>Adansonia gregorii</i> , <i>Celtis philippensis</i> Mid Woodland over <i>Buchanania obovata</i> , <i>Bauhinia cunninghamii</i> , <i>Pouteria sericea</i> , <i>Calytrix brownii</i> , <i>Lophostemon grandiflorus</i> Tall Sparse Shrubland over <i>Mnesithea rottboelioides</i> , <i>Heteropogon contortus</i> , <i>Ischaemum australe</i> , <i>Triodia bynoei</i> , <i>Cajanus latisepalus</i> Mid Open Tussock Grassland |
| 5 | 0.48 | 0.48 | <i>Eucalyptus pruinosa</i> +/- <i>Brachychiton diversifolius</i> , <i>Corymbia confertiflora</i> Low Open Woodland over <i>Acacia holosericea</i> , <i>Brachychiton tuberculatus</i> , <i>Petalostigma pubescens</i> , <i>Ampelocissus frutescens</i> , <i>Cochlospermum fraseri</i> Tall Sparse Shrubland over <i>Heteropogon contortus</i> , <i>Grewia retusifolia</i> , <i>Eriachne obtusa</i> , <i>Themeda triandra</i> , <i>Sehima nervosum</i> , <i>Waltheria indica</i> Mid Tussock Grassland |
| 6 | 42.31 | 42.18 | <i>Eucalyptus miniata</i> +/- <i>Erythrophleum chlorostachys</i> , <i>Corymbia bleeseri</i> , <i>Terminalia latipes</i> , <i>Corymbia dichromophloia</i> Mid Open Woodland over <i>Buchanania obovata</i> , <i>Persoonia falcata</i> , <i>Terminalia latipes</i> Tall Sparse Shrubland over <i>Triodia bitextura</i> , <i>Eriachne ciliata</i> , <i>Cartonema spicatum</i> , <i>Crotalaria medicaginea</i> , <i>Bulbostylis barbata</i> Mid Open Hummock Grassland |
| 7 | 55.25 | 54.92 | <i>Corymbia grandifolia</i> +/- <i>Corymbia foelscheana</i> , <i>Corymbia polycarpa</i> , <i>Melaleuca viridiflora</i> Mid Open Woodland over <i>Cochlospermum fraseri</i> , <i>Brachychiton tuberculatus</i> , <i>Bauhinia cunninghamii</i> , <i>Terminalia latipes</i> , <i>Grevillea decurrens</i> Tall Sparse Shrubland over <i>Aristida hygrometrica</i> , <i>Eriachne obtusa</i> , <i>Triodia bitextura</i> , <i>Schizachyrium fragile</i> , <i>Oldenlandia mitrasacmoides</i> Mid Open Tussock Grassland |
| 8 | 0.48 | 0.48 | <i>Dichanthium fecundum</i> , <i>Ludwigia perennis</i> , <i>Melochia corchorifolia</i> , <i>Nelsonia campestris</i> , <i>Eleocharis acutangula</i> Mid Tussock Grassland with upper strata +/- <i>Acacia farnesiana</i> , <i>Bauhinia cunninghamii</i> , <i>Melaleuca viridiflora</i> , <i>Melaleuca nervosa</i> Low Open Woodland |
| 10 | 64.37 | 64.35 | <i>Eucalyptus phoenicea</i> +/- <i>Corymbia dichromophloia</i> , <i>Erythrophleum chlorostachys</i> , <i>Corymbia ferruginea</i> , <i>Terminalia latipes</i> Low Open Woodland over <i>Calytrix exstipulata</i> , <i>Cochlospermum fraseri</i> , <i>Terminalia latipes</i> , <i>Croton arnhemicus</i> Tall Sparse Shrubland over <i>Triodia bitextura</i> , <i>Eriachne ciliata</i> , <i>Petalostigma quadriloculare</i> , <i>Stackhousia intermedia</i> , <i>Oldenlandia mitrasacmoides</i> Mid Open Tussock Grassland |
| 11 | 29.66 | 29.63 | <i>Corymbia polycarpa</i> +/- <i>Grevillea pteridifolia</i> , <i>Gyrocarpus americanus</i> Mid Open Woodland over <i>Melaleuca viridiflora</i> , <i>Acacia difficilis</i> , <i>Melaleuca nervosa</i> Medium Low Open Woodland over <i>Chrysopogon setifolius</i> , <i>Eriachne obtusa</i> , <i>Sorghum stipoides</i> , <i>Alloteropsis semialata</i> , <i>Murdannia graminea</i> Mid Tussock Grassland |
| 12 | 6.45 | 6.27 | <i>Buchanania obovata</i> , <i>Terminalia latipes</i> +/- <i>Corymbia polysciada</i> , <i>Owenia vernicosa</i> , <i>Xanthostemon paradoxus</i> Low Open Woodland over <i>Buchanania obovata</i> , <i>Cochlospermum fraseri</i> , <i>Croton arnhemicus</i> Mid Sparse Shrubland over <i>Triodia bitextura</i> , <i>Eriachne ciliata</i> , <i>Sorghum bulbosum</i> , <i>Bulbostylis barbata</i> , <i>Corchorus sidioides</i> Mid Open Hummock Grassland |
| 13 | 0.52 | 0.46 | <i>Corymbia ptychocarpa</i> +/- <i>Melaleuca leucadendra</i> , <i>Pandanus spiralis</i> , <i>Banksia dentata</i> Mid Woodland over <i>Pandanus spiralis</i> , <i>Acacia pellita</i> , <i>Acacia difficilis</i> , <i>Corymbia ptychocarpa</i> Low Open Palmland over <i>Mnesithea rottboelioides</i> , <i>Pandanus spiralis</i> , <i>Fimbristylis pauciflora</i> , <i>Scleria rugosa</i> , <i>Acacia pellita</i> Mid Tussock Grassland |

(Continued.)

| | | | |
|----|-------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15 | 5.26 | 5.26 | <i>Eucalyptus brevifolia</i> +/- <i>Corymbia dichromophloia</i> , <i>Eucalyptus phoenicea</i> , <i>Erythrophleum chlorostachys</i> Low Open Woodland over <i>Calytrix achaeta</i> , <i>Cochlospermum fraseri</i> , <i>Wrightia saligna</i> , <i>Grevillea prasina</i> , <i>Acacia lycopodiifolia</i> Mid Sparse Shrubland over <i>Triodia bitextura</i> , <i>Eriachne ciliata</i> , <i>Eriachne mucronata</i> , <i>Acacia translucens</i> , <i>Grevillea dryandri</i> Low Open Hummock Grassland |
| 16 | 11.44 | 11.44 | <i>Melaleuca sericea</i> +/- <i>Cochlospermum fraseri</i> , <i>Erythrophleum chlorostachys</i> , <i>Melaleuca minutifolia</i> Low Open Woodland over +/- <i>Calytrix exstipulata</i> , <i>Cochlospermum fraseri</i> Mid Sparse Shrubland <i>Triodia bitextura</i> , <i>Eriachne mucronata</i> , <i>Petalostigma quadriloculare</i> , <i>Eriachne ciliata</i> , <i>Fimbristylis pterygosperma</i> Low Open Hummock Grassland |
| 17 | 2.23 | 2.23 | <i>Corymbia ferruginea</i> +/- <i>Erythrophleum chlorostachys</i> , <i>Eucalyptus phoenicea</i> Low Open Woodland over <i>Cochlospermum fraseri</i> , <i>Grevillea agrifolia</i> , <i>Psydrax pendulina</i> , <i>Brachychiton fitzgeraldianus</i> Tall Sparse Shrubland over <i>Triodia bitextura</i> , <i>Eriachne ciliata</i> , <i>Eriachne obtusa</i> , <i>Ampelocissus frutescens</i> , <i>Haemodorum ensifolium</i> Mid Open Hummock Grassland |
| 18 | 11.44 | 11.43 | <i>Corymbia foelscheana</i> +/- <i>Corymbia confertiflora</i> , <i>Corymbia grandifolia</i> , <i>Brachychiton diversifolius</i> , <i>Bauhinia cunninghamii</i> Mid Woodland over <i>Petalostigma pubescens</i> , <i>Brachychiton tuberculatus</i> , <i>Planchonia careya</i> , <i>Hakea arborescens</i> , <i>Corymbia foelscheana</i> Tall Sparse Shrubland over <i>Heteropogon contortus</i> , <i>Sehima nervosum</i> , <i>Sorghum plumosum</i> , <i>Themeda triandra</i> , <i>Grewia retusifolia</i> Mid Tussock Grassland |
| 19 | 0.16 | 0.16 | <i>Melaleuca minutifolia</i> +/- <i>Terminalia platyphylla</i> , <i>Cochlospermum fraseri</i> Low Woodland over <i>Flueggea virosa</i> , <i>Hakea arborescens</i> , <i>Terminalia canescens</i> , <i>Cochlospermum fraseri</i> Mid Sparse Shrubland over <i>Panicum mindanaense</i> , <i>Themeda triandra</i> , <i>Grewia retusifolia</i> , <i>Bacopa floribunda</i> , <i>Ampelocissus frutescens</i> Mid Tussock Grassland |
| 20 | 4.77 | 4.71 | <i>Melaleuca viridiflora</i> +/- <i>Petalostigma pubescens</i> , <i>Acacia difficilis</i> , <i>Corymbia polycarpa</i> Low Woodland over <i>Acacia difficilis</i> , <i>Verticordia cunninghamii</i> , <i>Melaleuca viridiflora</i> , <i>Cochlospermum fraseri</i> Tall Sparse Shrubland over <i>Chrysopogon setifolius</i> , <i>Eriachne obtusa</i> , <i>Sorghum stipoideum</i> , <i>Scleria rugosa</i> , <i>Melaleuca viridiflora</i> Mid Tussock Grassland |
| 21 | 9.69 | 9.68 | <i>Melaleuca leucadendra</i> +/- <i>Terminalia platyphylla</i> , <i>Ficus coronulata</i> , <i>Nauclea orientalis</i> Mid Woodland over <i>Barringtonia acutangula</i> , <i>Acacia holosericea</i> , <i>Syzygium eucalyptoides</i> subsp. <i>eucalyptoides</i> , <i>Acacia pellita</i> , <i>Bauhinia cunninghamii</i> Low Open Woodland over <i>Mnesithea rottboelioides</i> , <i>Chrysopogon oliganthus</i> , <i>Cyperus conicus</i> , <i>Nelsonia campestris</i> , <i>Eriachne festucacea</i> Mid Open Tussock Grassland |
| 22 | 45.68 | 45.68 | Mix of <i>Acacia</i> spp., <i>Grevillea</i> spp., <i>Gardenia</i> spp., <i>Terminalia latipes</i> , <i>Buchanania obovata</i> Tall Sparse Shrubland over <i>Triodia bitextura</i> , <i>Triodia bynoei</i> , <i>Eriachne ciliata</i> , <i>Schizachyrium fragile</i> , <i>Bulbostylis barbata</i> Mid Open Hummock Grassland |
| 28 | 1.59 | 1.47 | <i>Xanthostemon paradoxus</i> , <i>Pouteria sericea</i> , <i>Acacia lamprocarpa</i> , <i>Ziziphus quadrilocularis</i> , <i>Alstonia spectabilis</i> Mid Woodland over <i>Grewia breviflora</i> , <i>Ziziphus quadrilocularis</i> , <i>Buchanania obovata</i> , <i>Celtis philippensis</i> , <i>Pouteria sericea</i> Low Woodland over <i>Pseudochaetochloa australiensis</i> , <i>Cyperus microcephalus</i> , <i>Jasminum didymum</i> , <i>Cayratia trifolia</i> , <i>Hypoestes floribunda</i> Mid Sparse Tussock Grassland |
| 30 | 0.57 | 0.53 | <i>Eleocharis sphacelata</i> , <i>Oryza australiensis</i> +/- <i>Pseudoraphis spinescens</i> , <i>Whiteochloa cymbiformis</i> , <i>Eleocharis acutangula</i> Low Closed Sedgeland |

Appendix B: Error matrix for the 1:25,000 and 1:100,000 vegetation community maps

| | | Reference Data (full floristic and road note accuracy assessment sites) | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------------|--------------|-------------------------------------------------------------------------|---|----|---|---|---|----|---|----|----|----|----|----|----|----|----|----|----|----|----|----|-----------|--|---|---|----|----|-----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 13 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 28 | Row Total | | | | | | |
| Mapping Data (polygon data) | 1 | 23 | | | | | | 3 | | | | | | | | | 1 | | | | | | | | | | 27 | | |
| | 2 | 1 | 3 | | | | | | 2 | | | | | | | | | | 1 | | 1 | | | | | | 8 | | |
| | 3 | | | 5 | | | 1 | 2 | | | | | | | | | 1 | | | | | 2 | | | | | | 11 | |
| | 4 | | | | 3 | | | 1 | | | | | | | | | | | | | | | | | | | | 4 | |
| | 5 | | | 1 | | 1 | | | 1 | | | | | | | | | | | | | | | | | | | 3 | |
| | 6 | 1 | 1 | | | | 7 | | | 1 | | | | | | | | | | | | | | | | | | 10 | |
| | 7 | 1 | | | | | | 4 | | | 1 | | | | | | | | | | | | | | | | | 6 | |
| | 8 | | | | | 1 | | | 1 | | | | | | | | | | | | | | | | | | | 2 | |
| | 10 | | | | | | | | | 11 | | | | | | | | | | | | | | | | | | | 11 |
| | 11 | | | 1 | 1 | | | | 1 | | 6 | | | | | | | | | | | | | | 1 | | | 10 | |
| | 12 | | | | | | | | | | | 2 | | | | | | | | | | | | | | | | | 2 |
| | 13 | | | | | | | | | | | | 0 | | | | | | | | | | | | | | | | 0 |
| | 15 | | | | | | | | | 1 | | 1 | | 1 | | | | | | | | | | | | | | | 3 |
| | 16 | | | | | | | | | | | 1 | | | 1 | | | | | | | | | | | | | | 2 |
| | 17 | | | 2 | | | | | | | | | | | | | 1 | | | | | | | | | | | | 3 |
| | 18 | | | | 3 | | | | | | | | | | | | | 7 | | | | | | | | | | | 10 |
| | 19 | 1 | | | | 1 | | | | | | | | | | | | | 0 | | | | | | | | | | 2 |
| | 20 | | | | | | | 1 | | | | | | | | | | | | | | | | | 2 | | | | 3 |
| | 21 | | | | | | | | | | | 1 | | | | | | | | | | | | | | 1 | | | 2 |
| | 22 | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 |
| | 28 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | 3 |
| | Column Total | 28 | 7 | 10 | 5 | 2 | 9 | 10 | 3 | 15 | 7 | 4 | 1 | 1 | 1 | 1 | 1 | 9 | 0 | 4 | 3 | 2 | 2 | | | | | | 123 |

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Biographies and photographs of the authors not available.