Received: 8 September 2024 | Revised: 26 January 2025 | Accepted: 21 April 2025

DOI: 10.1111/cobi.70099

Conservation Biology

CONTRIBUTED PAPER

Applying the IUCN Global Ecosystem Typology to classify, describe, and map ecosystems based on regional data and Indigenous knowledge

Alys R. Young[1,2] | **Hugh F. Davies**[3,4] | **Margaret L. Ayre**[2] | **Alana Brekelmans**[1,5,6] | **Brett A. Bryan**[1] | **Jane Elith**[2] | **Kate Hadden**[7] | **Mavis Kerinaiua**[1,8] | **David A. Keith**[9] | **Donna L. Lewis**[3,10] | **Kinjia M. Munkara-Murray**[2] | **Sarah Ryan**[7] | **Michaela Spencer**[5] | **Emily Nicholson**[1,2]

[1]School of Life and Environmental Sciences, Faculty of Science, Engineering, and Built Environment, Deakin University, Burwood, Victoria, Australia

[2]School of Agriculture, Food and Ecosystem Sciences, Faculty of Science, The University of Melbourne, Parkville, Victoria, Australia

[3]Research Institute for the Environment and Livelihoods, Charles Darwin University, Casuarina, Northern Territory, Australia

[4]School of Environmental and Rural Science, Faculty of Agriculture, Business and Law, University of New England, Armidale, New South Wales, Australia

[5]Northern Institute, Charles Darwin University, Casuarina, Northern Territory, Australia

[6]TC Beirne School of Law, University of Queensland, St Lucia, Queensland, Australia

[7]Tiwi Land Council, Winnellie, Northern Territory, Australia

[8]Tiwi Resources, Casuarina, Northern Territory, Australia

[9]Centre for Ecosystem Science, School of Biological, Earth and Environmental Science, University of New South Wales, Sydney, New South Wales, Australia

[10]Terrestrial Ecosystem Research Network (TERN), The University of Adelaide, Adelaide, South Australia, Australia

Correspondence
Alys R. Young, School of Life and Environmental Sciences, Faculty of Science, Engineering, and the Built Environment, Deakin University, 221 Burwood Highway, Burwood VIC 3125, Australia.
Email: a.young@research.deakin.edu.au

Article impact statement: The IUCN Global Ecosystem Typology guides the classification, description, and assessment of local ecosystems from disparate information.

Funding information
Australian Research Council, Grant/Award Number: LP170100305; Centre of Excellence in Quantum Biotechnology; Centre of Excellence in Synthetic Biology; Centre of Excellence for Plant Success in Nature and Agriculture; Foundation for National Parks and Wildlife, Grant/Award Number: Community conservation grant FNPW028CCG22

Abstract

Effective ecosystem conservation for biodiversity and human well-being relies on accurate information. Consistent approaches to classifying, describing, and assessing ecosystems can improve understanding of ecological processes, threats, and management. We explored how the International Union for Conservation of Nature (IUCN) Global Ecosystem Typology—a global classification framework based on ecosystem function—could support the development of a classification of ecosystems for the Tiwi Islands, Australia, by incorporating scientific information and Indigenous Tiwi knowledge to facilitate environmental management and conservation. We synthesized ecosystem information from previous research, field data, reports, and Tiwi knowledge authorities to develop a classification, descriptions, and a map of 14 terrestrial ecosystem types. These ecosystem types were defined and described based on ecological processes and were broader yet largely congruent with existing vegetation classifications. Including functional properties accounted for variation in the vegetation physiognomy exhibited by dynamic and disturbance-prone ecosystems, such as savannas. Because we considered Tiwi knowledge authorities and the IUCN Global Ecosystem Typology, our inventory included ecosystem types that were typically omitted from previous classifications, which should allow for more comprehensive assessments and management. Relating the new ecosystem typology to the IUCN Global Ecosystem Typology will facilitate comparisons among similar ecosystems, regarding, for example, effective threat abatement options. Describing the biota and processes opens new avenues for monitoring. More collaborative work is needed to explore how Western scientific ecosystem inventories operate alongside and in connection with management of Tiwi *murrakupuni* enacted by Tiwi people. Given the ongoing loss of biodiversity, ecosystem management must draw on information across domains, scales, and knowledge systems. We demonstrated an approach to this task and provided socioecologically relevant ecosystem information.

KEYWORDS
ecological community, Indigenous ecological knowledge, Landsat-9, landscape ecology, random forest, remote sensing

INTRODUCTION

Maintaining ecosystem integrity is a proactive and cost-effective approach to conservation that sustains biodiversity and people (Díaz et al., 2018; Nicholson et al., 2021; Noss, 1996). The management and conservation of ecosystems are predicated on comprehensive and accurate information that describes their characteristics, the processes that shape these characteristics (called drivers), and their distributions (Wurtzebach & Schultz, 2016). Local knowledge and data often underpin such ecosystem information. However, ecosystems share traits globally, allowing information to be inferred from similar ecosystems worldwide (Keith et al., 2020). Many fields contribute to ecosystem information, including research domains and institutions, government databases, and Indigenous or traditional knowledges. In general, ecosystem information must be fit for local goals, represent the unique assemblages of biodiversity, and be generalizable to and consistent with national and international scales for monitoring and reporting (Convention on Biological Diversity, 2022; Nicholson et al., 2024). The challenge in developing ecosystem knowledge lies in integrating information across such vastly different scales and domains effectively and with consistency (Chaplin-Kramer et al., 2022).

Recent advances in ecosystem science support linking information across scales and domains through consistent approaches to classify, describe, and assess ecosystems. Here, ecosystem refers to a dynamic complex of biotic communities with the abiotic environment interacting as a functional unit, as per the United Nations Convention on Biological Diversity (1992). Ecosystem types are differentiated by uniqueness in composition, structure, processes, and functions (Keith et al., 2020). The International Union for Conservation of Nature (IUCN) Global Ecosystem Typology (GET), an internationally accepted standard for classifying ecosystems (Keith et al., 2022; UNSD, 2021), provides a globally comprehensive typology of ecosystem types within a hierarchical structure of 6 levels. The higher levels (1–3) are defined and described with global relevance (Keith et al., 2020). The lower levels (5 – 6) emerge from local information, such as on-ground observations and plot-based data. Level 4, like the higher levels, is a top-down approach in which the level 3 class is divided by biogeographic boundaries to capture ecoregional expressions with distinct species compositions. The GET defines consistent and ecologically relevant units instrumental for conservation, such as risk assessments, monitoring, planning, and valuation (Keith, Ghoraba et al., 2024; Nicholson et al., 2024; Xiao et al., 2024).

Although global consistency in ecosystem information has benefits, ecosystem types must still be relevant to the local scale (Cumming et al., 2006; Schultz et al., 2019). Global summaries and broad information can obscure the local context and values, such as threatened and culturally important elements of biodiversity (Goolmeer et al., 2022; Turnhout & Boonman-Berson, 2011; Wyborn & Evans, 2021). These limitations can be addressed by describing ecosystems at the lower levels of classification schemes (Hunter & Addicott, 2021; Keith et al., 2022) and harmonizing across the available regional and local classification schemes (Muldavin et al., 2021). The GET has been used to develop new ecosystem classifications (e.g., Murray et al., 2020; Toor et al., 2022; Tóth et al., 2025). However, contextualizing globally consistent ecosystem information with Indigenous local knowledge is yet to be demonstrated.

There is growing recognition of Indigenous peoples and traditional local communities (IPLCs) and their diverse knowledges in global frameworks and multilateral agreements (Tengö et al., 2017). At the local scale, IPLC knowledges and practices contribute to many conservation-related topics, including ecosystem dynamics, assessments, restoration, and management (Brondízio et al., 2021; Ens et al., 2015; Gadgil et al., 1993) and ethnoecological research on landscape classification (Johnson & Hunn, 2010). Detailed classifications have been described by IPLCs globally (Babai & Molnár, 2013; Gantuya et al., 2019; Mark & Turk, 2003; Wartmann & Purves, 2018). Numerous collaborative partnerships involving IPLCs and ecologists showcase these efforts (Molnár et al., 2024; White et al., 2023), which can achieve outcomes better suited to particular socioecological contexts (Bach et al., 2019; McElwee et al., 2020; Moorcroft et al., 2012), improve scientific knowledge (Berkes et al., 2000; Gadgil et al., 1993), and result in conservation success (White et al., 2023). At the global scale, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) has adopted a landmark change in environmental governance by recognizing IPLCs as key stakeholders and supporting a diverse evidence base from multiple knowledge systems to inform assessments (Díaz et al., 2018; Hill et al., 2021). This change has influenced multilateral agreements.

We conducted the first application of the GET to developing a globally consistent yet locally relevant ecosystem typology from existing but disparate scientific information and Indigenous knowledges through a case study of the Tiwi Islands in northern Australia. This new typology for Tiwi ecosystems was designed to support contemporary management in a respectful manner with Tiwi peoples, rather than landscape classification by Tiwi people. The islands hold national and international conservation significance in that they support endemic, migratory, and threatened species and have relatively intact ecosystems (EcoSure, 2009; NRETAS, 2008; Woinarski & Baker, 2002; Woinarski et al., 2000). In accordance with ancestral governance practices, Tiwi people undertake strong and active ways of managing Tiwi people-places (*murrakupuni* in Tiwi language). Within and alongside these practices, biodiversity is managed with contemporary methods, including prescribed fire, marine debris collection, and invasive species management, and balanced with localized economic development predominantly through a large forestry operation (TLC, 2024a, 2024b; Woinarski & Baker, 2002).

We aimed first to apply the GET framework to develop a new ecosystem typology for the Tiwi Islands by synthesizing national, regional, and local information into ecosystem descriptions and conceptual models. Second, we sought to map the distribution of the ecosystem types to support spatial planning.

METHODS

Overview and positionality

Many of the steps in our approach interacted with each other (Figure 1). First, we identified and described the ecosystem types of the Tiwi Islands through an iterative process of reviewing the existing vegetation classifications and through consultation with Tiwi people with knowledge of the environment and the authority to share that knowledge (henceforth Tiwi knowledge authorities). We compiled written descriptions, photographs, and conceptual models for each ecosystem. Second, we compiled existing spatially explicit data and undertook fieldwork to identify example locations of each ecosystem type. We then used the example locations to train a random forest model with Landsat-9 satellite imagery and environmental variables to map the distribution of ecosystems.

We are an interdisciplinary research team of non-Indigenous Australian and Tiwi ecologists, land managers, social scientists, anthropologists, and knowledge experts. Among us, we have worked on the Tiwi Islands and with Tiwi people for many years through multiple past and current projects in research and management. All authors worked as a collaborative group to ensure the research was guided by our collective expertise.

Study area

The Tiwi Islands comprise Melville Island (5788 km^2) and Bathurst Island (1693 km^2), as well as smaller surrounding islands (Figure 2). The islands are in one Australian bioregion, Tiwi-Cobourg (DCCEEW, 2021), and one global ecoregion, Arnhem Land tropical savanna (Olson et al., 2001), and have a tropical monsoonal climate (Bureau of Meteorology, 2024).

Tiwi people own the Tiwi Islands under the *Northern Territory Land Rights Act 1976*, which is administered by the Tiwi Land Council. The 8 land-owning clans represented in the Tiwi Land Council are Jikilaruwu, Malawu, Mantiyupwi, Marrikawuyanga, Munupi, Wulirankuwu, Wurankuwu, and Yimpinari. The clans share one common language, Tiwi, and a rich cultural history (Kerinaiua & Rademaker, 2023). Approximately 2348 people reside on the Tiwi Islands, of which 85.1% self-identify as Indigenous (ABS, 2021). The population is largely congregated in 3 towns: Wurrumiyanga (1421 people), Pirlangimpi (315), and Milikapiti (414) (ABS, 2021). The Tiwi Land Council granted permission to undertake this research, access the data, and do fieldwork.

The Tiwi Land Council aims to use and develop planning tools to balance biodiversity conservation and economic development (TLC, 2022). This requires up-to-date, locally relevant, and spatially explicit information. The need for improved ecosystem information was identified, and the project was established through the *Ngawurra Luwajirri Ngirramini* Scientific Reference Committee, a long-running partnership between the Tiwi Land Council and The University of Melbourne that supports research partnerships related to the environment. Since 2022, research progress has been reported biannually to the committee.

Developing the ecosystem inventory

We reviewed 7 classification schemes that cover the Tiwi Islands (Appendix S1). We used *classification scheme* to refer to both hierarchical systems designed to classify the landscape and mapping datasets compiled based on a classification system. The regional schemes were the previous primary sources of information used for environmental management and planning. Parts of the Tiwi Islands have been subjected to land unit mapping for forestry and agriculture (Woinarski & Baker, 2002). These were not included because of their restricted spatial scope. We compared the ecological processes, vegetation structural formations (i.e., strata, physiognomy, cover, and height), and dominant species or genera documented in the descriptions and the mapped distribution, where available. The comparison involved an iterative process of conversations with managers and botanists and a literature review of the Tiwi-specific information and nearby areas. We assigned membership of each class per classification scheme to the GET ecosystem function groups (EFGs) (level 3) by assessing the similarities of the ecological processes and the properties resulting from common processes, such as vegetation structure and traits. For example, the C4 photosynthetic pathway appears in grasses that experience regular fire. We also checked the applicability of all other classes listed in the classification schemes to ensure the ecosystem inventory was comprehensive.

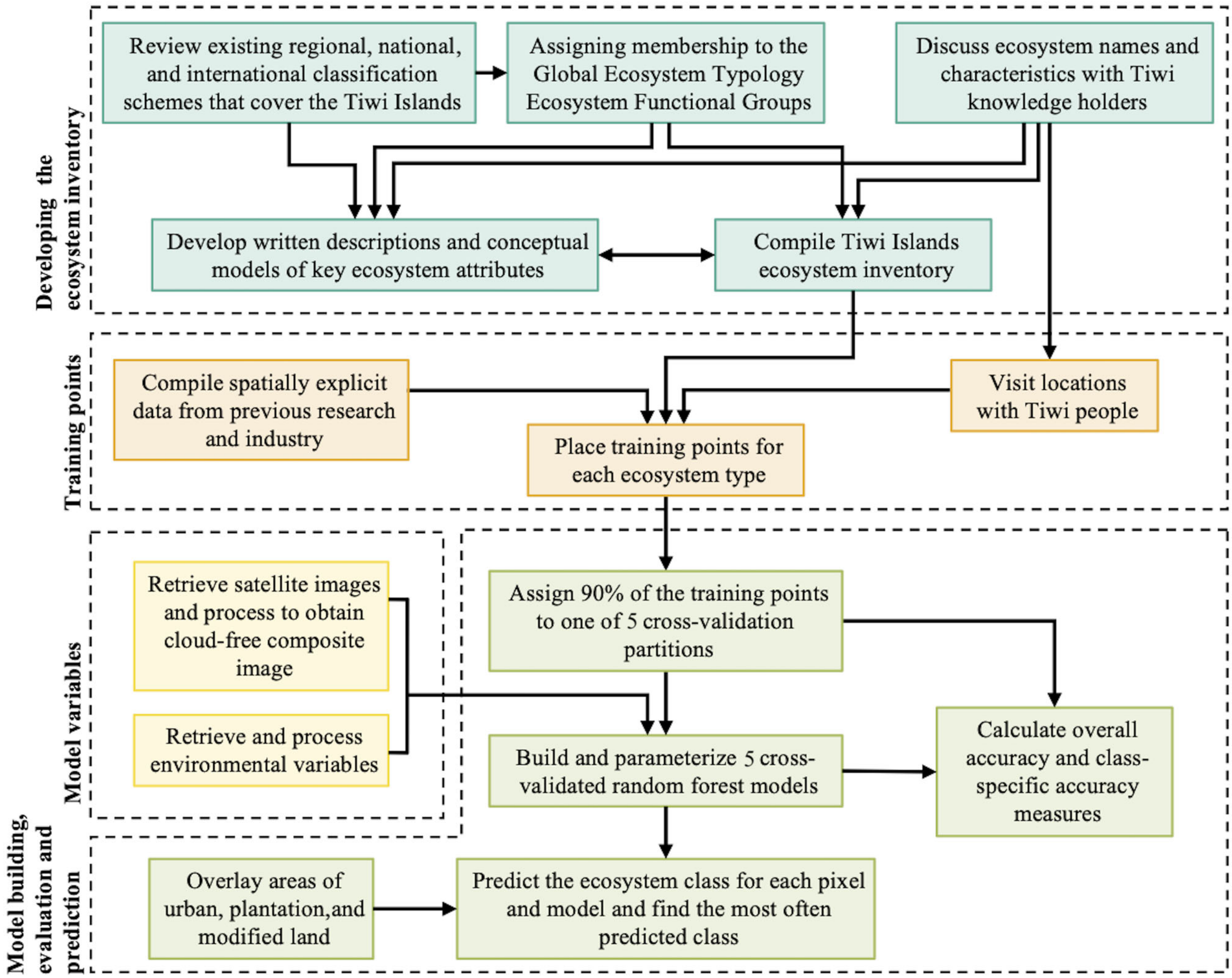

FIGURE 1 Overview of the methods to classify, describe, and map ecosystems based on the International Union for Conservation of Nature Global Ecosystem Typology for the Tiwi Islands, Australia.

We built the ecosystem inventory by comparing the classification schemes and the GET to identify all possible ecosystem types occurring on the Tiwi Islands. The resulting ecosystem types corresponded to the GET level 6 “subglobal ecosystem types” (hereafter Tiwi Island ecosystem types). In the classification schemes and ecosystem-specific information we reviewed, there was little information on entirely aquatic systems on the Tiwi Islands (e.g., streams). Therefore, we did not classify the aquatic ecosystems.

Discussions with Tiwi knowledge authorities

To ensure the ecosystem inventory supported the needs and aspirations of the Tiwi Land Council and Tiwi people for managing Tiwi Country (*murrakupuni*), we evaluated the information gathered through discussions with Tiwi knowledge authorities and the Tiwi rangers, who carry out management tasks. *Country* is an English language approximation that refer to “the traditional land and sea territories of Australia’s Aboriginal and Torres Strait Islander Peoples” (Woodward et al., 2020) and acknowledges the multidimensional relationships between Indigenous peoples and landscapes (Rose, 1996). These discussions were undertaken with research ethics approval by The University of Melbourne (1955248 and amendment 2021-13231-22694-3) and Deakin University (2022-097).

A variety of methods are applied in ethnoecology to engage with IPLCs (Newing et al., 2024). Methods demonstrated in the context of landscape classification, descriptions, and environmental planning include interviews (Babai & Molnár, 2013; Gantuya et al., 2019; Mark & Turk, 2003; Wartmann & Purves, 2018), workshops (Barnett et al., 2023; Hoverman & Ayre, 2012), site visits (Gantuya et al., 2019; Hoverman & Ayre, 2012; Thompson et al., 2019; Wartmann & Purves, 2018), participatory mapping (Hoverman & Ayre, 2012), and combinations of these methods. Prompts, such as photographs, words from dictionaries, maps, and models are also common (Barnett et al., 2023; Gantuya et al., 2019; Hoverman & Ayre, 2012; Mark & Turk, 2003). We used semistructured and unstructured methods to encourage greater active participation by Tiwi people in the research (Newing et al., 2024), including semistructured interviews and site visits (i.e., field walks or visits to Country), which

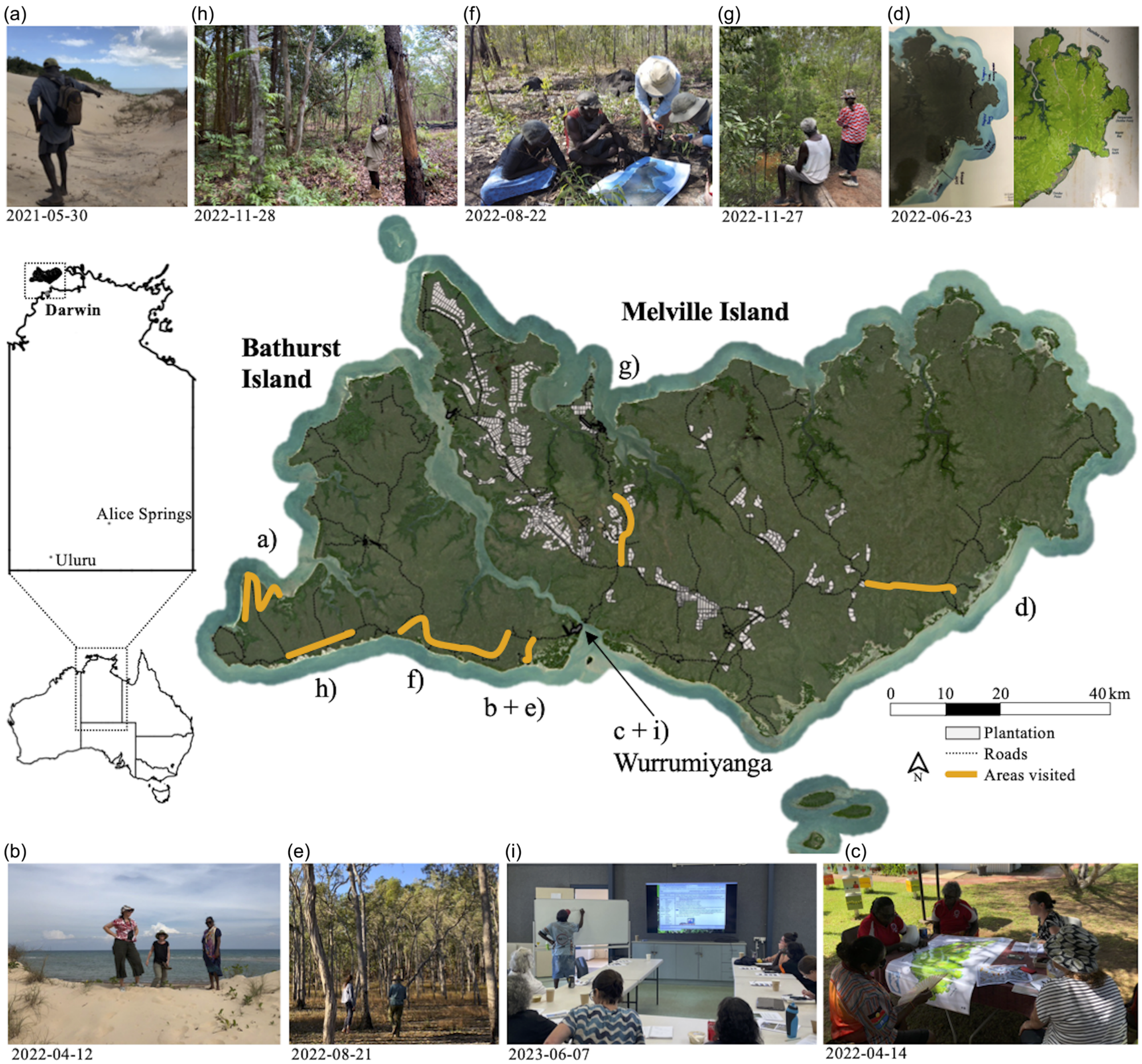

FIGURE 2 Locations (map) and photographs (a–i) of discussions with the Tiwi knowledge authorities regarding types, names, and characteristics of ecosystems and location of study area in Australia. Letters associated with the maps correspond to the picture letters.

are methods that have been used on the Tiwi Islands (Barnett et al., 2023; Hoverman & Ayre, 2012; Thompson et al., 2019).

All Tiwi knowledge authorities were bilingual, and conversations with the non-Tiwi speaking researchers were in English. Conservations between Tiwi knowledge authorities were often undertaken in Tiwi and translated to English when a consensus on terminology or meaning was met. The discussions were undertaken in conjunction with the development of an engagement protocol, the Turtuni Framework (M.K., personal observation). The framework was at times used to guide the activities reported on here.

From 2021 to 2023, we made 6 visits to study sites with 8 Tiwi knowledge authorities, had 2 conversations with 3 Tiwi knowledge authorities in Wurrumiyanga, had numerous ad hoc conversations with Tiwi Rangers (Figure 2a–i), and had one workshop with 11 attendees in Wurrumiyanga (Figure 2j). Lists of the Tiwi knowledge authorities' names and the conversation dates are in Appendix S1. This information is provided with oral consent from the individuals and at the request of the Tiwi Land Council. Different authors were involved in different activities based on their availability and interstate travel restrictions resulting from COVID-19. This process was enabled through key Tiwi institutions to respect Tiwi governance processes, including the Tiwi Land Council, Tiwi Resources, and Tiwi clan groups.

We engaged with Tiwi knowledge authorities in semistructured conversations regarding the ecosystem names, adjectives, and processes. During the site visits, the location visited often led to conversation. For the conversations in Wurrumiyanga, we used large, printed satellite maps. Interview questions are in Appendix S1. We discussed words in Tiwi language to name and describe the ecosystems. When a prompt was needed, we used words from the Tiwi Plants and Animals list of ecosystem names (TLC et al., 2001). We discussed the ecosystem processes, for example, fire (*yikwani* in Tiwi), and species that occur at the location and in the ecosystem in general. This led to topics of the meaning and significance of the location for the Tiwi knowledge authorities. Finally, we discussed impacts that were damaging either the location or the general ecosystem. This series of questions and topics was discussed in a flexible order and style to focus time on topics that the Tiwi knowledge authorities wished to discuss.

A workshop was held with Tiwi knowledge authorities in Wurrumiyanga, at which we discussed topics similar to those covered during the site visits. We used a visual presentation and printed document presentation format (photographs, descriptions, and maps) (Figure 2). The workshop was part of the Tiwi Resources' Knowledge Database project.

Developing ecosystem descriptions

Once the final set of ecosystem types was settled, we used information in the literature relative to each ecosystem, following guidelines for the IUCN Red List of Ecosystems (Keith, Ferrer-Paris, et al., 2024), to write descriptions, build cause-and-effect conceptual models, determine relationships with other classifications (described above), map distribution (described below), and compile photographs (Figure 3). For each ecosystem, we identified the characteristic and diagnostic native biota, the abiotic features, key ecological processes that influence ecosystem distribution or function, and the natural variation in these properties. To maintain local relevancy and represent Tiwi values, we included threatened species, culturally significant species, words in Tiwi language, and ecosystem services that arose in our discussions and in the literature (primarily, TLC et al. [2001]). The cause-and-effect conceptual models provided a visualization of the interactions between major ecosystem components. We systematically compiled information from the literature and field observations related to the 5 categories of ecosystem components specified by the GET: resource drivers, ambient environment, disturbance regimes, biotic interactions, and human activities (Keith et al., 2022).

Training points for mapping

We developed a training dataset of known occurrence points primarily from existing spatial data. Full details on the datasets are in Appendix S2. We collated all datasets held by the Tiwi Land Council and aligned the classes with the proposed Tiwi Island ecosystem types via the same methods as the cross-reference detailed in the "Developing the ecosystem inventory" section. These datasets were from a diverse range of data providers, including development proposals, aerial photographs, and academic and government research. Most resources related directly to one ecosystem, such as threatened flora surveys in wet rainforests (Liddle et al., 2008). Exceptions to this were aerial photographs that showed multiple ecosystems and site visits with the Tiwi knowledge authorities, who provided locations for *Melaleuca* swamps, grasslands, salt marsh, mangrove, sand dunes, sandy coastlines, rocky coastlines, treeless plains, Eucalypt open forest savanna, wet rainforests, and dry rainforests (Figure 3).

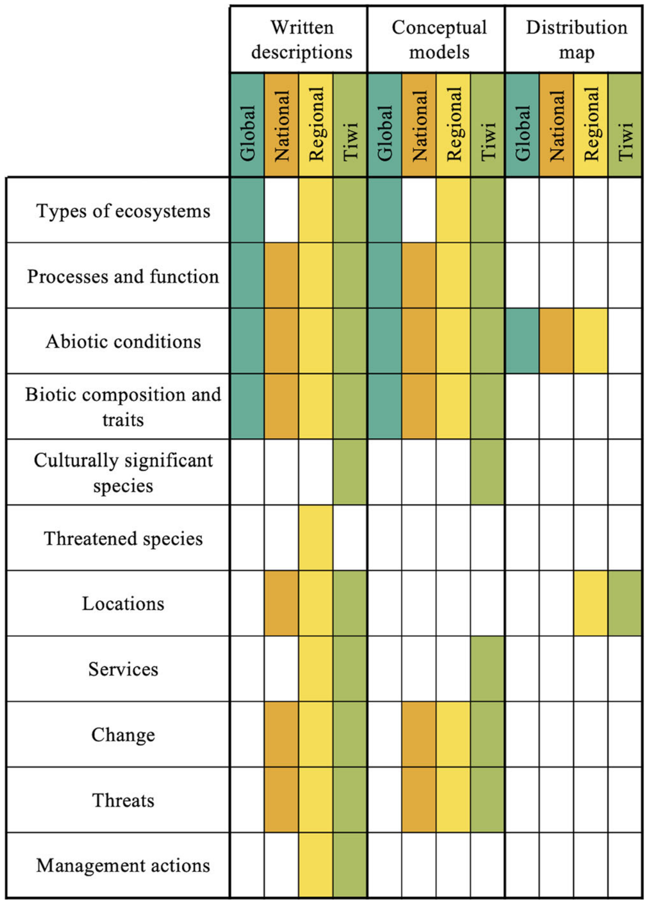

FIGURE 3 Contribution of knowledge sources at 4 scales (global, national, regional, and local) to the development of classification, description, and mapping of ecosystems.

Some ecosystem types were identified and described in the inventory but could not be mapped. It was not possible to distinguish between the eucalypt open forest savanna and the more variable eucalypt and mixed-species savanna in the existing datasets because of the high intraclass variability in canopy cover visible in the aerial photos and the variable definition used to define the mixed-species savanna. Therefore, eucalypt savanna was mapped as one class that represented a mosaic of the 2 ecosystems. The only data on rocky shorelines were from our site visits with Tiwi knowledge authorities—these provided too few training points for modeling.

We placed training points on a 30-m grid through visual interpretation in QGIS 3.22.12 by overlaying the datasets onto recent Sentinel-2 and Landsat-9 images. We thinned the points to a minimum of 100 m apart to minimize spatial autocorrelation (Congalton & Green, 1993). This resulted in 5298 training points for 11 ecosystem types (locations in Appendix S2).

Model variables

To map the ecosystem types, we needed ecologically relevant covariates (i.e., model variables). For the satellite imagery, we created a cloud-free Landsat-9 composite by using the median of images from January to May 2023 with <30% cloud cover and removing the remaining clouds with a QA-pixel mask in Google Earth Engine (Gorelick et al., 2017) (Appendix S3). We used the red and near-infrared bands to calculate the normalized difference vegetation index (NDVI), which represents vegetation primary productivity.

We compiled additional environmental variables to represent vegetation and landscape topography. To estimate groundwater availability, we used elevation data from the Shuttle Radar Topography Mission 5 m Smoothed Digital Elevation Model (Gallant et al., 2009) and created measures of slope and the topographic position index. We used 3 variables relating to vegetation height and structure that were the height at which 50%, 75%, and 95% of the vegetation biomass has been intercepted (Scarth et al., 2023). We also tested the inclusion of the long-term mean monthly rainfall (2005–2023) from the Australian SILO database (Jeffrey et al., 2001). However, the rainfall showed limited spatial variation for the islands and was omitted (details in Appendix S3).

We reprojected the variables to a 30-m resolution and the GDA2020 MGA52S coordinate reference system (EPSG: 7852). We tested the covariate correlation with Pearson's correlation coefficient with a 0.70 cutoff and selected among correlated variables through ecological reasoning or by modeling the covariates individually (Appendix S3). The final variables used in the model were the red and near-infrared bands of the satellite image, NDVI, height of 95% of the biomass, and elevation.

Model building, evaluation, and prediction

We developed a supervised random forest model with the ranger package (Wright & Ziegler, 2017) to classify ecosystems and predict their distribution in R 4.3.0 (R Core Team, 2018) with R studio 2023.09.1+949 (RStudio Team, 2020). A list of all software, packages, and versions used is in Appendix S4.

We randomly allocated the training points into 5 partitions for cross-validation. Cross-validation involves partitioning the data such that all but one of the partitions is used to build a model and predicting the held-out partition. In the *k*-fold cross-validation, the partitions are of equal size and the model building and predicting process is repeated so that each partition is held out once. We optimized the modeling parameters, resulting in 60 trees, 2 splitting variables, a depth of 6 nodes, and samples weighted by sample size (Appendix S4). We used the cross-validated models to predict the ecosystem type in the held-out partition and from this calculated the confusion matrix by assessing true and predicted ecosystem types. We calculated the overall accuracy and the class-specific accuracy measures from the cross-validated confusion matrix (Appendix S5), noting the limitations of accuracy metrics derived from nonrandomly sampled training points (Foody, 2002; Olofsson et al., 2013). We used the cross-validated models to predict the ecosystem type for the entirety of the islands. The final predicted class was the class predicted most frequently from the cross-validated models or with the mean highest probability where multiple classes were predicted in equal amounts. We overlayed polygons of the urban and forestry areas that had been previously developed.

RESULTS

Tiwi Islands ecosystems classification

We identified 14 ecosystem types (Table 1): 12 native terrestrial and terrestrial transitional (types 1–12) and 2 anthropogenic (types 13–14). We use the term *anthropogenic* to describe highly modified systems that no longer function naturally so as to align with the GET. We recognize that Indigenous peoples, including Tiwi people, have modified and managed ecosystems in Australia sustainably for millennia (Shawn-Fletcher et al., 2021). The ecosystem types we identified were eucalypt open forest savanna (*warta*, type 1), eucalypt and mixed species savanna (*warta*, type 2), treeless plains (*muriyini*, type 3), wet rainforest (*yawurlama*, type 4), dry rainforest (*yawurlama*, type 5), *Melaleuca* savanna (*punkaringa*, type 6), grasslands and sedgeland wetland (*turringiya*, type 7), mangrove (*mirriparinga* or *pamparinga*, type 8), coastal saltmarsh (*yarti*, type 9), sand dunes (*kurlimipiti* or *pungamparna*, type 10), sandy shorelines (*tingata*, type 11), rocky shorelines (*tingata*, type 12), urban and modified (type 13), and plantation (type 14). Of the natural ecosystems (i.e., nonanthropogenic), half the ecosystem types were fully terrestrial ($n = 6$, types 1–6) and half were transitional with either the marine realm ($n = 3$, types 10–12), freshwater ($n = 1$, type 7), or both ($n = 2$, types 8 and 9). Our application of the GET and discussions with Tiwi knowledge authorities prompted the inclusion of 3 unvegetated or sparsely vegetated ecosystem types (Figure 3): sand dunes (type 10), sandy shorelines (type 11), and rocky shorelines (type 12). These unvegetated ecosystems were either not included in previous classification schemes or aggregated into a single class (i.e., class 27 in the Australia National Vegetation Information System, NVIS).

Comparison with other classification schemes

In terms of the relationships to the GET, the 12 native ecosystem types (GET level 6) belonged to 10 EFGs (GET level 3), 7 functional biomes (level 2), and 4 realms (level 1) (Table 1). Biome is defined by the GET as the subdivision of realms (e.g., marine or terrestrial) by broad features of ecosystem structure and function, which contrasts with the biogeographic use of biome, where the term reflects climatic factors (Mucina, 2019).

No other single classification scheme reviewed captured all the ecosystem types we identified on the Tiwi Islands. The

TABLE 1 Cross-reference of the Tiwi Islands ecosystem types and associated terms in Tiwi language with the International Union for Conservation of Nature Global Ecosystem Typology and the previous vegetation classification for the islands.

Ecosystem type[a]	Term in Tiwi language[a,b]	Ecosystem functional group in the IUCN Global Ecosystem Typology[c] (level 3)	Generalized vegetation types of Tiwi Islands[d]	Key scientific references
Terrestrial or terrestrial–transitional ecosystems				
1. Eucalypt open forest savanna	*Warta*	T4.2 Pyric tussock savanna	*Eucalyptus* forests (4 subcategories)	Fox et al., 2001; Richards et al., 2012; Woinarski & Baker, 2002; Woinarski, Brennan, et al., 2003
2. Eucalypt and mixed species savanna	*Warta*	T4.2 Pyric tussock savanna	*Eucalyptus* forests (4 subcategories)	Woinarski & Baker, 2002; Woinarski, Brennan, et al., 2003
3. Treeless plains	*Muriyini*	T3.1 Seasonally dry tropical shrubland	Sparsely wooded plains (5 subcategories)	Wilson & Bowman, 1994; Wilson & Fensham, 1994; Woinarski & Baker, 2002
4. Wet rainforest	*Yawurlama* (jungle) *Kukuni* (freshwater) *Makatinga* (stream)	T1.1 Tropical or subtropical lowland rainforest	Wet monsoon forests (class 4b)	Fensham & Woinarski, 1992; Menkhorst & Woinarski, 1992; Russell-Smith, 1991; Russell-Smith & Bowman, 1992
5. Dry rainforest and vine thickets	*Yawurlama* (jungle) *Yartupwarri* (dry ground)	T1.2 Tropical or subtropical dry forest and thickets	Dry monsoon vine thickets (class 4a)	Russell-Smith, 1991; Russell-Smith & Bowman, 1992
6. *Melaleuca* savanna	*Punkaringa, pikaringini* (paperbark)	T4.2 Pyric tussock savanna	*Melaleuca* forests (2 subcategories)	Brocklehurst & Lynch, 2009; Woinarski, Brennan, et al., 2003
7. Grasslands and sedgeland wetland	*Turringiya*	TF1.4 Seasonal floodplain marshes	Swamps, sedgeland	Woinarski, Brennan, et al., 2003
8. Mangroves	*Mirriparinga* *Pamparinga*	MFT 1.2 Intertidal forests and shrublands	Mangroves (7 subcategories)	Brocklehurst & Edmeades, 1998; Messel et al., 1979; Woinarski, Brennan, et al., 2003
9. Coastal saltmarsh	*Yarti*	MFT1.3 Coastal saltmarsh and reed-bed	Samphire or saline coastal flat	Fox et al., 2001; Woinarski, Brennan, et al., 2003
10. Sand dunes	*Kurlimipiti* *Pungamparna*	MT2.1 Coastal shrublands and grasslands	Beaches, chenier ridges, grasslands	Brocklehurst & Edmeades, 1998; EcOz Environmental Services, 2012; Fensham, 1993
11. Sandy shorelines	*Tingata* (beach) *Wurrungalama, yartila* (bare area) *Kuluwunila* (dry beach)	MT1.3 Sandy shore	–	Chatto, 2001, 2003; Whiting et al., 2007
12. Rocky shorelines	*Tingata* (outcrops in sandy beaches)	MT1.1 Rocky shore	–	–
Anthropogenic ecosystems				
13. Urban and modified	–	T7.4 Urban industrial	–	–
		T7.5 Seminatural pastures and old fields		
14. Plantation	–	T7.3 Plantation	Plantations	–

[a]This research. The type number is used in text for clarity.
[b]TLC (2001).
[c]Keith et al. (2022).
[d]Brocklehurst and Edmeades (1998).

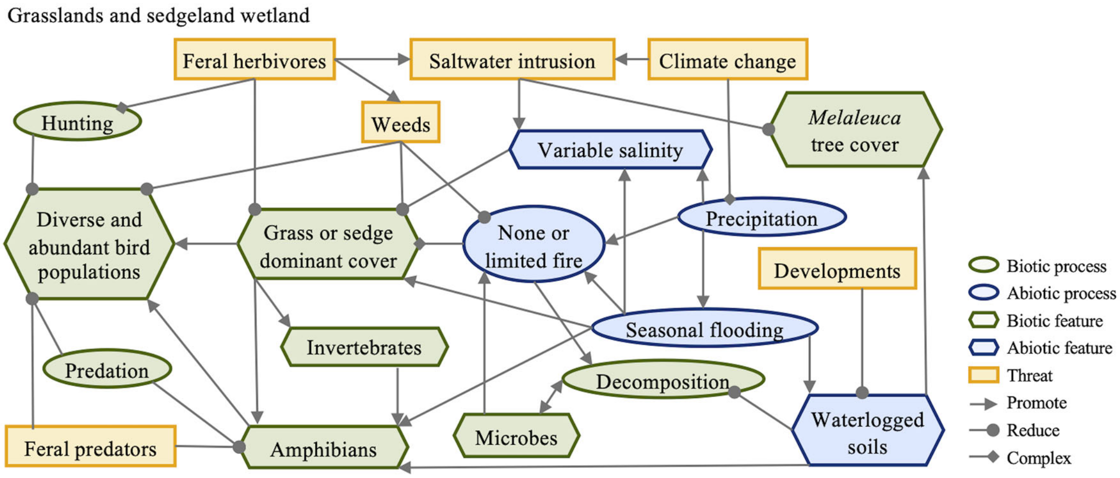

FIGURE 4 Exemplar cause-and-effect conceptual model of grassland and sedgeland wetlands (*turringiya* in Tiwi language) on the Tiwi Islands, northern Australia, developed following International Union for Conservation of Nature Red List of Ecosystem guidelines (Keith, Ferrer-Paris, et al., 2024), which links ecosystem processes, attributes, and threats. Similar models for each ecosystem type listed in Table 1 can be found in Appendix S6.

12 native terrestrial and terrestrial–transitional native ecosystem types for the Tiwi Islands based on our research were equivalent to 10 formations in the International Vegetation Classification and 14 major vegetation groups from the NVIS (Table 1; Appendix S8). Despite differences in the classification criteria and objectives, a one-to-one or one-to-many attribution between the schemes was possible for most classes. The ecosystem types corresponded in thematic scale to the generalized vegetation types previously described for the Tiwi Islands (Table 1; Appendix S8). However, a key difference to the generalized vegetation types was that we delineated 2 eucalypt savanna ecosystems (type 1 and 2) based on variability in the species composition and soil moisture and composition instead of by canopy cover. The treeless plains ecosystem type (type 3) did not align with a single category in the national and territory classification schemes, although it was recognized in previous classifications specific to the Tiwi Islands.

Tiwi Islands ecosystem descriptions

Two ecological processes that drove ecosystem properties in all or the majority of the Tiwi Islands ecosystems were moisture availability and fire (Appendix S6). Moisture availability was a key driver for all the ecosystem types, with moisture varying in salinity and availability over time (e.g., with tidal inundation or seasonal drought) (Figure 4). Stable freshwater availability was essential for the wet rainforest (*kukuni* yawurlama, type 4), and a seasonal deficit of freshwater influenced 6 other terrestrial ecosystem types (types 1–3 and 5–7) (Appendix S6). Regular salt and brackish water inundation supported mangrove ecosystems (type 8). Regular tidal saltwater inundation and regular disturbance resulted in distinct communities in the sandy and rocky shorelines (types 11 and 12, respectively), where salinity was high. Irregular inundation was key to the coastal saltmarsh (yarti, type 9) and the wetlands (turringiya, type 7) (Figure 4).

Freshwater availability also interacted with fire to distinguish ecosystem types. For example, fire mediated the boundaries between wet rainforests (type 4) and the eucalypt savannas (types 1 and 2) and was relatively lower in the rainforest due to the predominantly evergreen vegetation. Fire was also relatively low in the dry rainforest (type 5), despite the drier vegetation, which, based on the literature, may be explained by topographical protection. Although one name in Tiwi language was suggested for both the wet and dry rainforest, yawurlama, Tiwi knowledge authorities recognized and described differences between these ecosystem types based on soil moisture gradients, species composition, and services provided to Tiwi people (e.g., collection of yams). Tiwi knowledge authorities suggested Tiwi adjectives that could be used to distinguish among these rainforest ecosystem types: Tiwi words for freshwater, *kukuni* and *kukunila*; for freshwater stream, *makaringa*—to describe the wet rainforests; and *yartupwarri*, meaning dry ground for the dry rainforests (Table 1).

Tiwi knowledge authorities shared extensive information that contributed to the ecosystem descriptions (Figure 3), including characteristic species in ecosystems, such as saltwater crocodiles (*Crocodylus porosus*, *yirrikipayi* in Tiwi), magpie geese (*Anseranas semipalmata*, multiple names in Tiwi), and barramundi (*Lates calcarifer*, *arlamini* and *arlaminga* in Tiwi) in the grassland and sedgeland wetlands (type 7); ecosystem processes, such as interactions between these species (e.g., the predation of barramundi by crocodiles); and the relationships between Tiwi people and the ecosystems, for example, agile wallabies (*Macropus agilis*, *anjorra* in Tiwi) seek shade and water in rainforests, meaning rainforests are places to hunt wallaby. Tiwi knowledge authorities discussed their relationships with species, ecosystems, and important locations. For example, traditional medicinal plants are collected in the eucalypt open forest savanna (type 1), and yams (*Dioscorea* spp.) are collected from the dry rainforests (type 5). Sandy and rocky shorelines (types 11 and 12, respectively) are used to harvest mussels (*Polymesoda erosa*, *jukwarringa* in Tiwi) and mud crabs (*Scylla serrata*, *kurumpuka* and *wurlanga* in Tiwi), and locations where these practices are undertaken were identified on satellite images.

Threats and management

We identified multiple threats as acting or having the potential to act on each ecosystem (Figure 4, yellow boxes) from the literature and as observed by Tiwi people (Figure 3). Recurring threats across the ecosystems on the Tiwi Island are inappropriate fire regimes, invasive species, and interactions among these threats.

On the Tiwi Islands and other areas of northern Australia, fires naturally occur in high frequency at low intensity (Murphy et al., 2013; Williams et al., 2017); an inappropriate fire regime is defined as high-severity fires occurring in the late dry season (i.e., after July) (Fox et al., 2001). Fire was identified as an important process in the savanna ecosystem types (types 1–3) and infrequently recorded in rainforest patches (type 5–6) and grasslands (type 7). Changes in fire frequency, severity, or extent cause significant impacts on the biotic communities. Fire management was cited as a crucial tool Tiwi rangers use to manage multiple ecosystems on behalf of Tiwi landowners and the Tiwi Land Council (Richards et al., 2012; TLC, 2024a).

In terms of invasive species, feral herbivores, in particular buffalo (*Bubalus bubalis*, *jarranga* in Tiwi) and pig (*Sus scrofa*, *pikipiki* in Tiwi), degrade multiple ecosystems on the Tiwi Islands by reducing plant regeneration, uprooting plants, spreading weeds, and reducing water quality (Figure 4). This damage has been observed by Tiwi knowledge authorities at multiple locations (Figure 3). Feral cats (*Felis catus*) are a growing problem because they kill mammals, birds, and reptiles (Davies et al., 2017, 2021). They are a current management focus (TLC, 2024a, 2024b) (Figure 4). Exotic weeds degrade multiple ecosystems by altering fire regimes and outcompeting native species (Woinarski, Hadden, et al., 2003) (Figure 4; Appendix S6) and hence are also a current management focus (TLC, 2024a).

Mapping Tiwi Islands ecosystems

The Tiwi Islands ecosystem distribution model achieved a high overall accuracy of 83.86% (Appendix S5) and predicted large expanses of eucalypt savanna (types 1 and 2), patchy areas of treeless plains (type 3) and *Melaleuca* savanna (type 6), and coastlines lined by mangroves (type 8) (Figure 5). Across the ecosystem classes, ocean (*winga*) was consistently predicted with the lowest error (commission error [CE] = 0.00, omission error [OE] = 0.01). In contrast, *Melaleuca* savanna was overpredicted (CE = 0.74). Treeless plains were also often misclassified, albeit to a lesser extent, both falsely predicting treeless plains when another ecosystem truly occurred (false positive, CE = 0.34) and falsely predicting another ecosystem when treeless plains truly occurred (false negative OE = 0.3). Similarly, wet rainforests tended to be overpredicted (CE = 0.36) because of the misclassification of dry rainforests (OE = 0.20).

DISCUSSION

We developed an ecosystem typology that brought together local, regional, and national information in a global framework to classify, describe, and map ecosystems on the Tiwi Islands. Our new typology captured a greater range of ecosystem types for the Tiwi Islands terrestrial landscape than any other single classification reviewed, thereby supporting more comprehensive planning. Our results illustrate that defining ecosystem types by function effectively captures the high spatiotemporal variation in dynamic and disturbance-prone ecosystems, which has implications for management. Tiwi knowledge authorities offered important insights into the ecosystem classes and descriptions, which provide a valuable basis for future monitoring of ecosystem condition and services. Our results illustrate the benefits gained by connecting knowledge systems and scales, including local Indigenous knowledge and scientific knowledge from local to global scales.

A comprehensive inventory

Drawing on existing classification schemes and Tiwi knowledge enabled the development of an ecosystem inventory for the Tiwi Islands that was more comprehensive than any earlier classifications and prompted the inclusion of locally important ecosystem types. Together with GET indicative maps, Tiwi knowledge authorities identified 3 unvegetated and sparsely vegetated ecosystems that were not part of previous classifications: sand dunes, sandy shorelines, and rocky shorelines. Sand dunes, a prominent landform on Bathurst Island, provide ecosystem services, such as medicinal plants (Thompson et al., 2019) and hunting, and have cultural significance. Similarly, the treeless plains ecosystem (*muriyini*, type 3) did not easily align with an existing vegetation class in the national or Northern Territory classifications. Such gaps in the previous classifications mean that management decisions may have been misinformed regarding ecosystem location and extent. Sparsely vegetated dunes are affected by sand mining, for which there is recurring interest on the Tiwi Islands (EcOz Environmental Services, 2012). By improving the comprehensiveness of the ecosystem inventory via Tiwi knowledge authorities and the global framework, we created a typology and map that support better spatial planning overall and better planning for ecosystems important to Tiwi people.

Ecosystems defined by function and processes

Another important characteristic of the Tiwi Islands ecosystem typology is that it defined ecosystem classes by ecological processes and function. In doing so, it represented dynamic savanna ecosystems, such as those that dominate the Tiwi Islands, by emphasizing the role of fire as an ecological process and reducing reliance on vegetation structure. Vegetation structure is a core property used in vegetation classification, but it is less

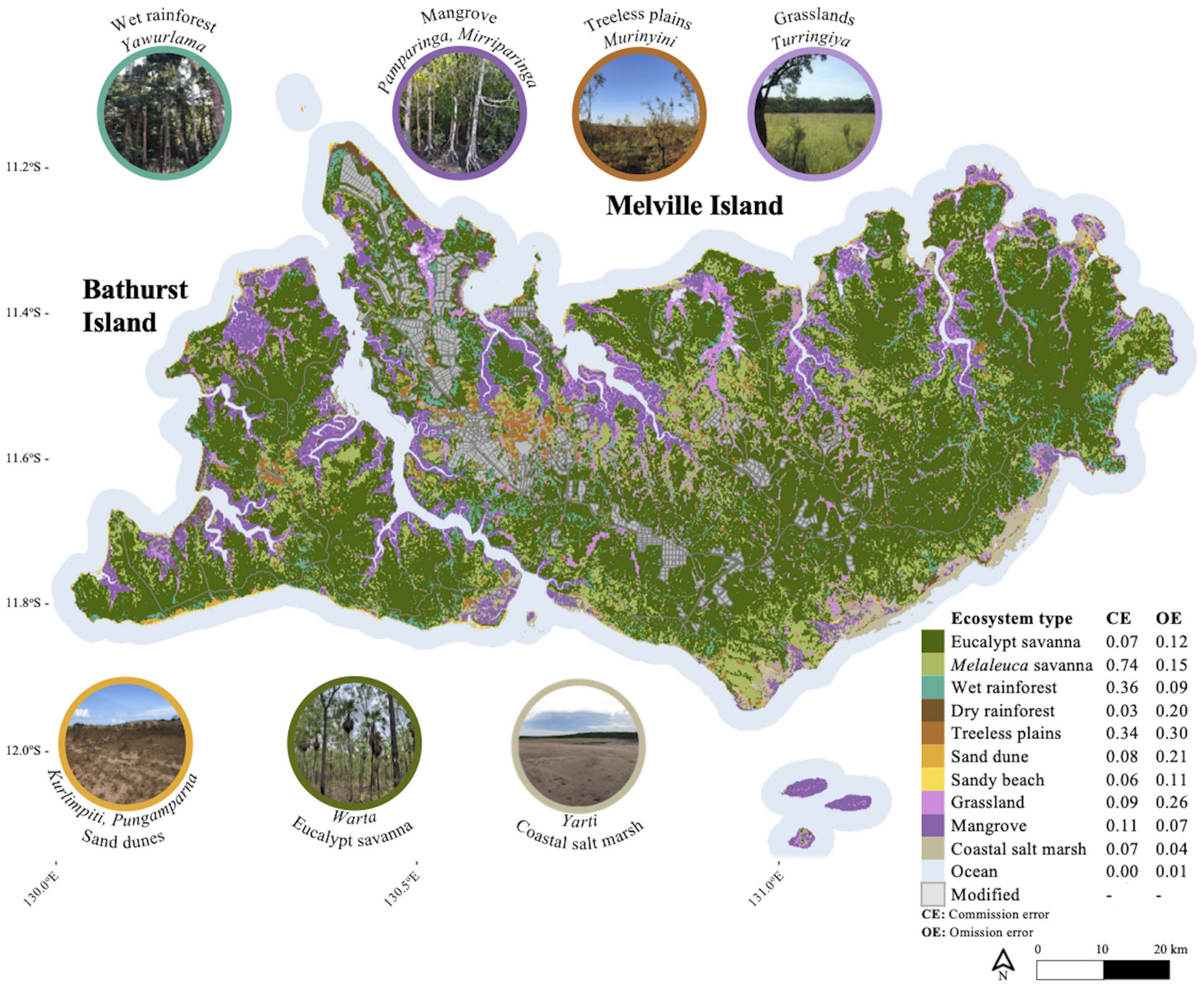

FIGURE 5 Distribution of the ecosystem types on the Tiwi Islands, Australia, and exemplar photos of select ecosystems and their names in Tiwi language (italics).

usefulness for distinguishing ecosystems with spatiotemporally variable structural or floristic forms (Fox et al., 2001; Parr et al., 2014; Williams et al., 2017). Structural classifications for savannas, as done previously for the Tiwi Islands, can produce inaccurate extent estimates and contribute to inappropriate management decisions (Griffith et al., 2017; Phelps et al., 2022; Ratnam et al., 2011). In contrast, defining savanna ecosystems based on fire frequency, seasonal drought, biota whose traits are shaped by those processes (Williams et al., 2017), and the abundance of seasonally flammable C4 grasses results in a functional classification that accounts for ecosystem dynamics and variation. Whether defined by vegetation structure or ecosystem processes, savanna variability is still a challenge to map (Hanan et al., 2014; Hurskainen et al., 2019), which has implications for policy and conservation that rely heavily on accurate spatial representations for strategic planning and management (Dorrough et al., 2021). We mapped the 2 eucalypt savanna ecosystems (type 1 and 2) as a single category because of limitations in the reference dataset. Given the dominance of fire in both eucalypt savanna ecosystems and similar threats from invasive species, management of the 2 ecosystems can still be supported by the ecosystem map. However, protecting the unique biota requires these ecosystems to be mapped separately.

Management implications

An ecosystem typology that identifies key ecosystem processes also has substantial benefits for management. For savannas, low canopy cover or high fire frequency can be misinterpreted as degradation, and reforestation programs or fire suppression may be wrongly implemented as a result (Parr et al., 2014; Phelps et al., 2022). Instead, maintaining and restoring natural ecosystem processes are effective options for management (Griffith et al., 2017; Keith, Ghoraba, et al., 2024; Wurtzebach & Schultz, 2016). Conceptual models are powerful tools to identify key processes, potential threats, and hence management priorities (Keith, Ghoraba, et al., 2024; Wurtzebach & Schultz, 2016). Similarly, ecosystem management is enhanced through improved knowledge sharing across jurisdictions through crossreferencing with the GET. For example, feral buffalo have damaged floodplains across northern Australia (Bowman et al., 2010; Bradshaw et al., 2007). Although the extent of such impacts on the Tiwi Islands is undocumented, potential impacts (Figure 4) and management actions could be informed by experiences from the ecologically similar Kakadu National Park, including quantifying impacts and developing controls (Bradshaw et al., 2007). Given the substantial damage of buffalo and pigs on rainforests, for the Tiwi Islands prioritizing invasive species management at locations where yams are collected or wallabies hunted would balance both conservation and Tiwi priorities. Recent partnerships in Australia to combine Indigenous and conservation objectives by targeting actions at significant sites have proven highly effective at local (Bach et al., 2019) and national scales (Moorcroft et al., 2012).

Monitoring

Alongside identifying the key ecological processes for Tiwi Islands ecosystems, we described the biota for each ecosystem, opening new avenues for monitoring. By monitoring the characteristic biota, it is possible to leverage available datasets to determine ecosystem condition and trends, including mammals and birds for the Tiwi Islands (Davies et al., 2018, 2019, 2021). In other Indigenous and traditional local communities, characteristic plant species are often a salient feature in landscape descriptions (Babai & Molnár, 2013; Gantuya et al., 2019), which could be considered as a potential basis for monitoring ecological state and changes. Monitoring culturally significant elements of biodiversity (as well as ecological metrics) can indicate ecosystem condition and the maintenance of cultural values, such as yam populations in rainforest patches, medicinal plants in the eucalypt savanna, or whelk abundance in mangroves collected for food (Thompson et al., 2019; TLC et al., 2001). Biocultural indicators are an emerging approach to ecosystem assessments that capture ecological integrity and the services provided to people by ecosystems. The IPBES compiled hundreds of locally developed indicators covering aspects of social and cultural well-being for use in holistic monitoring of nature based on the relationships between people and ecosystems (Díaz et al., 2018; McElwee et al., 2020).

Challenges

Although bringing together multiple knowledge systems and scales can create novel insights, understanding and managing differences between knowledge systems is not straightforward (McElwee et al., 2020). Tiwi knowledge authorities expressed values related to either the ecosystems or locations on Tiwi Country, such as through the practices of camping, hunting, and storytelling. This contrasts with the conventional practices of classifying, describing, and mapping typically used in the ecological sciences but aligns with descriptions of Indigenous knowledges as offering place-based understandings that incorporate ecological, spiritual, and cultural dimensions (Berkes et al., 2000). These differences reflect the unique ways the respective knowledge systems understand, describe, and classify landscapes (i.e., ontological differences) based on their foundational beliefs and logics (i.e., epistemological differences) (Johnson & Hunn, 2010; Mark & Turk, 2003). One option to work with these differences and to respect and honor important Tiwi locations is to prioritize management at particular sites, as suggested earlier. In this research collaboration, we found that written descriptions and conceptual models proved useful mechanisms to bring together Tiwi knowledge and ecological knowledge and supported qualitative and quantitative data representations, which often challenge cross-cultural knowledge partnerships (McElwee et al., 2020). Instead of seeking a comparison between the Tiwi and Western ecological conceptualizations of landscapes, we aimed to manage our ontological and epistemological differences in creative ways (i.e., through discussion, sharing knowledge on Country together) to create an ecosystem inventory that is ecologically sound and culturally relevant for the management of Tiwi *murrakupuni*.

Spatial planning

A crucial aim of this research was operationalizing the ecosystem inventory into a distribution map for spatial planning. Our modeling produced high overall accuracy but low accuracy for specific classes (Appendix S5). The high overall accuracy was potentially overestimated because of the random allocation of the training points into the cross-validation folds (Stehman & Foody, 2019); some validation points were close to training points and likely had similar characteristics. Low accuracy for a specific class is typical for structurally heterogeneous classes (Congalton et al., 2014) and directly opposes the benefit of ecosystem units in capturing variability. These potential and actual accuracy issues impede the use of the ecosystem map, especially for fine-scale planning. More research could improve the quality and quantity of the training data and covariates and thus improve the accuracy of this map (Figure 5). Such improvements in mapping could target ecosystems classes with low accuracy or those that contribute services to Tiwi people.

Future applications

The detailed typology and map of ecosystems will help Tiwi Island land managers and Tiwi institutions apply globally standardized assessment tools. Foundational ecosystem information facilitates ecological assessments (Keith, Ferrer-Paris et al., 2024) and assessments of the services ecosystems, including ecosystem contributions to culture and human well-being (Díaz et al., 2018; Hill et al., 2021). Ecological and ecosystem services assessments are complementary (Xiao et al., 2024), together supporting the continued provisioning of services. Given the headline role of ecological assessments in current multilateral agreements (Nicholson et al., 2024), the Tiwi ecosystem inventory supports Tiwi knowledge to inform and influence national and global conservation strategies.

ACKNOWLEDGMENTS

This research was funded by the Australian Research Council (ARC, LP170100305) in partnership with the Tiwi Land Council. A.B. was funded by the ARC Discovery Indigenous Project, the Centre of Excellence for Plant Success in Nature and Agriculture, the Centre of Excellence in Synthetic Biology, and the Centre of Excellence in Quantum Biotechnology. We thank C. Kerinaiua, B. Tipiloura, S. Munkara, G. Munkara, J. L. Munkara, M. Munkara, F. Kerinaiua, A. Kurrupuwu, and D. Dunn for discussing ecosystem concepts. We acknowledge Y. Kelly and N. Sawyer for organizing the database meeting and thank the attendees: A. Tipuamantamirri, M. Carmel, L. Kantilla, L. Tipuamantamirri, A. Kurrupuwu, J. Puautjimi, M. Alimankinni, A. Munkara, K. Tipiloura, Y. Tipuamantamirri, and M. Tipiloura. Country visits were supported by the Foundation for National Parks and Wildlife community conservation grant (FNPW028CCG22). We are grateful to the Tiwi Land Council, Tiwi resources, Tiwi rangers, and researchers at Charles Darwin University for the logistical support. We are also grateful to V. Howlett for assistance with data collection. We thank the 3 anonymous reviewers for their constructive feedback. Analyses and writing were undertaken on the lands of the Larrakia and Wurundjeri Woi Wurung peoples.

Open access publishing facilitated by Deakin University, as part of the Wiley - Deakin University agreement via the Council of Australian University Librarians.

ORCID

Alys R. Young https://orcid.org/0000-0002-9562-2253
Hugh F. Davies https://orcid.org/0000-0002-8473-4540
Margaret L. Ayre https://orcid.org/0000-0001-7909-7391
Alana Brekelmans https://orcid.org/0000-0003-3724-9312
Brett A. Bryan https://orcid.org/0000-0003-4834-5641
Jane Elith https://orcid.org/0000-0002-8706-0326
David A. Keith https://orcid.org/0000-0002-7627-4150
Donna L. Lewis https://orcid.org/0000-0002-3891-3142
Michaela Spencer https://orcid.org/0000-0003-2936-7343
Emily Nicholson https://orcid.org/0000-0003-2199-3446

REFERENCES

Australian Bureau of Statistics (ABS). (2021). *Population: Census*. https://www.abs.gov.au/census/find-census-data/search-by-area

Babai, D., & Molnár, Z. (2013). Multidimensionality and scale in a landscape ethnoecological partitioning of a mountainous landscape (Gyimes, Eastern Carpathians, Romania). *Journal of Ethnobiology and Ethnomedicine*, *9*(1), Article 11.

Bach, T. M., Kull, C. A., & Rangan, H. (2019). From killing lists to healthy country: Aboriginal approaches to weed control in the Kimberley, Western Australia. *Journal of Environmental Management*, *229*, 182–192.

Barnett, J., Konlechner, T., Waters, E., Minnapinni, M. W., Jarillo, S., Austral, B., De Santis, J., Head, L., Rioli, C., & King, A. (2023). "Winga is trying to get in": Local observations of climate change in the Tiwi Islands. *Earth's Future*, *11*(3), Article e2022EF002808.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*(5), 1251–1262.

Bowman, D. M. J. S., Prior, L. D., & De Little, S. C. (2010). Retreating *Melaleuca* swamp forests in Kakadu National Park: Evidence of synergistic effects of climate change and past feral buffalo impacts. *Austral Ecology*, *35*(8), 898–905.

Bradshaw, C. J. A., Field, I. C., Bowman, D. M. J. S., Haynes, C., & Brook, B. W. (2007). Current and future threats from non-indigenous animal species in northern Australia: A spotlight on World Heritage Area Kakadu National Park. *Wildlife Research*, *34*(6), 419–436.

Brocklehurst, P., & Edmeades, B. (1998). Vegetation communities. In *The history and natural resources of the Tiwi Islands, Northern Territory* (pp. 147–184). Parks and Wildlife Commission of the Northern Territory.

Brocklehurst, P., & Lynch, B. (2009). *Northern Territory Melaleuca forest survey* (Technical Report 25/2009D). Department of Natural Resources, Environment, The Arts and Sport.

Brondízio, E. S., Aumeeruddy-Thomas, Y., Bates, P., Carino, J., Fernández-Llamazares, Á., Ferrari, M. F., Galvin, K., Reyes-García, V., McElwee, P., Molnár, Z., Samakov, A., & Shrestha, U. B. (2021). Locally based, regionally manifested, and globally relevant: Indigenous and local knowledge, values, and practices for nature. *Annual Review of Environment and Resources*, *46*, 481–509.

Bureau of Meteorology. (2024). *Climate statistics for Point Fawcett (site 200731) and Pirlangimpi Airport (site 014142) between 1979 and 2024 (product IDCJCM0029)*.

Chaplin-Kramer, R., Brauman, K. A., Cavender-Bares, J., Díaz, S., Duarte, G. T., Enquist, B. J., Garibaldi, L. A., Geldmann, J., Halpern, B. S., Hertel, T. W., Khoury, C. K., Krieger, J. M., Lavorel, S., Mueller, T., Neugarten, R. A., Pinto-Ledezma, J., Polasky, S., Purvis, A., Reyes-García, V., … Zafra-Calvo, N. (2022). Conservation needs to integrate knowledge across scales. *Nature Ecology & Evolution*, *6*(2), 118–119.

Chatto, R. (2001). *The distribution and status of colonial breeding seabirds in the Northern Territory* (Technical Report 70). Parks & Wildlife Commission of the Northern Territory.

Chatto, R. (2003). *The distribution and status of shorebirds around the coast and coastal wetlands of the Northern Territory*. Parks and Wildlife Commission of the Northern Territory.

Congalton, R. G., & Green, K. (1993). A practical look at the sources of confusion in error matrix generation. *Photogrammetric Engineering and Remote Sensing*, *59*(5), 641–644.

Congalton, R. G., Gu, J., Yadav, K., Thenkabail, P., & Ozdogan, M. (2014). Global land cover mapping: A review and uncertainty analysis. *Remote Sensing*, *6*(12), 12070–12093.

Convention on Biological Diversity. (2022). *Kunming-Montreal Global Biodiversity Framework* (CBD/COP/15/L.25). https://www.cbd.int/doc/c/e6d3/cd1d/daf663719a03902a9b116c34/cop-15-l-25-en.pdf

Cumming, G. S., Cumming, D. H. M., & Redman, C. L. (2006). Scale mismatches in social-ecological systems: Causes, consequences, and solutions. *Ecology and Society*, *11*(1), Article 14. https://www.jstor.org/stable/26267802

Davies, H. F., McCarthy, M. A., Firth, R. S. C., Woinarski, J. C. Z., Gillespie, G. R., Andersen, A. N., Geyle, H. M., Nicholson, E., & Murphy, B. P. (2017). Top-down control of species distributions: Feral cats driving the regional extinction of a threatened rodent in northern Australia. *Diversity and Distributions*, *23*(3), 272–283.

Davies, H. F., McCarthy, M. A., Firth, R. S. C., Woinarski, J. C. Z., Gillespie, G. R., Andersen, A. N., Rioli, W., Puruntatameri, J., Roberts, W., Kerinaiua, C., Kerinauia, V., Womatakimi, K. B., & Murphy, B. P. (2018). Declining populations in one of the last refuges for threatened mammal species in northern Australia. *Austral Ecology*, *43*(5), 602–612.

Davies, H. F., Rangers, T. L., Nicholson, E., & Murphy, B. P. (2021). Northern brown bandicoot (*Isoodon macrourus*) and common brushtail possum (*Trichosurus vulpecula*) density on the Tiwi Islands: Insights and implications. *Pacific Conservation Biology*, *28*(3), 224–230.

Davies, H. F., Rioli, W., Puruntatameri, J., Roberts, W., Kerinaiua, C., Kerinauia, V., Womatakimi, K. B., Gillespie, G. R., & Murphy, B. P. (2019). Estimating site occupancy and detectability of the threatened partridge pigeon (*Geophaps smithii*) using camera traps. *Austral Ecology*, *44*(5), 868–879.

Department of Climate Change, Energy, the Environment and Water (DCCEEW). (2021). *Interim Biogeographic Regionalisation for Australia (IBRA)* (Version 7). https://www.dcceew.gov.au/environment/land/nrs/science/ibra

Department of Natural Resources, Environment, The Arts and Sport (NRETAS). (2008). *Sites of conservation significance: Tiwi Islands*.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., Hill, R., Chan, K. M. A., Baste, I. A., Brauman, K. A., Polasky, S., Church, A., Lonsdale, M., Larigauderie, A., Leadley, P. W., van Oudenhoven, A. P. E., van der Plaat, F., Schröter, M., Lavorel, S., … Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, *359*(6373), 270–272.

Dorrough, J., Tozer, M., Armstrong, R., Summerell, G., & Scott, M. L. (2021). Quantifying uncertainty in the identification of endangered ecological communities. *Conservation Science and Practice*, *3*(11), Article e537.

EcoSure. (2009). *Prioritisation of high conservation status offshore islands*. Australian Government Department of the Environment, Water, Heritage and the Arts.

EcOz Environmental Services. (2012). *Kilimiraka Notice of Intent: Kilimiraka Mineral Sands Project*. Matilda Zircon.

Ens, E. J., Pert, P., Clarke, P. A., Budden, M., Clubb, L., Doran, B., Douras, C., Gaikwad, J., Gott, B., Leonard, S., Locke, J., Packer, J., Turpin, G., & Wason, S. (2015). Indigenous biocultural knowledge in ecosystem science and management: Review and insight from Australia. *Biological Conservation*, *181*, 133–149.

Fensham, R. J. (1993). The environmental relations of vegetation pattern on chenier beach ridges on Bathurst Island, Northern Territory. *Australian Journal of Botany*, *41*(3), 275–291.

Fensham, R. J., & Woinarski, J. C. Z. (1992). *Yawulama: The ecology and conservation of monsoon forest on the Tiwi Islands, Northern Territory*. National Rainforest Conservation Program.

Foody, G. M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80*(1), 185–201.

Fox, I. D., Neldner, V. J., Wilson, G. W., & Bannink, P. J. (2001). *The vegetation of the Australian tropical savannas*. Environmental Protection Agency.

Gadgil, M., Berkes, F., & Folke, C. (1993). Indigenous knowledge for biodiversity conservation. *Ambio*, *22*(2), 151–156.

Gallant, J., Wilson, N., Tickle, P. K., Downling, T., & Read, A. (2009). *3 second SRTM Derived Digital Elevation Model (DEM) Version 1.0* [Computer software]. Geoscience Australia. http://pid.geoscience.gov.au/dataset/ga/69888

Gantuya, B., Avar, Á., Babai, D., Molnár, Á., & Molnár, Z. (2019). "A herder's duty is to think": Landscape partitioning and folk habitats of Mongolian herders in a mountain forest steppe (Khuvsugul-Murun region). *Journal of Ethnobiology and Ethnomedicine*, *15*(1), Article 54.

Goolmeer, T., Skroblin, A., Grant, C., Leeuwen, S., Archer, R., Gore-Birch, C., & Wintle, B. A. (2022). Recognizing culturally significant species and Indigenous-led management is key to meeting international biodiversity obligations. *Conservation Letters*, *15*(6), Article e12899. https://doi.org/10.1111/conl.12899

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote Sensing of Environment*, *202*, 18–27.

Griffith, D. M., Lehmann, C. E. R., Strömberg, C. A. E., Parr, C. L., Pennington, R. T., Sankaran, M., Ratnam, J., Still, C. J., Powell, R. L., Hanan, N. P., Nippert, J. B., Osborne, C. P., Good, S. P., Anderson, T. M., Holdo, R. M., Veldman, J. W., Durigan, G., Tomlinson, K. W., Hoffmann, W. A., … Bond, W. J. (2017). Comment on "The extent of forest in dryland biomes". *Science*, *358*(6365), Article eaao1309.

Hanan, N. P., Tredennick, A. T., Prihodko, L., Bucini, G., & Dohn, J. (2014). Analysis of stable states in global savannas: Is the CART pulling the horse? *Global Ecology and Biogeography*, *23*(3), 259–263.

Hill, R., Díaz, S., Pascual, U., Stenseke, M., Molnár, Z., & Van Velden, J. (2021). Nature's contributions to people: Weaving plural perspectives. *One Earth*, *4*(7), 910–915.

Hoverman, S., & Ayre, M. (2012). Methods and approaches to support Indigenous water planning: An example from the Tiwi Islands, Northern Territory, Australia. *Journal of Hydrology*, *474*, 47–56.

Hunter, J. T., & Addicott, E. (2021). Poplar box woodlands of Eastern Australia: An assessment of a threatened ecological community within the IVC framework. *Vegetation Classification and Survey*, *2*, 241–255.

Hurskainen, P., Adhikari, H., Siljander, M., Pellikka, P. K. E., & Hemp, A. (2019). Auxiliary datasets improve accuracy of object-based land use/land cover classification in heterogeneous savanna landscapes. *Remote Sensing of Environment*, *233*, Article 111354.

Jeffrey, S. J., Carter, J. O., Moodie, K. B., & Beswick, A. R. (2001). Using spatial interpolation to construct a comprehensive archive of Australian climate data. *Environmental Modelling & Software*, *16*(4), 309–330. https://doi.org/10.1016/S1364-8152(01)00008-1

Johnson, L. M., & Hunn, E. S. (Eds.). (2010). *Landscape ethnoecology: Concepts of biotic and physical space*. Berghahn Books.

Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., & Kingsford, R. T. (Eds.). (2020). *IUCN Global Ecosystem Typology 2.0: Descriptive profiles for biomes and ecosystem functional groups*. International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2020.13.en

Keith, D. A., Ferrer-Paris, J. R., Ghoraba, S. M. M., Henriksen, S., Monyeki, M., Murray, N. J., Nicholson, E., Rowland, J. A., Skowno, A., Slingsby, J. A., Storeng, A. B., Valderrábano, M., & Zager, I. (Eds.). (2024). *Guidelines for the application of IUCN Red List of ecosystems categories and criteria version 2*. International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.RLE.1.en

Keith, D. A., Ferrer-Paris, J. R., Nicholson, E., Bishop, M. J., Polidoro, B. A., Ramirez-Llodra, E., Tozer, M. G., Nel, J. L., Mac Nally, R., Gregr, E. J., Watermeyer, K. E., Essl, F., Faber-Langendoen, D., Franklin, J., Lehmann, C. E. R., Etter, A., Roux, D. J., Stark, J. S., Rowland, J. A., … Kingsford, R. T. (2022). A function-based typology for Earth's ecosystems. *Nature*, *610*(7932), 513–518.

Keith, D. A., Ghoraba, S. M. M., Kaly, E., Jones, K. R., Oosthuizen, A., Obura, D., Costa, H. M., Daniels, F., Duarte, E., Grantham, H., Gudka, M., Norman, J., Shannon, L. J., Skowno, A., & Ferrer-Paris, J. R. (2024). Contributions of the IUCN Red List of Ecosystems to risk-based design and management of protected and conserved areas in Africa. *Conservation Biology*, *38*(3), Article e14169.

Kerinaiua, M., & Rademaker, L. (2023). *Tiwi Story: Turning history downside up*. Newsouth Books.

Liddle, D. T., Gibbons, R., & Taylor, R. (2008). *Recovery plan for the threatened plants of the Tiwi Islands in the Northern Territory of Australia*. Northern Territory Department of Natural Resources, Environment and the Arts.

Mark, D. M., & Turk, A. G. (2003). Landscape categories in Yindjibarndi: Ontology, environment, and language. In W. Kuhn, M. F. Worboys, & S. Timpf (Eds.), *Spatial information theory. Foundations of geographic information science* (Vol. 2825, pp. 28–45). Springer.

McElwee, P., Fernández-Llamazares, Á., Aumeeruddy-Thomas, Y., Babai, D., Bates, P., Galvin, K., Guèze, M., Liu, J., Molnár, Z., Ngo, H. T., Reyes-García, V., Roy Chowdhury, R., Samakov, A., Shrestha, U. B., Díaz, S., & Brondízio, E. S. (2020). Working with Indigenous and local knowledge (ILK) in large-scale ecological assessments: Reviewing the experience of the IPBES Global Assessment. *Journal of Applied Ecology*, *57*(9), 1666–1676.

Menkhorst, K. A., & Woinarski, J. C. Z. (1992). Distribution of mammals in monsoon rainforests of the Northern Territory. *Wildlife Research*, *19*, 295–316.

Messel, H., Wells, A. G., & Green, W. J. (1979). *Surveys of tidal river systems in the Northern Territory of Australia and their crocodile populations: Monograph 6: Some river and creek systems on Melville and Grant Islands*. Pergamon Press.

Molnár, Z., Aumeeruddy-Thomas, Y., Babai, D., Díaz, S., Garnett, S. T., Hill, R., Bates, P., Brondízio, E. S., Cariño, J., Demeter, L., Fernández-Llamazares, Á., Guèze, M., McElwee, P., Öllerer, K., Purvis, A., Reyes-García, V., Samakov, A., & Singh, R. K. (2024). Towards richer knowledge partnerships between ecology and ethnoecology. *Trends in Ecology & Evolution*, *39*(2), 109–115.

Moorcroft, H., Ignjic, E., Cowell, S., Goonack, J., Mangolomara, S., Oobagooma, J., Karadada, R., Williams, D., & Waina, N. (2012). Conservation planning in a cross-cultural context: The Wunambal Gaambera Healthy Country Project in the Kimberley, Western Australia. *Ecological Management & Restoration*, *13*(1), 16–25.

Mucina, L. (2019). Biome: Evolution of a crucial ecological and biogeographical concept. *New Phytologist*, *222*(1), 97–114.

Muldavin, E. H., Addicott, E., Hunter, J. T., Lewis, D., & Faber-Langendoen, D. (2021). Australian vegetation classification and the International Vegetation Classification framework: An overview with case studies. *Australian Journal of Botany*, *69*(7), 339–356.

Murphy, B. P., Bradstock, R. A., Boer, M. M., Carter, J., Cary, G. J., Cochrane, M. A., Fensham, R. J., Russell-Smith, J., Williamson, G. J., & Bowman, D. M. J. S. (2013). Fire regimes of Australia: A pyrogeographic model system. *Journal of Biogeography*, *40*(6), 1048–1058.

Murray, N. J., Keith, D. A., Duncan, A., Tizard, R., Ferrer-Paris, J. R., Worthington, T. A., Armstrong, K., Hlaing, N., Htut, W. T., Htat Oo, A., Zay Ya, K., & Grantham, H. (2020). Myanmar's terrestrial ecosystems: Status, threats and conservation opportunities. *Biological Conservation*, *252*, Article 108834.

Newing, H., Brittain, S., Buchadas, A., del Giorgio, O., Grasham, C. F., Ferritto, R., Garcia Marquez, J. R., Khanyari, M., König, B., Kulkarni, A., Murali, R., Qin, S., Rakowski, J., Winn, F., & Ghoddousi, A. (2024). 'Participatory' conservation research involving indigenous peoples and local communities: Fourteen principles for good practice. *Biological Conservation*, *296*, Article 110708.

Nicholson, E., Andrade, A., Brooks, T. M., Driver, A., Ferrer-Paris, J. R., Grantham, H. S., Gudka, M. S., Keith, D. A., Kontula, T., Lindgaard, A., Londono-Murcia, M. C., Murray, N. J., Raunio, A., Rowland, J. A., Sievers, M., Skowno, A. L., Stevenson, S. L., Valderrabano, M., Vernon, C. M., … Obura, D. (2024). Roles of the Red List of Ecosystems in the Kunming-Montreal Global Biodiversity Framework. *Nature Ecology & Evolution*, *8*, 614–621. https://doi.org/10.1038/s41559-023-02320-5

Nicholson, E., Watermeyer, K. E., Rowland, J. A., Sato, C. F., Stevenson, S. L., Andrade, A., Brooks, T. M., Burgess, N. D., Cheng, S.-T., Grantham, H. S., Hill, S. L., Keith, D. A., Maron, M., Metzke, D., Murray, N. J., Nelson, C. R., Obura, D., Plumptre, A., Skowno, A. L., & Watson, J. E. M. (2021). Scientific foundations for an ecosystem goal, milestones and indicators for the post-2020 global biodiversity framework. *Nature Ecology & Evolution*, *5*(10), 1338–1349. https://doi.org/10.1038/s41559-021-01538-5

Noss, R. F. (1996). Ecosystems as conservation targets. *Trends in Ecology & Evolution*, *11*(8), 351.

Olofsson, P., Foody, G. M., Stehman, S. V., & Woodcock, C. E. (2013). Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. *Remote Sensing of Environment*, *129*, 122–131.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., & Kassem, K. R. (2001). Terrestrial Ecoregions of the World: A New Map of Life on Earth: A new global map of terrestrial ecoregions provides an innovative tool for conserving biodiversity. *Bioscience*, *51*(11), 933–938.

Parr, C. L., Lehmann, C. E. R., Bond, W. J., Hoffmann, W. A., & Andersen, A. N. (2014). Tropical grassy biomes: Misunderstood, neglected, and under threat. *Trends in Ecology*, *29*(4), 205–213.

Phelps, L. N., Andela, N., Gravey, M., Davis, D. S., Kull, C. A., Douglass, K., & Lehmann, C. E. R. (2022). Madagascar's fire regimes challenge global assumptions about landscape degradation. *Global Change Biology*, *28*(23), 6944–6960.

Tiwi Land Council (TLC). Puruntatameri, J., Puruntatameri, R., Pangiraminni, A., Burak, L., Tipuamantymirri, C., Tipakalippa, M., Puruntatameri, J., Puruntatameri, P., Pupangamirri, J. B., Kerinaiua, R., Tipiloura, D., Orsto, M.-M., Kantilla, B., Kurrupuwu, M., Puruntatameri, P. F., Puruntatameri, T. D., Puruntatameri, L., Kantilla, K., … Wightman, G.. (2001). *Tiwi plants and animals: Aboriginal flora and fauna knowledge from Bathurst and Melville Islands, northern Australia*. Parks and Wildlife Commission of the Northern Territory and Tiwi Land Council. https://publications.csiro.au/rpr/pub?list=BRO&pid=procite:588fba7f-178b-40aa-86ee-c2644078a3b6

R Core Team. (2018). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing.

R Studio Team. (2020). *RStudio: Integrated development for R*. RStudio, PBC. http://www.rstudio.com

Ratnam, J., Bond, W. J., Fensham, R. J., Hoffmann, W. A., Archibald, S., Lehmann, C. E. R., Anderson, M. T., Higgins, S. I., & Sankaran, M. (2011). When is a 'forest' a savanna, and why does it matter? *Global Ecology and Biogeography*, *20*(5), 653–660.

Richards, A. E., Andersen, A. N., Schatz, J., Eager, R., Dawes, T. Z., Hadden, K., Scheepers, K., & Van Der Geest, M. (2012). Savanna burning, greenhouse gas emissions and indigenous livelihoods: Introducing the Tiwi Carbon Study. *Austral Ecology*, *37*(6), 712–723.

Rose, D. B. (1996). *Nourishing terrains: Australian aboriginal views of landscape and wilderness*. Australian Heritage Commission.

Russell-Smith, J. (1991). Classification, species richness, and environmental relations of monsoon rain forest in northern Australia. *Journal of Vegetation Science*, *2*(2), 259–278.

Russell-Smith, J., & Bowman, D. M. J. S. (1992). Conservation of monsoon rainforest isolates in the Northern Territory, Australia. *Biological Conservation*, *59*, 51–63.

Scarth, P., Armston, J., Lucas, R., & Bunting, P. (2023). *Vegetation height and structure - Derived from ALOS-1 PALSAR, Landsat and ICESat/GLAS, Australia coverage* (Version 1). Terrestrial Ecosystem Research Network. https://portal.tern.org.au/metadata/TERN/de1c2fef-b129-485e-9042-8b22ee616e66

Schultz, C. A., Timberlake, T. J., Wurtzebach, Z., McIntyre, K. B., Moseley, C., & Huber-Stearns, H. R. (2019). Policy tools to address scale mismatches: Insights from U.S. forest governance. *Ecology and Society*, *24*(1), Article 21. https://www.jstor.org/stable/26796926

Shawn-Fletcher, M., Hamilton, R., Dressler, W., & Palmer, L. (2021). Indigenous knowledge and the shackles of wilderness. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(40), Article e2022218118.

Stehman, S. V., & Foody, G. M. (2019). Key issues in rigorous accuracy assessment of land cover products. *Remote Sensing of Environment*, *231*, Article 111199.

Tengö, M., Hill, R., Malmer, P., Raymond, C. M., Spierenburg, M., Danielsen, F., Elmqvist, T., & Folke, C. (2017). Weaving knowledge systems in IPBES, CBD and beyond—Lessons learned for sustainability. *Current Opinion in Environmental Sustainability*, *26–27*, 17–25.

Thompson, A., Munkara, G., Kantilla, M., & Tipungwuti, J. (2019). Medicinal plant use in two Tiwi Island communities: A qualitative research study. *Journal of Ethnobiology and Ethnomedicine*, *15*(1), Article 40.

Tiwi Land Council (TLC). (2022). *Tiwi Land Council annual report 2021–22*. https://www.tiwilandcouncil.com/documents/uploads/Annual%20Report%202021-22.pdf

Tiwi Land Council (TLC). (2024a). *Tiwi Land Council annual report 2023–24*. https://www.tiwilandcouncil.com/documents/uploads/Annual%20Report%202023-24.pdf

Tiwi Land Council (TLC). (2024b). *Tiwi Land Council Corporate Plan 2024–28*. https://www.tiwilandcouncil.com/documents/Uploads/Corporate%20Plan%202024-28.pdf

Toor, M., Dryden, C., Basheer, A., Razee, N. S., Habeeb, S., Perkin, S., & Murray, N. J. (2022). *Applying the IUCN global ecosystem typology to the Maldives*. IUCN Maldives and Government of Maldives. https://www.environment.gov.mv/v2/wp-content/files/publications/20220410-pub-iucn-global-ecosystem-mv.pdf

Tóth, A. B., Terauds, A., Chown, S. L., Hughes, K. A., Convey, P., Hodgson, D. A., Cowan, D. A., Gibson, J., Leihy, R. I., Murray, N. J., Robinson, S. A., Shaw, J. D., Stark, J. S., Stevens, M. I., van den Hoff, J., Wasley, J., & Keith, D. A. (2025). A dataset of Antarctic ecosystems in ice-free lands: Classification, descriptions, and maps. *Scientific Data*, *12*(1), Article 133.

Turnhout, E., & Boonman-Berson, S. (2011). Databases, scaling practices, and the globalization of biodiversity. *Ecology and Society*, *16*(1), Article 35. https://www.jstor.org/stable/26268850

United Nations Statistics Division (UNSD). (2021). *System of Environmental-Economic Accounting—Ecosystem Accounting: Final draft, Version 5*. Department of Economic and Social Affairs, Statistical Division, United Nations. https://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf

United Nations Convention on Biological Diversity. (1992). https://treaties.un.org/doc/Treaties/1992/06/19920605%2008-44%20PM/Ch_XXVII_08p.pdf

Wartmann, F. M., & Purves, R. S. (2018). 'This is not the jungle, this is my barbecho': Semantics of ethnoecological landscape categories in the Bolivian Amazon. *Landscape Research*, *43*(1), 77–94.

White, R. M., Schmook, B., Calmé, S., Giordano, A. J., Hausser, Y., Kimmel, L., Lecuyer, L., Lucherini, M., Méndez-Medina, C., & Peña-Mondragón, J. L. (2023). Facilitating biodiversity conservation through partnerships to achieve transformative outcomes. *Conservation Biology*, *37*(3), Article e14057.

Whiting, S., Hadden, K., Long, J., Lauder, A., Kleidon, A., & Cook, K. (2007). *Sea Turtle conservation and education on the Tiwi Islands*. Australian Government Department of the Environment and Water Resources.

Williams, R. J., Cook, G. D., Liedloff, A. C., & Bond, W. J. (2017). Australia's tropical savannas: Vast, ancient and rich landscapes. In D. A. Keith (Ed.), *Australian vegetation* (3rd ed., pp. 368–388). Cambridge University Press.

Wilson, B. A., & Bowman, D. M. J. S. (1994). Factors influencing tree growth in tropical savanna: Studies of an abrupt Eucalyptus boundary at Yapilika, Melville Island, northern Australia. *Journal of Tropical Ecology*, *10*(1), 103–120.

Wilson, B. A., & Fensham, R. J. (1994). A comparison of classification systems for the conservation of sparsely wooded plains on Melville Island, Northern Australia. *Australian Geographer*, *25*(1), 18–31.

Woinarski, J. C. Z., & Baker, B. (2002). *Biodiversity Audit - Bioregional case study*. Parks and Wildlife Commission of the Northern Territory.

Woinarski, J. C. Z., Brennan, K., Cowie, I., Kerrigan, R., & Hempel, C. (2003). *Biodiversity conservation on the Tiwi Islands, Northern Territory: Part 1. Environments and plants*. Northern Territory Government Department of Infrastructure, Planning and Environment.

Woinarski, J. C. Z., Brennan, K., Hempel, C., Firth, R. S. C., & Watt, F. (2000). *Biodiversity conservation on the Tiwi Islands: Plants, vegetation types and terrestrial vertebrates on Melville Island. A report to the Tiwi Land Council*. Parks and Wildlife Commission of the Northern Territory.

Woinarski, J. C. Z., Hadden, K., Hicks, J., & McLeod, D. (2003). *Biodiversity conservation on the Tiwi Islands, Northern Territory: Part 3. Management and planning for biodiversity conservation*. Northern Territory Government Department of Infrastructure, Planning and Environment.

Woodward, E., Hill, R., Harkness, P., & Archer, R. (Eds.). (2020). *Our Knowledge Our Way in caring for Country: Indigenous-led approaches to strengthening and sharing our knowledge for land and sea management. Best Practice Guidelines from Australian experiences*. NAILSMA and CSIRO. www.csiro.au/ourknowledgeourway

Wright, M. N., & Ziegler, A. (2017). Ranger: A fast implementation of random forests for high dimensional data in C++ and R. *Journal of Statistical Software*, *77*(1), 1–17. https://doi.org/10.18637/jss.v077.i01

Wurtzebach, Z., & Schultz, C. (2016). Measuring ecological integrity: History, practical applications, and research opportunities. *Bioscience*, *66*(6), 446–457.

Wyborn, C., & Evans, M. C. (2021). Conservation needs to break free from global priority mapping. *Nature Ecology & Evolution*, *5*(10), 1322–1324.

Xiao, H., Driver, A., Etter, A., Keith, D. A., Obst, C., Traurig, M. J., & Nicholson, E. (2024). Synergies and complementarities between ecosystem accounting and the Red List of Ecosystems. *Nature Ecology & Evolution*, *8*, 1794–1803.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Young, A. R., Davies, H. F., Ayre, M. L., Brekelmans, A., Bryan, B. A., Elith, J., Hadden, K., Kerinaiua, M., Keith, D. A., Lewis, D. L., Munkara-Murray, K. M., Ryan, S., Spencer, M., & Nicholson, E. (2025). Applying the IUCN Global Ecosystem Typology to classify, describe, and map ecosystems based on regional data and Indigenous knowledge. *Conservation Biology*, e70099. https://doi.org/10.1111/cobi.70099