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An assessment of vegetation mapping scale for reserve management: does scale of assessment dominate assessment outcomes?

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Abstract

Scale is a critical factor in biodiversity assessments; assessments at inappropriate scales can compromise assessments and drive poor management outcomes. A key dataset for many conservation reserves is a map of vegetation patterns. However, the appropriateness, scale and accuracy of mapped vegetation values is rarely assessed. This study assessed vegetation mapping undertaken at differing scales using two common competing methods. The aim was to assess map utility for management planning within an important conservation reserve (Mugii Murum-ban State Conservation Area—MSCA) integral to the globally significant Greater Blue Mountains World Heritage Area in eastern Australia. Mapping typical of a common modelling approach failed to detect six of 21 vegetation types within MSCA. These vegetation types are part of four rare and/or endangered ecosystems. Overall accuracy (66%) was lower than sub-regional scale mapping based on air photo interpretation (77%) backed by higher levels of field data and local knowledge. Thus higher levels of spatial attribution applied to the modelling was not associated with increased map accuracy, although accuracy varied largely among vegetation types. The modelled map product has a consistent methodology across the state of New South Wales and provides important context for sub-regional mapping, but proved inappropriate for reserve management planning.

Keywords Vegetation type · Ecosystem · Scale · Biodiversity · Management · Reserve

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Introduction

Biodiversity assessment and planning is fundamentally driven by data (Bayraktarov et al. 2019). The method by which data is derived is of primary importance—scale of derivation must be fit for the scale of application (Badgley 2003; Socolar et al. 2016; König et al. 2019; Wyborn and Evans 2022). Where data is applied at inappropriate scales management will be poor and resources misapplied (e.g., Gordon and Newton 2006). National or state level planning needs differ greatly to planning and management needs at a local or reserve scale. At these broad scales critical management decisions generally set policy or funding (see Simmonds et al. 2021). In contrast, reserve scale planning drives direct intervention and requires spatially accurate biodiversity data at an appropriate scale. Conservation reserves span from hectares to millions of hectares, but typically management centres on a scale of thousands (with more than 70% of global reserves being < 10 km^2—Cantu-Salazar and Gaston 2010). Within reserves, vegetation and habitat values will also vary ranging from fine-scale values (Watchorn et al. 2022) to dominance of whole reserves (e.g., www.gov.nl.ca/ecc/natural-areas/wer/eres/ accessed 16/5/22). However, many terrestrial vegetation types are variegated across scales of 1–1000 hectares (e.g., Bailey 1985; Tierney 2022) and vegetation type the primary metric for management (Keith 2009). Hence, generally, biodiversity values should at least be known at these scales. Although management can also critically fail if not applied at very fine scales (e.g., Wilk et al. 2018).

Mapping of vegetation type is undertaken by a range of methods (www.oxfordbibliographies.com/view/document/obo-9780199830060/obo-9780199830060-0176.xml—accessed 20/5/2022) and map scale dependent upon a range of variables. However, the number of data points has a strong positive relationship to accuracy (Stockwell and Peterson 2002). Resourcing for interpolation via increasingly complex models or spatial layers should only be undertaken where it can be verified as increasing accuracy (Kyriakidis and Dungan 2001; Weiskopf et al. 2022). Whilst there are a range of methods by which this accuracy might be assessed (e.g., Dakos and Solar-Toscano 2017), ultimately managers must focus on accuracy in predicting on-ground occurrence.

Despite the importance of understanding data accuracy at the reserve scale (e.g., Shriner et al. 2006; Banks and Skilleter 2007), there are surprisingly few relevant studies. A further factor not adequately assessed in the literature is the importance of local expertise and experience (Braga-Pereira et al. 2022; Wyborn and Evans 2022). Locally derived assessments often carry the benefit of extensive local field reconnaissance or knowledge which can be difficult to capture at a broader scale. This fine-grained knowledge may often be important for on-ground reserve management (Wilk et al. 2018).

This study compares vegetation assessments derived from broad (state level) to local (reserve) scales for a typical conservation reserve (typical in size; vegetation type variation and management complexity). It tracks the lineage of mapped known local scale biodiversity values. The aim was to assess the impact of the application of differing assessments of vegetation type across scales on reserve planning outcomes. The study was undertaken in New South Wales (NSW), Australia (Fig. 1). Here an extensive state scale vegetation mapping program (OEH 2017) drives biodiversity assessment using predictive models to estimate biodiversity values based generally on their modelled association to broad vegetation types (DPIE 2020). The study compares assessments based on this dataset with data derived from sub-regional scale mapping based on a common mapping approach applied at this scale which utilizes higher levels of field survey and limited spatial modelling (DEC 2006a, b).
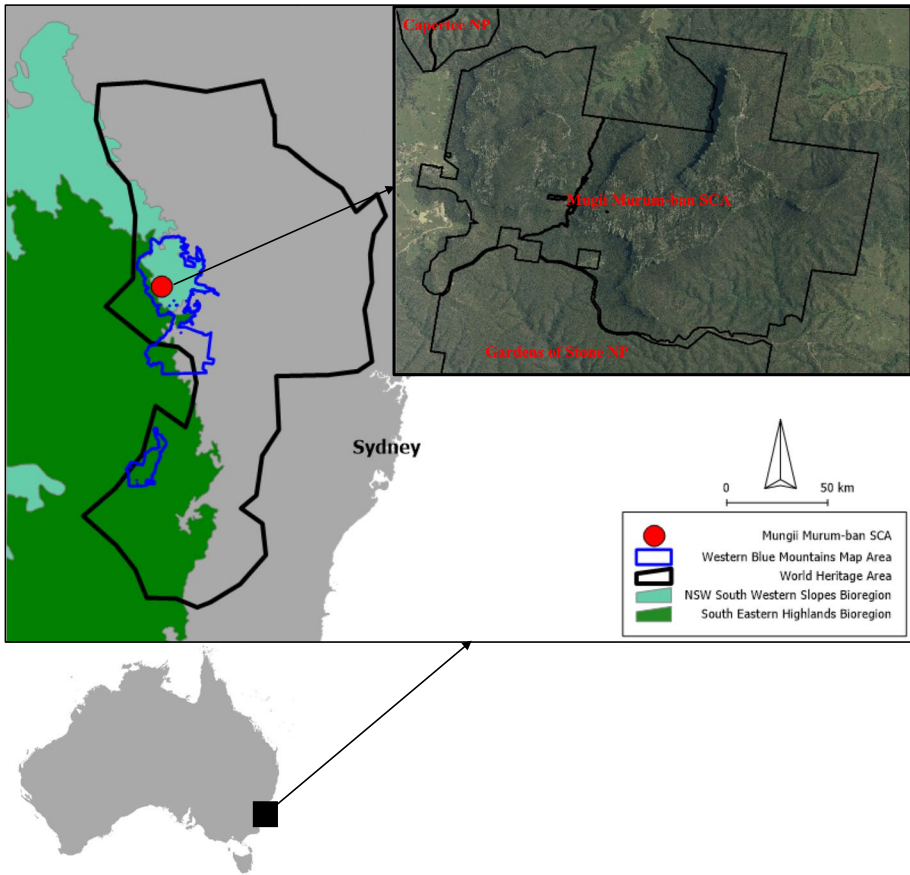
Fig. 1 The location of Mugii Murum-ban State Conservation Area in eastern Australia relative to DEC (2006) map area, Greater Blue Mountains World Heritage Area and the boundaries of the two bioregions which it borders. The air photo shows the proximity of Mugii Murum-ban SCA to Capertee National Park (NP) and Gardens of Stone NP. Other areas not marked are private property with mixed farming and remnant vegetation

The terms vegetation type and ecosystem require clear definitions for effective use. Herein an ecosystem is defined using the function based approach of the Global Ecosystem Typology (Keith et al. 2020) to mean a Global Ecosystem Type—a complex of organisms and their associated physical environment within an area at the fifth level down the six level Global Ecosystem Typology. For example, many of the forests in this study have similar functional properties and nest within the Temperate Pyric Humid Forests (T2.5) Ecosystem Functional Group. Vegetation type is then defined as a variant or subunit of a Global Ecosystem Type. However, it is acknowledged that other approaches exist and may offer differing advantages such as currently higher spatial resolution (e.g., Sayre et al. 2020).

Study area

This study centres on Mugii Murum-ban State Conservation Area (MSCA—Fig. 1). MSCA has been mapped by sub-regional scale mapping (DEC 2006a, b—hereafter referred to as DEC) and state scale mapping (Central Tablelands Region Version 1_0_ VIS_ID 4778; available at www.seed.nsw.nsw.gov.au—hereafter referred to as CT). These maps represent ecosystem variants as vegetation types (also referred to as Map Units—MU). MSCA is a 3655 ha reserve which forms an important link between Capertee National Park and The Gardens of Stone National Park within Capertee Valley New South Wales (Fig. 1). MSCA is within the Blue Mountains World Heritage Area (Fig. 1), one of the most significant conservation areas in Australia, which includes diverse vegetation types and endemic threatened species (DEC 2008). To the west the slopes of the Great Dividing Range support drier woodlands and forest types, hence MSCA sits at the junction of distinct bioregions (Fig. 1). State Conservation Areas are a reserve type which do not preclude all ongoing disturbance (www.environment.nsw. gov.au/topics/parks-reserves-and-protected-areas/types-of-protected-areas—accessed 6/7/22) yet MSCA holds a diversity of critically endangered to vulnerable species and vegetation types (RPS 2014). Thus an understanding of biodiversity values and their spatial patterns is paramount to avoid on-going ecosystem and species decline.

Sub-regional map

DEC mapping (157,124 ha) utilized an approach common throughout NSW. It mapped a western portion of the GBMWHA (~ 1,000,000 ha) near bioregion boundaries (Fig. 1; Thackway and Cresswell 1995) and thus provides mapping for a chain of important conservation reserves (Fig. 1). Mapping was based on a "comprehensive" field survey program and "extensive field reconnaissance" (DEC 2006a) to develop an understanding of vegetation patterns, air photo interpretation (API) to derive vegetation spatial patterns and a classification of vegetation via multivariate similarity (1257 full floristic plots). API was undertaken using 1:25,000 colour photos in conjunction with data layers for geology, soil, elevation, rainfall and aspect. MSCA was subject to field reconnaissance and 25 of the full floristic plots were undertaken within it. Spatial accuracy of the API was reported as over 95% within 37.5 m for line work using higher resolution (1:40,000) air photos tested on 10% of polygons.

State mapping

The CT map (VIS_ID 4778) is a component of the NSW state map program (SVTM) that employs a consistent methodology across NSW (OEH 2017). The methodology maps Plant Community types (PCTs) which are vegetation types largely delineated on floristic patterns. CT mapping utilized over 400 floristic plots analysed using UPGMA clustering in Primer (Clarke and Gorley 2006) with significant groups identified using SIMPROF to define PCTs. Spatial modelling of PCTs was undertaken via Boosted Regression Trees on over one hundred candidate environmental predictor variables, including climate, geology, soil, geophysical data, and terrain indices. Then PCTs were allocated to polygons derived from a segmentation algorithm using high spatial resolution imagery (ADS40—50 cm; see details of ADS imagery in DPE 2022) and

constrained by structural features and IBRA (Interim Bioregionalisation of Australia v7; available from www.seed.nsw.gov.au and see Thackway and Cresswell 1995). No additional floristic plots for MSCA are reported for the CT mapping in the state plot dataset and the level of reconnaissance limited.
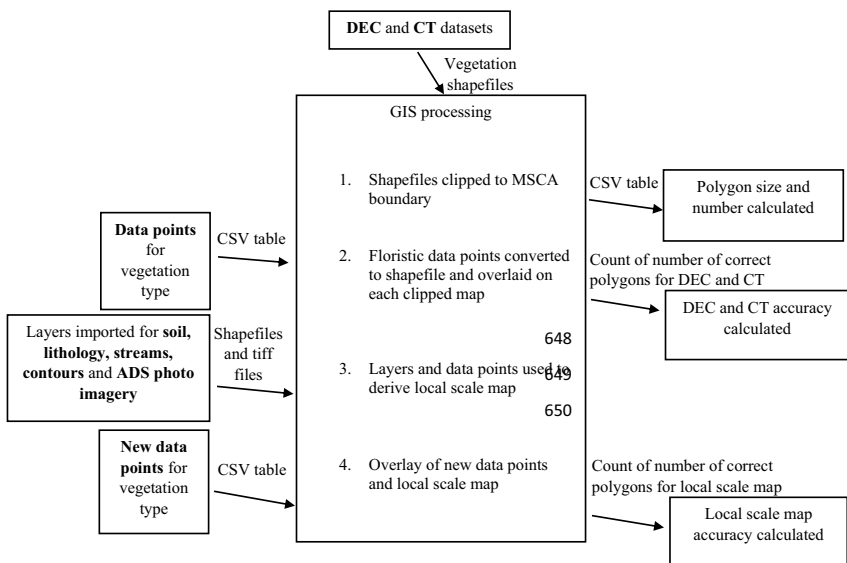
Method

Mapping

Accuracy

The DEC and CT map were imported into QGIS (version 3.12) then clipped to the MSCA boundary and exported as shapefiles to Manifold GIS 8.0 for further processing (Fig. 2). Map units in DEC and the CT map were equated using the BioNet Vegetation Classification (www.environment.nsw.gov.au/research/Visclassification.htm)—accessed 15 July 2021 and data in DEC (2006a, b) and OEH (2012). Then the floristic accuracy of each map

a. Workflow for data processing

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                          ┌─────────────────────────────┐
                          │   DEC and CT datasets       │
                          └─────────────────────────────┘
                                        │ Vegetation
                                        │ shapefiles
                          ┌─────────────▼───────────────────────┐
                          │            GIS processing             │
                          │                                        │         CSV table    ┌──────────────────────┐
  ┌──────────────┐        │  1. Shapefiles clipped to MSCA        │────────────────────▶ │ Polygon size and     │
  │ Data points  │ CSV    │     boundary                          │                       │ number calculated    │
  │ for          │ table  │                                        │                      └──────────────────────┘
  │ vegetation   │──────▶ │  2. Floristic data points converted   │   Count of number of correct
  │ type         │        │     to shapefile and overlaid on      │   polygons for DEC and CT
  └──────────────┘        │     each clipped map                  │                       ┌──────────────────────┐
  ┌──────────────────┐    │                              648      │────────────────────▶ │ DEC and CT accuracy  │
  │ Layers imported  │ Shapefiles                                  │                      │ calculated           │
  │ for soil,        │ and tiff│                          649      │                      └──────────────────────┘
  │ lithology,       │ files│  3. Layers and data points used to   │
  │ streams,         │──────▶│     derive local scale map           │
  │ contours and ADS │    │                              650       │
  │ photo imagery    │    │                                        │
  └──────────────────┘    │  4. Overlay of new data points        │   Count of number of correct
  ┌──────────────┐        │     and local scale map               │   polygons for local scale map
  │ New data     │ CSV    │                                        │                       ┌──────────────────────┐
  │ points for   │ table  │                                        │────────────────────▶ │ Local scale map      │
  │ vegetation   │──────▶ │                                        │                       │ accuracy calculated  │
  │ type         │        └───────────────────────────────────────┘                      └──────────────────────┘
  └──────────────┘
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b. Datasets used and source

Dataset	Type	Source
DEC	Map and descriptions of sub-regional vegetation	DEC (2006) *The Vegetation of the Western Blue Mountains including the Capertee, Coss, Jenolan & Gurnang Areas Volumes* 1 & 2 **https://www.seed.nsw.gov.au/**
CT	Map and descriptions of part of a state-wide map in the Central Tablelands	OEH (2012) *The Native Vegetation of North-west Wollemi National Park and Surrounds. Volume 1* **https://www.seed.nsw.gov.au/**
Data points	Assessment of vegetation type at points in MSCA	Field data collected before 2022 – **supplementary data S2**
Lithology and soil	Underlying geology and soil mapping	NSW_SeamlessGeology_GDA94_v2_1 **https://www.seed.nsw.gov.au/**
Stream	Map of streams for the state of New South Wales	NSW stream layer **https://www.seed.nsw.gov.au/**
Contours	Mapped altitudes for state of New South Wales	NSW contour layer **https://www.seed.nsw.gov.au/**
ADS imagery	High resolution air photo for Wallerawang area	NSW Imagery Basemap Service **https://portal.spatial.nsw.gov.au/**
New data points	Assessment of vegetation type at points in MSCA	Field data collected 2022 – **supplementary data S2**

Fig. 2 Workflow for data processing, data used, processing steps and outputs. **a** Workflow for data processing. **b** Datasets used and source

within MSCA was scored by overlaying 357 floristic data points previously assigned to a map unit of DEC (2006a, b). Floristic data points consisted of 77 full floristic quadrats and 280 rapid data points. (details of quadrats and rapid data points in RPS (2014): data available in BioNet—www.bionet.nsw.gov.au) and taxonomy in Plantnet (plantnet.rbgsyd.nsw. gov.au). Briefly, quadrats were standard 400 m^2 plots with all tracheophytes scored using a 6-point Braun-Blanquet score. Rapid data points are visual assessments of the three dominant species in overstorey (defined for these points as > 3 m), mid-storey and ground cover (to 1 m) observed from a single point that were observed within a vegetation. All data points involved a consistent observer (D Tierney).

Spatial scale

The number and size of polygons (mean ± se) mapped by DEC and CT within the SCA were calculated from an exported csv file from the MSCA clipped maps. Thus relative spatial detail was defined by differences in the number and size of mapped polygons.

Conservation values

The conservation value of each map for vegetation type was compared in two ways.

Detection of significant vegetation types The number of significant vegetation types detected as present within MSCA was determined for both maps. Significant vegetation types were defined as a threatened ecological community (TEC) under Australian State (legislation.nsw.gov.au/view/html/inforce/current/act-2016-063, accessed 2/7/2022) or Commonwealth (legislation.gov.au/Details/C2021C00182, accessed 2/7/2022) legislation or a regionally restricted or poorly known vegetation type. Vegetation type descriptions provided in DEC (2006a) and OEH (2012) were assigned to TECs by referencing TEC determinations (https://www.environment.nsw.gov.au/topics/animals-and-plants/threatened-species/ nsw-threatened-species-scientific-committee/determinations/final-determinations, accessed 2/7/2022). Regionally restricted and poorly known vegetation types (rare vegetation types) were assessed based on the Relative Ecosystem Rarity scale (https://www.epa.gov/enviroat-las/ecosystem-rarity-toolbox accessed 23/4/22) which assesses rarity via normalized rank (100 = highest rarity; 0 = lowest rarity) using estimated areas reported for DEC and CT. Rarity may be assessed by absolute area (e.g., up to a few hundred hectares has been considered rare for vegetation types, and herein < 200 ha was used as an indicator of potential rarity—Wiser et al. 2013). Rarity assessment via absolute area, however, has limitations (e.g., McLean and Ronalds 2000), whilst relative rarity can provide a prioritization for management. Poorly known vegetation types were those where DEC or CT provided no estimate of the vegetation type extent in the region (i.e., it was unmapped in the sub-region and likely highly restricted). Detection (verified presence within MSCA) was scored where floristic data or imagery was unambiguously confirmatory (S1).

Relative accuracy of vegetation mapping MSCA was remapped at a fine scale using floristic survey points and high resolution air photos (Wallerwang_2009131; ADS imagery captured 2009). Mapping was undertaken in Manifold GIS (as above) using overlays of: 1. Georeferenced orthorectified ADS40 air photo imagery (DPE 2022) viewed at ~1:5000. 2. The 357 data points described above and an additional 25 data points (full floristic quadrats undertaken for DEC 2006a; b). 3. Soil and lithology mapping in NSW_SeamlessGeol-

ogy_GDA94_v2_1. 4. NSW contour layer 5. NSW stream layer (all soil, geology, contour and stream data available at www.seed.nsw.gov.au, accessed 25/7/2021). Each polygon was inspected and boundaries redrawn where difference in vegetation pattern (crown cover; texture and colour; perceived height) were discerned with reference to landscape patterns (e.g., aspect; slope; stream and gully patterns; mapped soil and lithology) known to correlate with vegetation type. This mapping was assessed for accuracy using an additional 31 new rapid data points (S2—rdps 281–311) and 10 new quadrats (S2—quadrats 78–88). Overall relative accuracy of DEC and CT was then calculated (relative accuracy = % accuracy / % accuracy of local map). Spatial overlap (% of overlap of mapped polygons) of significant communities mapped by DEC and CT with the local map was then used to determine relative accuracy using overlays in Manifold GIS.

Results

Mapping

Accuracy

DEC determined 21 map units to be present in the SCA (Fig. 3). The accuracy of floristic attribution was 77%. CT determined 15 map units to be present with four units mapped by DEC not mapped (Fig. 4). The accuracy was 66%.
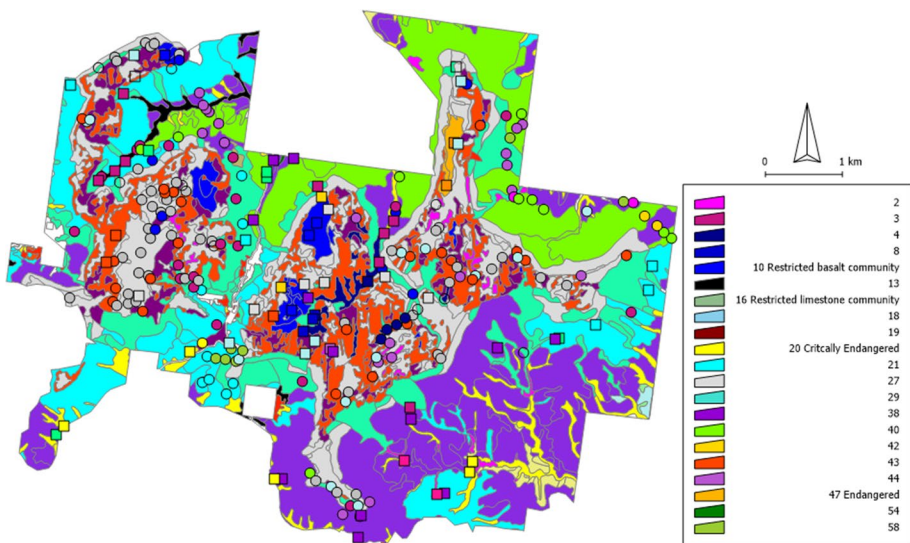
Fig. 3 Vegetation mapped within Mugii Murum-ban State Conservation Area by DEC overlaid with floristic data points used for assessing DEC accuracy. Data points coloured to the map unit each represents with circles being rapid data points and squares quadrats. Numbers in the legend are the map unit numbers of DEC and the DEC report can be used to assess the composition and similarity of vegetation types. The conservation status of four communities of particular conservation concern shown by text (being of restricted distribution, endangered or critically endangered)
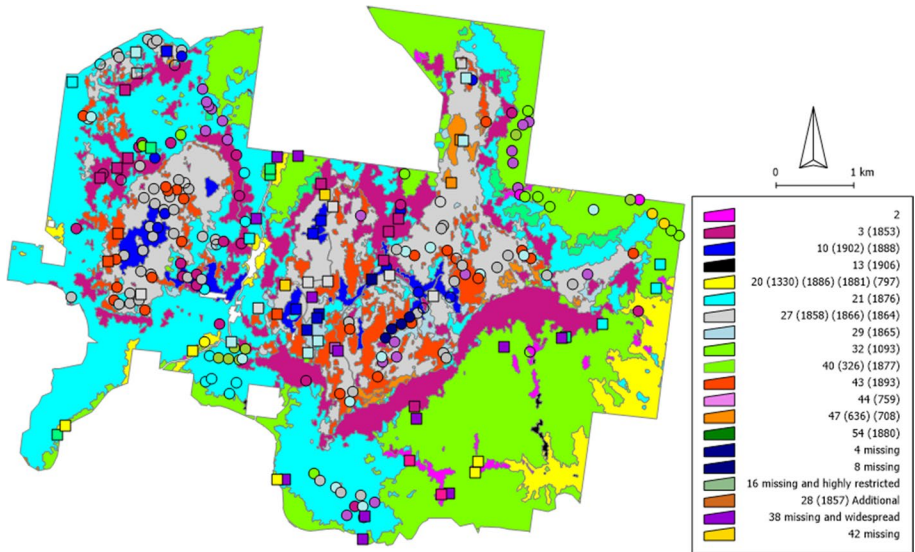
Fig. 4 Vegetation mapped within Mugii Murum-ban State Conservation Area by CT overlaid with floristic data points used for assessing CT accuracy. Data points coloured to the map unit each represents with circles being rapid data points and squares quadrats. Numbers in the legend are the map unit numbers of DEC. Map units mapped by DEC but not by CT shown in legend as "missing" and CT map unit equivalents shown in brackets

Spatial scale

DEC mapped 998 polygons with a mean polygon size of 3.53 ± 3.54 ha. CT mapped 3892 polygons with a mean polygon size 0.91 ± 0.04 ha. Hence the spatial detail of the CT mapping was ~ four times more detailed than that of DEC mapping.

Conservation value

Detection of significant vegetation types DEC determined six vegetation types to be potentially rare in the sub-region (< 200 ha) and four of these were mapped within MSCA (Table 1; Fig. 3). Of these: 1. The Endangered Ecological Community (EEC)—Genowlan Point Allocasuarina nana heathland EEC (also referred to as Rocky Heath—MU47) occurs only within MSCA and was also mapped by CT (Fig. 4). 2. The restricted/poorly known Capertee Limestone Hills Grey Box-Grass Tree-Spinifex Woodland (a highly unusual woodland—MU16 on Fig. 3) was mapped by DEC but not CT, despite strong evidence for its presence which predated the CT mapping (Table 1; S1). 3. A Dry Rainforest community at its western limit (MU2) was mapped by both DEC and CT. 4. A Wet Sclerophyll Forest type (MU4) also approaching the western limit for this community was mapped by DEC but not CT. Additionally, a nationally Critically Endangered Ecological Community that is very poorly represented in reserves (Tierney et al. 2021—White Box—Yellow Box—Blakely's Red Gum Grassy Woodland and Derived Native Grassland in the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern

Table 1 Rationale for qualification as a significant community within the sub-region, extent (hectares and % of sub-region) and relative rarity (ranked from 100=most rare to 0=least rare with % >90 in bold) in the DEC study area and in MSCA

Community (Community variant—MU of DEC 2006a, b)	Rationale	Sub-region extent (%) Relative rarity	MSCA extent Relative accuracy DEC Relative accuracy CT		Evidence in MSCA (S 1)
Warm Temperate Rainforest (MU1)	Regionally rare	4 (0.003) **100**	0	NA NA	None
Dry Rainforest (MU2)	Regionally rare	39 (0.02) **93**	12	11 16	Strong (floristic plots)
Wet Sclerophyll Forest (MU4)	Regionally rare	71 (0.04) 85	29	73 0	Strong (floristic plots)
Capertee Limestone Hills Grey Box-Grass Tree Spinifex (MU16)	Regionally rare	108 (0.07) 80	1.6	100 0	Strong (rapid data point)
Box Gum Woodland (MU20)	Critically Endangered	5457 (3.5) 13	113	55 17	Strong (floristic plots)
Rocky Heath—endangered community (MU47)	Endangered (MSCA only)	16 (0.01) **97**	16	100 33	Strong (floristic plots)
Melaleuca Thicket (MU57)	Regionally rare (Capertee Valley only)	32 (0.02) **95**	0	NA NA	None

The extent (hectares), relative accuracy (%) of the mapping for both DEC and CT and evidence for the community in MSCA

NA not mapped

Highlands, NSW South Western Slopes, South East Corner and Riverina Bioregions) was mapped in MSCA by both DEC and CT (map unit 20).

Relative accuracy of vegetation mapping Remapping of MSCA (Fig. 5) resulted in an accuracy of 83%. The overall relative accuracy of DEC and CT was 92% and 80% respectively to this local map. However, a large variation in relative accuracy occurred among communities. Of note: 1. The total area of Dry Rainforest (MU2—regionally rare) found within MSCA increased considerably in the local mapping due to previous low accuracy mapping of this vegetation type by DEC and CT (Table 1—relative accuracy of DEC and CT both less than 20%—and see evidence in S1). 2. A Wet Sclerophyll Forest (MU8) mapped within MSCA by DEC (2006a; b) (canopy dominated by *Eucalyptus fastigata* and *Eucalyptus piperita*) was generally dominated by *E. cypellocarpa* (MU3). 3. A Shrubby Woodland (MU30—dominated by *Eucalyptus sieberi*) was incorrectly mapped within the SCA, this species was not found within MSCA and these areas were MU29 (dominated by *Eucalyptus piperita*). 4. The Open Forest MU32 not previously mapped within MSCA occurred in small areas. 5. A considerable increase of a Stringybark Shrubby Woodland (MU40) resulted from reduced mapping of MU21 and MU38 within MSCA. In sum, relative accuracy of DEC and CT was low for a number of vegetation types, including regionally rare and nationally threatened types, with the CT mapping generally less accurate (Table 1).
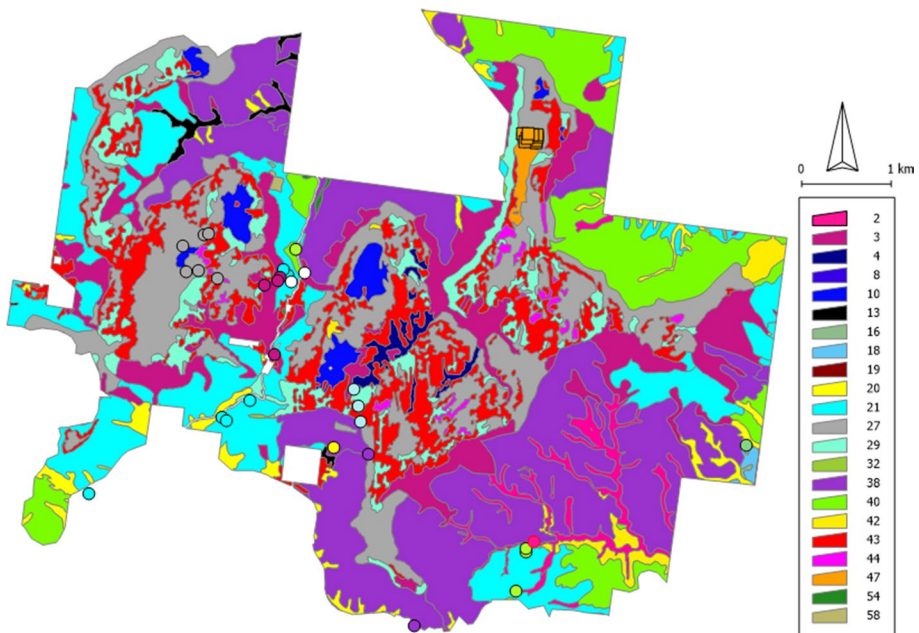
Fig. 5 Derived local scale map of vegetation communities within the SCA displayed via DEC (2006a, b) map units. Rapid data points undertaken to assess accuracy shown as circles and quadrats shown as squares with both coloured to the map units they represent except for two circles coloured white which do not match any map unit in the SCA

Discussion

There is a rich history and ongoing debate about the nature of vegetation types, how they vary through time and space and the drivers and level of stochasticity to species assembly (Cavender-Bares et al. 2019 accessed 3/7/22). Thus the extent to which local vegetation patterns represent critically important conservation units is not fully resolved. Overall, however, local and rare vegetation types with distinct phylogenies are likely of high habitat (Holdway et al. 2012.) and conservation (Cavender-Bares and Cavender 2011) value, potentially centres for evolutionary processes (e.g., Gross 2008; Lawrence et al. 2012; Alexander et al. 2022) and thus rightly the focus of reserve management (Smith et al. 2019). Local and rare vegetation types frequently are restricted to landscape features that are themselves rare. For example, in this study, MU16 is noted as a variant of the broad ranging Box Gum Woodland (Tierney et al. 2021) but on restricted limestone derived soils (DEC 2006b). This variant also supports *Triodia scariosa* and *Xanthorrhoea*, which occur sporadically across the landscape, but function as important faunal resources (Swinburn et al. 2007; Verdon et al. 2020). Similarly MU47, which is restricted to MSCA, is associated with a restricted landscape feature (a large ironstone band) but floristically and structurally distinct from other heathlands (https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10344 accessed 2/7/22). These vegetation types may be difficult to detect or under mapped. However, management and monitoring within local conservation reserves will be weakened and resources likely misallocated if their mapping is poor (Wyborn and Evans 2022).

At larger scales (e.g., global; national; state level) mapping is required of broad associations or ecosystems (e.g., Chaplin-Kramer et al. 2002; Keith et al. 2020). Thus CT mapping provides a common map methodology at the state level that allows for the assessment of the status of ecosystems for broadscale management and planning (OEH 2017). However, ecological decline is often cumulative and driven by loss across multiple points (e.g., Mayani-Parás et al. 2021) where rare species and assemblages can contribute disproportionately to ecosystem function (Leitão et al. 2016) and loss of species interactions a key driver of decline (Valiente-Banuet et al. 2015). Thus tracking biodiversity values requires mapping that adequately maps vegetation types for local reserve management, but broader scale mapping allows for this to be placed in a national or global context (Keith et al. 2020).

At the reserve level CT was of low overall accuracy relative to DEC, although still within an accuracy range commonly recorded (Franklin et al. 2001; O'Donoghue and Lyons 2007; EcoLogical 2011; Lewis and Phinn 2011; Tierney 2022). However, critically, CT did not map six of 21 vegetation types mapped by DEC. This included two rare vegetation types and mapped only one third of another, despite evidence for their presence. Detailed spatial attribution of map polygons by CT (4 times the detail of DEC mapping) was not associated with increased map accuracy in this comparative study. Instead, the most inaccurately mapped rare vegetation types (MU2 and MU20—19 and 36% accuracy averaged across the DEC and CT maps respectively) occurred predominately in the south-east of MSCA with difficult access and relatively few survey points. This is consistent with the noted association of data quantity to map accuracy (Stockwell and Peterson 2002). Rare vegetation types are also inherently associated with risk (IUCN 2016). Thus for these systems there is a confluence of high conservation value, high risk and a potential for low map accuracy where mapping is not fit for purpose.

A further consideration is that many assessment methods characterise vegetation types by centroids (a hypothetical "average"—Anderson 2001) or by inclusion within defined statistical bands (DPIE 2020) which exclude rare outliers. These methods are often used to make crucial irreversible decisions (Goncalves et al. 2015). Since reserves are often scarce resources (Maxwell et al. 2020) efficiency in their management is warranted, but statistical processes that exclude rare outliers have potential to produce perverse outcomes given their conservation value. Additionally, mapping vegetation types into discrete units which drive statistical assessments does not account for potentially important spatial gradational patterns (Powell et al. 2004) and temporal dynamics (Hunter 2001). It is also important to note that this study has not assessed the validity of the modelling undertaken by the assessed studies, only their accuracy in predicting on-ground occurrence. Imagery quality may also vary through time affecting map accuracy. However, in this instance imagery quality has improved whilst map accuracy declined among assessed studies, so it was not a factor that produced lower accuracy (see imagery details in DEC 2022).

Large investments in ecosystem management are required to reverse widespread global decline (Brondizio et al. 2019), but funding is limited (Wintle et al. 2019). Thus conservation planning has long sought efficient solutions to conservation goals (e.g., Margules and Pressey 2000). The base data that drives such planning is of critical importance and the mapping of vegetation type a critical base dataset. This study determined important differences in map accuracy for rare vegetation types among mapping programs focused at differing spatial scales with differing techniques and datasets. In this instance sub-regional mapping using higher levels of expert knowledge and an associated field program within a reserve generated important knowledge for management. In contrast assessments heavily reliant upon modelled outputs may have limited local accuracy (Felix and Binney 1989; Burns et al. 2020) and should be carefully evaluated before use at local scales.

Declarations

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