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EVALUATING THE PLANT COMMUNITY PATTERNS IN MANTANANI BESAR ISLAND USING GIS AND PHYTOSOCIOLOGICAL SURVEY

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Mantanani Besar Island, in Kota Belud, Sabah, Malaysia, is both a tourist site and an important ecological site for many species. Despite the ecological importance, information on the distribution of plant species remains limited. This study aims to fill this gap by examining community patterns using vegetation mapping and a phytosociological survey. Based on our spatial analysis, approximately 84% of this island's surface area is covered by forests, categorised into two distinct types: inland and coastal forest. Further investigation based, 55 quadrat plots (10m × 10m) that were randomly established in the classified forested area confirmed 66 species, representing 63 genera and 38 families. Two of the 66 recorded species were listed in the IUCN and Malaysia Plant Red Lists. The ANOSIM and Mantel's tests revealed four plant community types in the island's forested areas. Our survey the first comprehensive plant species checklist and community patterns on the island. We also concluded that combining both methods is beneficial for designing vegetation mapping.

Keywords: Malaysia, plant species, vegetation mapping, forest, statistical analysis, checklist, mapping

INTRODUCTION

Mantanani Besar Island, located in Malaysia, holds significant ecological and biodiversity importance. For instance, this island serves as a sanctuary for numerous migratory bird species, making it a crucial stopover point during their journeys (Sheldon et al. 1983, Mohd Fauzi 2022). These ecological attributes underscore the island's role in preserving and supporting diverse wildlife populations, contributing to its ecological and biodiversity significance.

The island is home to approximately 650 populations and attracts around 70,000 visitors annually (Martin-Daguet et al. 2013, Kristy 2021). The small island's unique biodiversity, coupled with its status as a tourism development site, plays a crucial role in promoting socio-economic and cultural development for the local community (Lee et al. 2018). Furthermore, this combination has the potential to attract a higher number of visitors. Nevertheless, amid increasing tourism development (BIMP-EAGA 2017, Alferd et al. 2023), concerns about its impact on this unique biodiversity have intensified (Rajamani & Marsh 2010, Sodhi et al. 2010, Reef check 2017, 2019, Joseph et al. 2019, Mohd Fauzi 2022).

The conservation of this unique ecosystem is significantly important for maintaining future ecological balance and human well-being (Rostal et al. 2013, Chee et al. 2016, Isbell et al. 2017). Despite its significance, previous research primarily focused on the effects of specific ecology, geographic characteristics, and socio-economic factors, leaving a gap in understanding the island's natural environment and vegetation conditions (Mohd Harun et al. 2019). Vegetation, which plays a crucial role in biomass storage and net primary productivity, also provides vital habitats and food resources for terrestrial, marine, and coastal flora and fauna (Barbier et al. 2008, Corlett 2016, Rajpar 2018). It serves as a bioindicator, highlighting its essential role in ecological functions. However, to the best of our knowledge, few documents have touched upon the island's vegetation, with limited scope (Sheldon et al. 1983, Bakewell 2012, Mojiol et al. 2019).

Hence, it is imperative to have a comprehensive understanding of the island's natural environment, focusing on estimating its plant community patterns. The lack of vegetation mapping on Mantanani Besar Island can be attributed to the following two primary reasons. First, accessing the island is challenging due to its location and limited transportation options. Furthermore, in tropical regions (including islands), designing accurate mapping requires long-term and extensive phytosociological surveys because of their extensive forests (Jha & Chowdary 2007, Wong & Neo 2019). In Malaysia, there are a total of 878 islands, among them, only three islands have extensive vegetation maps (Kitayama & Shaari 1987, Lattif et al. 1999, Wong et al. 1999). This suggests that comprehensive vegetation mapping has been conducted on only a few islands.

The islands of this Malaysia (including Borneo) are distinguished as regions of immense biodiversity and hotspots, making them globally valuable areas (Mittermeier et al. 1997, Myers 1988, Myers et al. 2000). Nevertheless, increasing developmental activities on these islands (Wong 1998, Gaveau et al. 2018) has threatened this rich biodiversity and ecosystem (Pickering & Hill 2007). Therefore, vegetation mapping is increasingly important for the conservation of tropical islands, including those in Malaysia.

To address this issue, the process has been significantly eased by using spatial analysis of Geographic Information Systems (GIS) with satellite imagery (Colditz et al. 2011, Wulder et al. 2018). GIS is becoming an important tool for vegetation mapping in Malaysia, particularly in forested areas. This tool reveals previously unreachable areas and provides a wealth of information for conservation management.

Indeed, in Malaysia, several examples of using GIS in vegetation mapping were presented by Ismail (2010) and Omar et al. (2018). The phytosociological survey, historically significant, continues to be utilised. Furthermore, the digitalised data collection techniques led to statistical analysis for determining plant community patterns and vegetation mapping (e.g., Wikum & Shanholtzer 1978, Legendre et al. 2002, Sarah et al. 2015). Consequently, both methods have been widely employed for vegetation mapping to analyse community patterns and distributions. In this research, we adopt a multifaceted approach to assess the island's vegetation comprehensively. Our methodology comprises the following steps: (1) Employing remote sensing techniques to identify and map various vegetation types and subsequently comparing these findings with existing maps. (2) Conducting a phytosociological survey within plots established in different vegetation types to compile a checklist of plant species. (3) Analysing community distributions across the island based on the plant compositions observed within these plots.

MATERIAL AND METHODS

Study Site

The data collection was conducted twice in the Mantanani Besar Island (6˚42'42.839"N and 116˚21'10.440"E) from August 24-30 and November 21-25, 2022. The island is approximately 40 km offshore of the west coast of Sabah, Malaysia. The provided information states that the island spans an area of approximately 2.01 km^2, and it is estimated that 80% of its landmass is covered by forested areas (Mustapa et al. 2019). The island's maximum elevation of 59 m (Lakim et al. 2013). The island maintains a steady tropical climate with temperatures around 29-31°C, while rainfall experiences variable levels from 39.5-179.13 mm year-round (World Weather Online 2023).

Previous general classification of forest on the island by BIMP-EAGA (2017) are: (1) The northwestern region comprises rocky limestone bluffs, which are thought to support diverse plant species (representing the "Original vegetation"), (2) The central to the northern region is classified as a "Regenerating Forest" across a wide area, (3) The coastal along the southern side is listed as an "Open scrub" mixture with the thin-trunk tree, and (4) The eastern tips are dominated by terrains populated primarily by *Casuarina equisetifolia* (marked as "Casuarina"). In some of these areas, it has been observed that crops such as coconuts, bananas, and mangoes are cultivated as sources of income and food for the local community (Sheldon et al. 1983, Bakewell 2012).

Quantifying vegetation coverage

The island's vegetation map was created using GIS software (ArcMap version 10.8) and WorldView-3 satellite imagery taken on 16 March 2019. The imagery comprises true color bands at a 1.24 m resolution (pan-sharpened). We adopted an objective-based approach for image classification, which characterises various pixels into homogeneous image objects (Gao et al. 2006; Duro et al. 2012; Blaschke et al. 2014).

Next, a support vector machine was implemented, leveraging its ability to produce reliable results with minimal training classes (Vapnik 2000, Liu et al. 2019). The objectives were classified into six classes (beach, buildings, football field/grassland, inland forest, coastal forest, naked ground) which were simultaneously adjusted using a reclassify tool. Lastly, we applied the tabulate area tool to quantify the proportion of forested areas. All imagery underwent geometrically corrected to align with the Universal Transverse Mercator (UTM) projection, using the WGS 84 coordinate system as a reference.

Sampling design and data collection

To further quantitatively reveal the plant community type of the inland and coastal forest classified based on satellite images, a total of 55 quadrat plots (10 m x 10 m) were randomly established using GIS software (Figure 1). All observed plant species and their coverage rate within these plots were recorded using Braun-Blanquet's method (1964), adopting Van der Maarel's (1979) ordinal scale (Table 1).

Species identification

Plant species were identified by second author in the field. Voucher specimens for those taxa that cannot be identified in field were collected and preserved in plastic bags for identification by comparing the specimens in

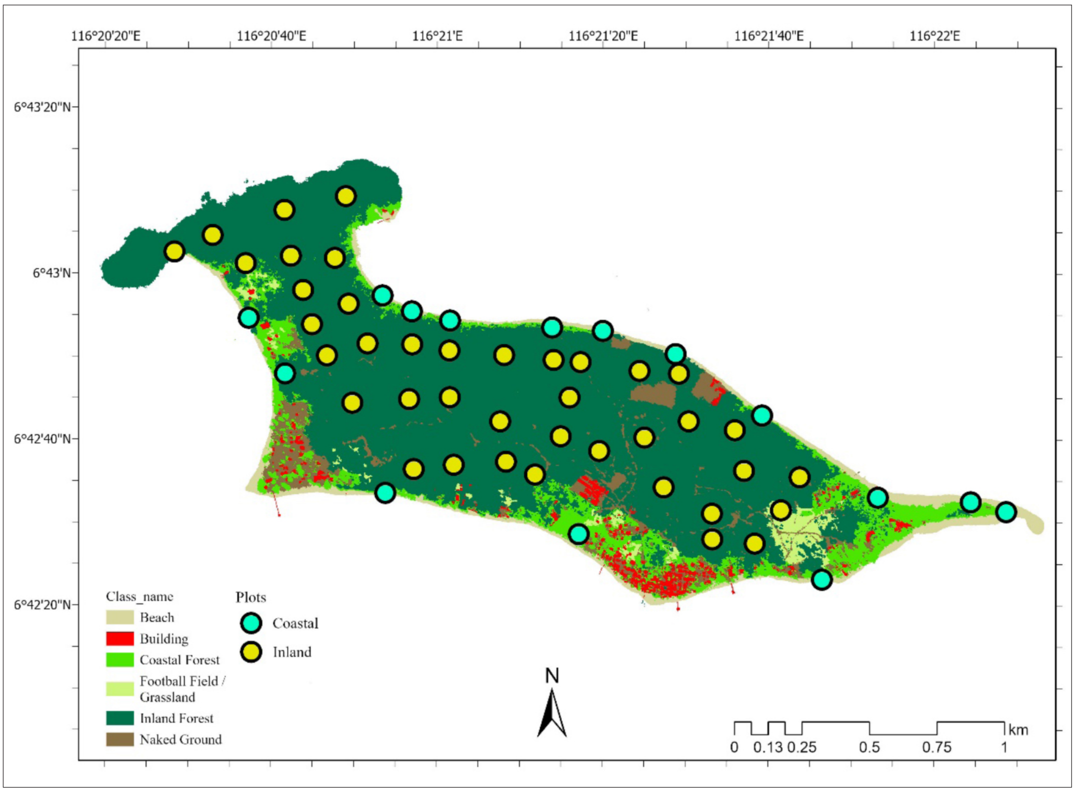

Figure 1 Map of the sampling plots in Mantanani Besar Island. The background land cover map is based on the spatial analysis result of Worldview-3 satellite imagery

Table 1 Braun-Blanquet's combined scaling table

Value of coverage	Original Scale	Ordinal Scale	Percentage Scale
< 1%	r	1	0.02
< 5%	+	2	0.1
5-10%	1	3	2.5
10-25%	2	4	15
25-50%	3	5	37.5
50-75%	4	6	62.5
> 75% coverage	5	7	87.5

Sandakan Herbarium in Sepilok (SAN) and Bornensis Herbarium of Universiti Malaysia Sabah (BORH). The conservation status of these species was determined by referring to the IUCN and the Malaysia Plant Red List (Yong et al. 2021, IUCN 2022).

Statistical analysis

The phytosociological data were analysed using the 'vegan' package Version 2.6-4 (Oksanen et al. 2022) in R software Version 4.1.2 (R Core Team 2021). Before data analysis, we converted the ordinal scale into a cover percentage scale according to Tüxen and Ellenberg's (1937) (Table 1) and applied a logarithmic transformation to enhance statistical robustness.

For the Hierarchical Cluster Analysis (HCA), Bray-Curtis dissimilarity index (Bray & Curtis 1957) was used, and the Flexible-β(Beta) algorithm shaped the dendrogram construction (McCune & Mefford 2006). Based on its proven efficacy across multiple plant community classification studies, we set a β value to -0.25 to influence the shape of dendrogram clustering (McCune & Grace 2002, Lötter et al. 2013, Roberts 2015). In order to determine the optimal group number for the dendrogram, we utilised a specific computational algorithm in the R software (R Core Team 2011). The heatmap, based on van der Maarel's (1979) ordinal scales, is plotted using the 'gplots' package Version 3.1.3 (Warnes et al. 2022).

We then utilised Analysis of Similarity (ANOSIM) and Mantel's test to determine the significant differences in community patterns. ANOSIM is a non-parametric multivariate test that calculates an R statistic ranging from -1 to 1 based on a dissimilarity coefficient (Clarke 1993). A high positive R-value indicates a substantial difference between the compared groups. On the other hand, Mantel's test was conducted using Pearson's correlation to assess the relationship between community patterns and geographic distances. The geographic distances were converted to an Euclidean dissimilarity index using a 'geosphere' package Version 1.5-18 (Hijmans et al., 2022). Lastly, a Similarity Percentage (SIMPER) was conducted to identify the species contributing to each classified cluster. All the statistical tests were set at $p < 0.05$ significant levels, and to ensure the robustness of our findings, 999 permutation tests were executed.

RESULTS

Vegetation coverage

Our spatial analysis with the image classification method revealed that approximately 84% of the island's land area is covered by forest, corroborating the findings of Mustapha et al. (2019). Applying tabulate area tools on detailed high-image classification allowed us to distinguish between two primary forest types: inland forest (72.68%) and coastal forest (11.28%). Meanwhile, the latter is considered to be as predominantly an area for the *Pandanus dubius*, *Casuarina equisetifolia*, and *Cocos nucifera*, primarily around the coastal region, consistent with findings reported by Sheldon et al. (1983) and Mojiol et al. (2019). Consequently, our spatial analysis functioned as a baseline dataset and modeling method for future foundational research, yet it also reemphasized the challenges associated with forest types and classification accuracy.

Classification of plant community type

We identified a total of 66 plant species spread across 63 genera and 38 families at our study site (Table 2). All the species were identified into species level except four that identified at genus level, namely *Lisea* sp. (Lauraceae), *Drysoxylum* sp. (Meliaceae), *Jasminum* sp. (Oleaceae), and *Dracaena* sp. (Ruscaceae). Among the species we identified, *Intisia bijuga* (Near Threatened) and *Trigonachras acuta* (Vulnerable) were recognised as endangered according to the IUCN (IUCN, 2020) and Malaysia Plant Red List (Yong et al. 2021).

The plant community types analysis, showed significant differences among the four plant community types (ANOSIM: $R = 47\%$ $P = 0.001$; Mantel: $R = 23\%$ $P = 0.001$), namely, 'Dominant Forest,' 'Planted Forest,' 'Limestone Forest,' and 'Coastal Forest,' respectively (Figure 2).

Table 2 Recorded plant species within sampling plots, conservation status, and number of observations in each cluster

Family	Species	Conservation Status	A N = 38	B N = 29	C N = 27	D N = 30
Amaryllidaceae	*Crinum asiaticum*	-	0	2	0	2
Anacardiaceae	*Buchanania arborescens*	Least Concern[a]	30	6	3	0
	Campnosperma auriculatum	Least Concern[a]	2	0	3	4
	Dracontomelon dao	Least Concern[a]	0	0	1	0
Apocynaceae	*Alstonia macrophylla*	Least Concern[ab]	0	1	1	0
	Ochrosia oppositifolia	Least Concern[ab]	0	0	0	4
	Tabernaemontana alternifolia	-	4	5	1	3
Arecaceae	*Calamus ornatus*	-	1	0	1	0
	*Cocos nucifera**	-	3	10	2	1
	Oncosperma tigillarium	-	0	1	0	0
Asteraceae	*Chromolaena odorata*	-	0	2	0	0
Boraginaceae	*Cordia subcordata*	Least Concern[a]	0	0	0	1
Burseraceae	*Canarium odontophyllum*	-	0	0	1	0
Calophyllaceae	*Calophyllum inophyllum**	Least Concern[a]	0	0	1	1
Cannabaceae	*Celtis philippensis*	Least Concern[a]	1	0	0	0
Casuarinaceae	*Casuarina equisetifolia**	Least Concern[ab]	12	7	0	1
Celastraceae	*Salacia chinensis*	-	1	1	0	2
Combretaceae	*Terminalia catappa*	Least Concern[a]	1	0	4	0
	Terminalia phellocarpa	Least Concern[a]	2	0	2	0
Convolvulaceae	*Ipomoea pes-caprae**	Least Concern[ab]	0	2	0	1
Cyperaceae	*Cyperus rotundus*	Least Concern[a]	3	1	0	0
Ebenaceae	*Diospyros maritima*	Least Concern[a]	29	3	7	2
Euphorbiaceae	*Euphorbia cyathophora*	-	0	1	0	0
	Spathiostemon javensis	Least Concern[a]	1	0	2	0
	Suregada multiflora	-	6	0	1	3

continued

Table 2 Continued

Family	Species	Conservation Status	A N = 38	B N = 29	C N = 27	D N = 30
Fabaceae	*Caesalpinia bonduc*	Least Concern[a]	0	0	0	1
	Dendrolobium umbellatum	Least Concern[a]	3	0	0	0
	Desmodium triflorum	Least Concern[a]	0	1	0	1
	Intsia bijuga	Near Threatened[a]	1	0	0	2
	*Millettia pinnata**	Least Concern[a]	0	0	0	1
	Serianthes grandiflora	Least Concern[a]	0	0	0	1
	Sophora tomentosa	Least Concern[a]	0	0	0	4
Lamiaceae	*Premna serratifolia**	Least Concern[a]	1	1	0	2
	Vitex negundo	Least Concern[a]	0	2	0	0
Lauraceae	*Cassytha filiformis*	-	0	2	0	0
	Litsea sp.	-	0	0	0	1
Lecythidaceae	*Barringtonia racemose*	Least Concern[ab]	0	1	0	1
Malvaceae	*Hibiscus tiliaceus**	Least Concern[a]	0	2	0	0
Meliaceae	*Dysoxylum sp.*	-	5	0	8	0
Moraceae	*Ficus septica*	Least Concern[a]	2	4	0	1
	Ficus virens	Least Concern[a]	0	1	1	0
Myrtaceae	*Syzygium sp.*	-	2	0	2	0
Oleaceae	*Chionanthus pluriflorus*	Least Concern[a]	10	0	0	0
	Jasmine sp.	-	0	0	0	2
Orobanchaceae	*Tylophora indica*	-	4	5	0	0
Pandanaceae	*Pandanus dubius*	Least Concern[a]	0	3	2	6
	*Pandanus odoratissimus**	-	0	1	0	0
Passifloraceae	*Turnera ulmifolia*	Least Concern[a]	0	5	0	0
Phyllanthaceae	*Glochidion obscurum*	-	20	8	1	1
Poaceae	*Ischaemum muticum*	Least Concern[a]	0	5	0	0
Polypodiaceae	*Microsorum scolopendria*	Least Concern[ab]	1	0	0	0
Primulaceae	*Ardisia elliptica*	-	6	1	2	0
Putranjivaceae	*Drypetes littoralis*	-	3	0	2	0
Rubiaceae	*Canthium confertum*	-	1	0	0	0
	Guettarda speciosa	Least Concern[a]	1	0	0	7
	Ixora philippinensis	Least Concern[ab]	8	0	0	0
	Morinda citrifolia	-	1	0	0	1
	Psychotria malayana	-	1	0	1	0
Ruscaceae	*Dracaena sp.*	-	0	0	1	0

continued

Table 2 Continued

Family	Species	Conservation Status	A N = 38	B N = 29	C N = 27	D N = 30
Rutaceae	*Clausena excavata*	-	1	0	0	0
	Micromelum minutum	Least Concern[a]	4	0	1	1
	Severinia disticha	-	2	0	1	1
Sapindaceae	*Allophylus cobbe**	Least Concern[b]	2	1	0	0
	Trigonachras acuta	Vulnerable [b]	6	0	1	0
Sapotaceae	*Mimusops elengi*	Least Concern[a]	3	0	0	1
	Pouteria obovate	-	2	0	2	0

Note: "a" = IUCN, "b" = Malaysia Plant Red List, "*" = The species previously recorded in Mojiol et al. (2019) study. The following 18 species were mentioned in Mojiol et al. (2019) but were not recorded in this study: 1) *Areca catechu* (Arecaceae), 2) *Excoecaria agallocha* (Euphorbiaceae), 3) *Macaranga tanarius* (Euphorbiaceae), 4) *Adenanthera pavonia* (Fabaceae), 5) *Aganope heptaphylla* (Fabaceae), 6) *Caesalpinia crista* (Fabaceae), 7) *Canavalia maritima* (Fabaceae), 8) *Derris trifoliata* (Fabaceae), 9) *Peltophorum pterocarpum* (Fabaceae), 10) *Scaevola taccada* (Goodeniaceae), 11) *Barringtonia asiatica* (Lecythidaceae), 12) *Thespesia populnea* (Malvaceae), 13) *Aglaia cucullata* (Meliaceae), 14) *Agalia* sp. (Meliaceae), 15) *Ficus macrocarpa* (Moraceae), 16) *Eugenia (Syzygium) grandis* (Myrtaceae), 17) *Turnera diffusa* (Passifloraceae), 18) *Drynaria quercifolia* (Polypodiaceae).

The SIMPER analyses revealed that 12 of the 66 plant species contributed significantly to the differences between these communities. Predominantly, *Buchanania arborescens*, *Diospyros maritima*, and *Glochidion obscurum* were consistently observed across most plots, referred to herein as the 'Dominant Forest' (Figure 2). In the 'Plantation Forest,' located in the south near populated coastal areas, the *Cocos nucifera*, *Ischaemum muticum*, and *Turnera ulmifolia* are the high-contribution species (Figure 2). In the northwest, the 'Limestone Forest' (Figure 2) area is characterised by *Dysoxylum* sp., *Campnosperma auriculatum*, and *Terminalia catappa*, which construct a unique community. Lastly, the 'Coastal Forest' in the northern coastal region is distinguished by its distinctive community of *Pandanus dubius*, *Guettarda speciosa*, and *Sophora tomentosa* (Figure 2).

DISCUSSION

Throughout this study, integrating spatial analysis with phytosociological surveys has given us a deeper understanding of the plant community patterns on Mantanani Besar Island. While spatial analysis identified two forest types, our statistical analysis from the phytosociological survey revealed distinct community types within each forest category. For inland forests, we discovered community types that partially align with existing maps (BIMP-EAGA 2017). Among these, species such as *Buchanania arborescens*, *Diospyros maritima*, and *Glochidion obscurum*, observed in the 'Dominant Forest,' are likely the most influential across the island. Conversely, the 'Limestone Forest' exhibits significantly different community type, a finding that supports Saw (2010) and Kiew et al. (2019). In a deeper insight, the limestone foothills and hilltops appear to host distinct community patterns. For example, numerous *Dysoxylum* sp. were observed at the hilltop site, but not at the foothill site. Although the *Dysoxylum* genus is considered widespread in Malaysia's lowlands and limestone areas, our survey indicates its presence in only specific locations, underscoring the need for further research on this species (Yong et al. 2021). Additionally, species such as *Ardisia elliptica* and *Hibiscus tiliaceus* were identified at the limestone foothills, suggesting a unique community pattern. However, parts of the limestone foothills have been transformed into 'Plantation Forest,' resulting in community loss (Figure 2). These distinctive community characteristics, not evident from our initial analysis due to the limited sampling in this area, necessitate additional research to clarify these findings.

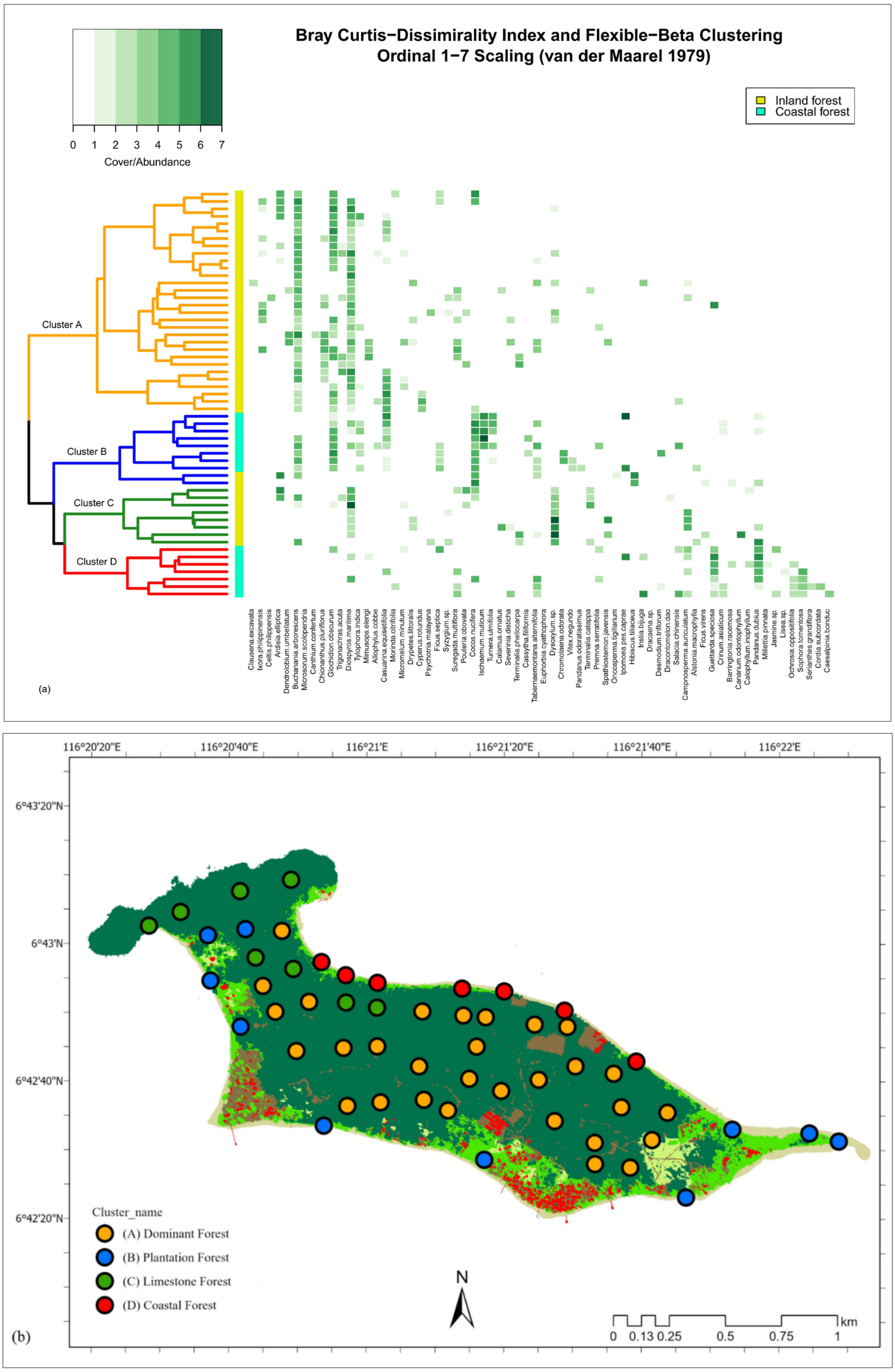

Figure 2 (a): Hierarchical Cluster Analysis (HCA) results. 1) Dendrogram depicting four main clusters with varying species compositions: Dominant Forest (orange), Plantation Forest (blue), Limestone Forest (green), and Coastal Forest (red). 2) Color key indicates species cover/abundance scale from 0 (none) to 7 (abundant). 3) Color bars differentiate "Inland (Gold)" and "Coastal (Lime green)" vegetation. (b): Distribution of plant community identified by Hierarchical Cluster Analysis (HCA)

In coastal forests, distinct compositions were observed between the north and south, highlighting significant differences between plant communities in untouched coastal areas ('Coastal Forest') and those in coastal areas influenced by human habitation ('Plantation Forest'). The prevalence of *Cocos nucifera* in the 'Plantation Forest' corroborates the theory that its introduction results from anthropogenic activities, as suggested by prior studies (Sheldon et al. 1983). While Sheldon et al. (1983) and Mojiol et al. (2019) reported *Casuarina equisetifolia* as the predominant species in coastal areas, our findings indicate *Pandanus dubius* as the dominant species, deviating from their observations. Furthermore, we also discovered a few presences of *Intsia bijuga*, a "Near Threatened" species (IUCN 2022), in this area. Since *Intsia bijuga* has historically been utilised by Malaysians and the local community for construction, there is a pressing need to ensure its conservation (Orwa et al. 2009, Marler 2015). These discrepancies in dominant species may arise from the differing sampling methods used. Mojiol et al. (2019) primarily employed the transect method in coastal areas, focusing on an individual dataset, whereas our study utilised random quadrant plots across the entire island, employing a cover-abundance dataset with statistical analysis. Although the transect method is effective for assessing species richness and distribution in specific areas, random quadrant methods are more suitable in environments with undefined plant community compositions, such as on Mantanani Besar Island (Legendre et al. 2002). Among these, *Casuarina equisetifolia* was observed in some inland forest plots, indicating the possibility that it may not be a dominant species. Furthermore, Mojiol et al. (2019) identified 28 plant species in coastal forests, 18 of which were not observed in our study. In contrast, our research identified 36 plant species not reported by Mojiol et al. (2019), suggesting that both approaches may overlook rare species due to limited sampling scopes or insufficient sample sizes, potentially affecting the results (Goslee, 2006). To achieve a more comprehensive species checklist, a combination of both sampling design techniques is recommended (Huebner 2007, Senyanzode et al. 2020).

Overall, our statistical analysis proved more effective in identifying key plant species and characterising each community pattern with higher reliability than analyses based solely on spatial data. However, this analysis has prompted several recommendations for future research. Traditionally, studies on plant species cover/abundance have frequently employed the scaling methods of Tūxen and Ellenberg (1937) and Braun-Blanquet (1964). A significant limitation of these scales is their inability to account for the actual number of individuals, potentially leading to inaccuracies in hierarchical cluster analysis (HCA) and multivariate tests (Podani 2006; Camiz et al. 2017). Given the scarcity of plant species datasets for the island, rigorously collecting baseline data is essential before drawing definitive conclusions. Afterward, we recommend exploring various ordinal scales outlined by Van der Maarel (1979, 2007) to compare community patterns and investigate different clustering methods (Aho 2006, Podani 2006, Tichý et al. 2010). Ultimately, our research has not only updated our knowledge of the island's plant species and community patterns but also pinpointed areas for methodological enhancement in survey methodologies.

Our methodology has provided a comprehensive understanding of plant community patterns on Mantanani Besar Island. However, the increasing tourism development, coupled with the rising sea level, may adversely impact its vegetation communities, particularly within coastal forests (Koiting et al. 2015, BIMP-EAGA 2017). Consequently, continuous mapping and assessment of the island's vegetation are paramount. While Worldview-3 satellite imagery offers advantages for evaluating coastal areas (McCarthy & Halls 2014), the precision in classifying inland forests requires further clarification. To address this, utilising high-resolution satellite or airborne imagery alongside specific spatial datasets and analysis techniques, is crucial for modeling more accurate vegetation maps (Li et al. 2015, Reddy et al. 2015, Onishi & Ise 2021, Beloiu et al. 2023). Furthermore, conducting phytosociological surveys with robust statistical analyses is recommended to accurately identify forest classifications and plant community types (Al-Tahir & Saeed 2003, Ismail 2010, Nizam et al. 2012, Ahmad et al. 2023). Implementing these comprehensive methodologies is anticipated to greatly improve the accuracy of vegetation mapping, thereby offering deeper insights into the island's diverse vegetation ecosystems.

CONCLUSION

Mantanani Besar Island is renowned for its unique ecosystem and stands as a popular tourist destination. However, the burgeoning tourism development poses significant risks, including the potential reduction of forest coverage and the introduction of invasive species. Therefore, comprehending the island's plant species diversity and community patterns becomes crucial for guiding its sustainable development and conservation initiatives. Through our study, we have provided an updated plant species checklist and elucidated the community patterns on the island. To the best of our knowledge, this study represents the first comprehensive phytosociological survey covering the entire island. Additionally, our research highlights the importance of integrating spatial analysis with phytosociological surveys to develop a dependable vegetation map. Given the limited studies concerning island plant community patterns in Malaysia, our research methodology offers a beneficial blueprint for future studies in this domain.

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