

APPLICATION OF CLUSTER AND MDS TECHNIQUES IN THE ECOLOGICAL EVALUATION OF MANGROVE VEGETATION IN CUT MAMPLAM

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Abstract: The structure of the plant community significantly influences the equilibrium of the surrounding environment, affecting the trophic interactions within its ecosystem. The investigation of mangrove vegetation in Cut Mamplam village was carried out in September 2021 to determine the condition and structural characteristics of the mangrove ecosystem by multivariate analysis. The mangrove vegetation in Cut Mamplam Village was sampled at three observation stations by establishing a transect parallel to the coast. Subsequently, the community structure was examined and assessed using cluster analysis and nonmetric multidimensional scaling using the PRIMER v7 software. The study findings indicate that the mangrove forest vegetation in Cut Mamplam Village consists of five species from three families. *Avicennia alba*, *A. lanata*, *Bruguiera gymnorrhiza*, *Rhizophora mucronata* and *Sonneratia alba*. The highest density of mangrove vegetation was observed in *A. alba* in all categories: trees (616.67 ind/ha), seedlings (833.33 ind/ha) and saplings (6666.67 ind/ha). Additionally, the highest important value index (IVI) was recorded in *A. alba* for all categories: trees (232.16%), seedlings (102.40%), and saplings (228.43%). A similarity of mangrove density between species was noted at 60%, resulting in the formation of two distinct groups. Regarding the basal area, the vegetation stands of *A. alba* and *A. lanata* exhibited the highest values (280.61 and 266.03 m²/ha, respectively). The similarity of basal area among the observed species was 20%, resulting in the formation of two distinct groups. Additionally, Station II, classified as having mature vegetation, demonstrated a maturity similarity of 80% between observation stations.

Keywords: Multivariate statistic, cluster analysis, MDS, mangrove vegetation

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Introduction

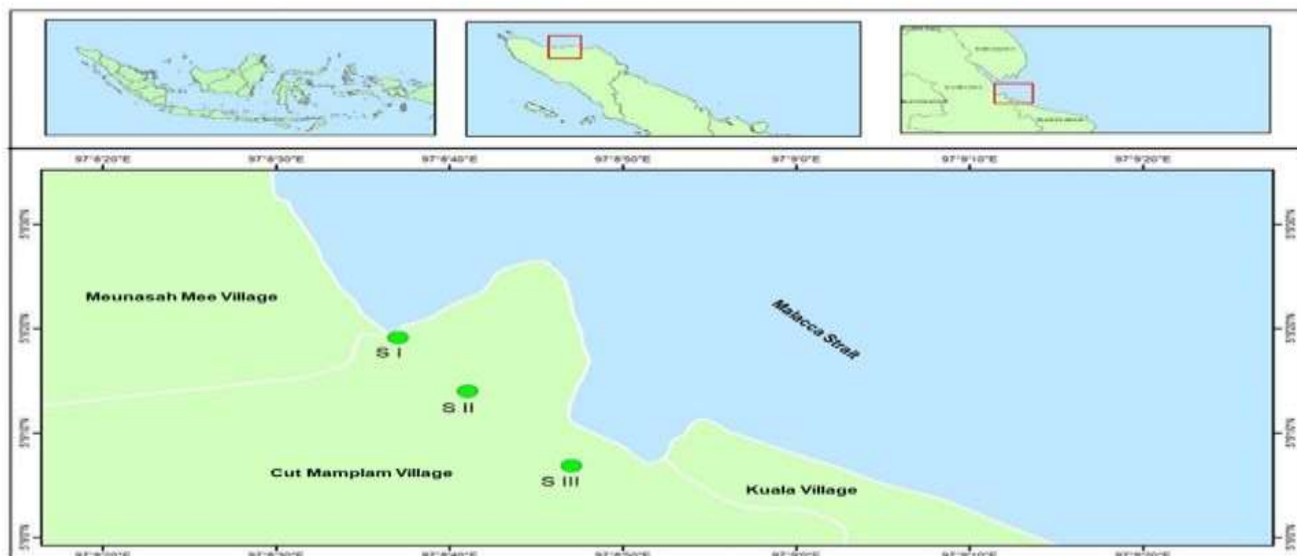
Multivariate analysis is a statistical method that involves a dataset comprising measurements of multiple individuals or objects (Rencher, 2002; Anderson, 2003). It facilitates the interpretation of complex systems (Indelicato et al., 2018) and serves as a tool for data scaling (Junior et al., 2019). This analysis enables the grouping and optimization of similarities among data (Cruz-Cardenas et al., 2017) to understand the variations present within the data set (Kumar et al., 2018). Multivariate analysis is extensively used to interpret environmental data, including differentiation between natural inputs and anthropogenic activities (Facchinelli et al., 2001; Lucho-Constantino et al., 2005; da Silva et al., 2016; Filho et al., 2017), selection or determination of soil, sediment, and air characteristics (Araujo et al., 2013; Khwedim et al., 2015; Singh & Ramanathan, 2015; Junior et al., 2019), identification of sources of water pollution (Delshab et al., 2016; Ezraneti et al., 2021), and evaluation of the structure of mangrove community (Syahrial et al., 2023; Efriyeldi et al., 2023).

In botany, multivariate analysis is extensively used for morphological assessment, distribution research, and the estimation of the maturity level of vegetative stands. Vegetation refers to a group of plants or crops that inhabit a certain area or region within an ecosystem. These plant communities may exhibit distribution patterns based on spatial and temporal factors (Campbell et al., 2004). According to van der Maarel (2005), not all plants that develop are capable of becoming vegetation; for instance, fields cultivated with maize or gardens planted with flowers. Kartawinata (2010) asserted that vegetation consists solely of plants; however, when physical and biotic components are integrated, an ecosystem is formed. Vegetation structure or analysis is used to forecast the condition of plant vegetation in a given area. This structure results from the spatial arrangement of plant stands and life forms, stratification or vegetation cover, characterized by parameters such as diameter, height, distribution, canopy diversity, and species continuity (Fachrul, 2007). The parameters utilized include density, frequency, and dominance (Mueller-Dombois & Ellenberg, 1974). Moreover, vegetation analysis serves to determine the proportion of plant species, ranging from dominant to nondominant (Sriyani, 2012), with mangroves being a frequently seen or scientifically examined vegetation type.

Mangroves are coastal plants that establish forests and ecosystems in tropical and subtropical regions (Maiti & Chowdhury, 2013; Polania et al., 2015; Alongi, 2018). They are located in protected estuaries (Analuddin et al., 2013; Maiti & Chowdhury, 2013), along riverbanks (Maiti & Chowdhury, 2013; Duke, 2016; Ismoyo et al., 2017), and in lagoons (Maiti & Chowdhury, 2013). These plants have distinct characteristics compared to others (Chakraborty, 2013; Motamedi et al., 2014; Zakaria et al., 2018), exhibit high productivity (Wang et al., 2013; Hartati & Harudu, 2016; Osland et al., 2016), but are vulnerable (Grosholz, 2002; Lara et al., 2011) due to their proximity to anthropogenic activities (Zhang et al., 2014; Eddy et al., 2015; Kepel et al., 2018) and the impacts of climate change (Lara et al., 2011). Menendez et al. (2020) indicated that mangrove ecosystems are currently undergoing significant damage and loss. This phenomenon is attributable to the transformation of aquaculture, agriculture and coastal development (Alongi, 2002; Lovelock et al., 2015; Adame et al., 2018; Schuerch et al., 2018),

leading to increased erosion and decreased coastal fisheries production, as evidenced in the Indo-Pacific and Caribbean (Lovelock et al., 2015), Sri Lanka (Harkes et al., 2015), and the northern coast of Java, Indonesia (Ilman et al., 2016).

The highest density of mangrove vegetation was observed in *Avicennia alba* in all categories: trees (616.67 ind/ha), seedlings (833.33 ind/ha) and saplings (66666.67 ind/ha). Furthermore, the highest important value index (IVI) was recorded in *A. alba* for all categories: trees (232.16%), seedlings (102.40%) and saplings (228.43%). A similarity in mangrove density between species was observed at 60%, resulting in the formation of two distinct groups. Regarding the basal area, *A. alba* and *A. lanata* vegetation exhibited the highest values (280.61 and 266.03 m²/ha, respectively). The similarity of the basal area among the observed species was



Distinct groups. Furthermore, Station II, classified as having mature vegetation, demonstrated a maturity similarity of 80% between observation stations.

Methods

The study was carried out in September 2021 in the mangrove forest of Cut Mamplam Village, Muara Dua

District, Lhokseumawe City, Aceh Province, with three observation stations. Station I is at coordinates 05°09'19" E and 97°08'38" N, while Station II is at coordinates 05°09'16" E and 97°08'41" N, and Station III is at coordinates 05°09'13" E and 97°

Figure 1. Map of mangrove vegetation study site in Cut Mamplam Village, 08'43" N (Figure 1). Lhokseumawe.

20%, resulting in the formation of two

Mangrove vegetation data in Cut Mamplam Village was obtained by establishing a 40 m long line transect (SNI, 2011) perpendicular to the coastline. This transect was divided into sample plots of 10 x 10 m for the tree category, with 5 x 5 m plots designated for the sapling category within each tree plot,

and 1 x 1 m plots for the seedling category. The measuring requirements for the circumference of the mangrove trunk are based on MNLH (2004), where as the categorization criteria for the trunk's circumference or diameter in the tree, sapling, and seedling categories are derived from Bengen (2000). The mangrove vegetation data collected were subsequently analyzed for community structure (density, relative density, frequency, relative frequency, dominance, relative dominance, and IVI) according to Fachrul (2007). This analysis was further evaluated using cluster analysis and nonmetric multidimensional scaling (MDS) via the PRIMER v7 program, with basal area analysis of mangrove vegetation adhering to the equation of Kasim and Lamalango (2019).

Results

Mangrove diversity and distribution

The diversity of mangrove vegetation in Cut Mamplam Village comprises five species in three families. Acanthaceae (*A. alba* and *A. lanata*), Rhizophoraceae (*Bruguiera gymnorrhiza* and *Rhizophora mucronata*), and Sonneratiaceae (*Sonneratia alba*). *A. alba* was observed in all tree category stations, while *S. alba*, *R. mucronata*, *B. gymnorrhiza* and *A. alba* were observed in the seedling category, and *A. lanata* and *A. alba* were also present in the seedling category (Table 1). Furthermore, members of the Acanthaceae family (*A. alba* and *A. lanata*) were observed to thrive in coastal areas (front zone) or near community ponds and land (back zone), while in the

Table 1. Diversity and distribution of mangrove vegetation in Cut Mamplam Village, Lhokseumawe
Species found (+); Species not found (-).

Observation station									
Species		Family		I	II	III			
Tree category									
A.	alba	Acanthaceae	+	+	+				
A.	lanata	Acanthaceae	+		+	-			
B.	gymnorrhiza	Rhizophoraceae	+			-	+	R. mucronata	Rhizophoraceae
+	-	+	S. alba	Sonneratiaceae	+	-	+		
Sapling category									
Avicennia alba		Acanthaceae	+	+	+				
Avicennia lanata		Acanthaceae		+	-	-			
Bruguiera gymnorrhiza		Rhizophoraceae	+			+	+	+	Rhizophora mucronata
		Rhizophoraceae	+	+	+				
Sonneratia alba		Sonneratiaceae	+	+		+			
Seedling category									
Avicennia alba		Acanthaceae	+	+	+				
Avicennia lanata		Acanthaceae		+	+	+			
Bruguiera gymnorrhiza		Rhizophoraceae	+			-	+		

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<i>Rhizophora mucronata</i> Rhizophoraceae	-	-	+
<i>Sonneratia alba</i> Sonneratiaceae	-	-	-

Middle zone, species from the Rhizophoraceae family (*B. gymnorrhiza* and *R. mucronata*) and Sonneratiaceae (*S. alba*) were identified as growing (Figure 2). Mangrove density and important value index (IVI)

The density of *A. alba* mangrove vegetation in Cut Mamplam Village exceeds that of other species in the tree, sapling and seedling categories, with densities of 616.67 ind/ha, 833.33 ind/ha, and 66666.67 ind/ha, respectively (Table 2). Cluster analysis using the Bray-Curtis similarity index, followed by MDS

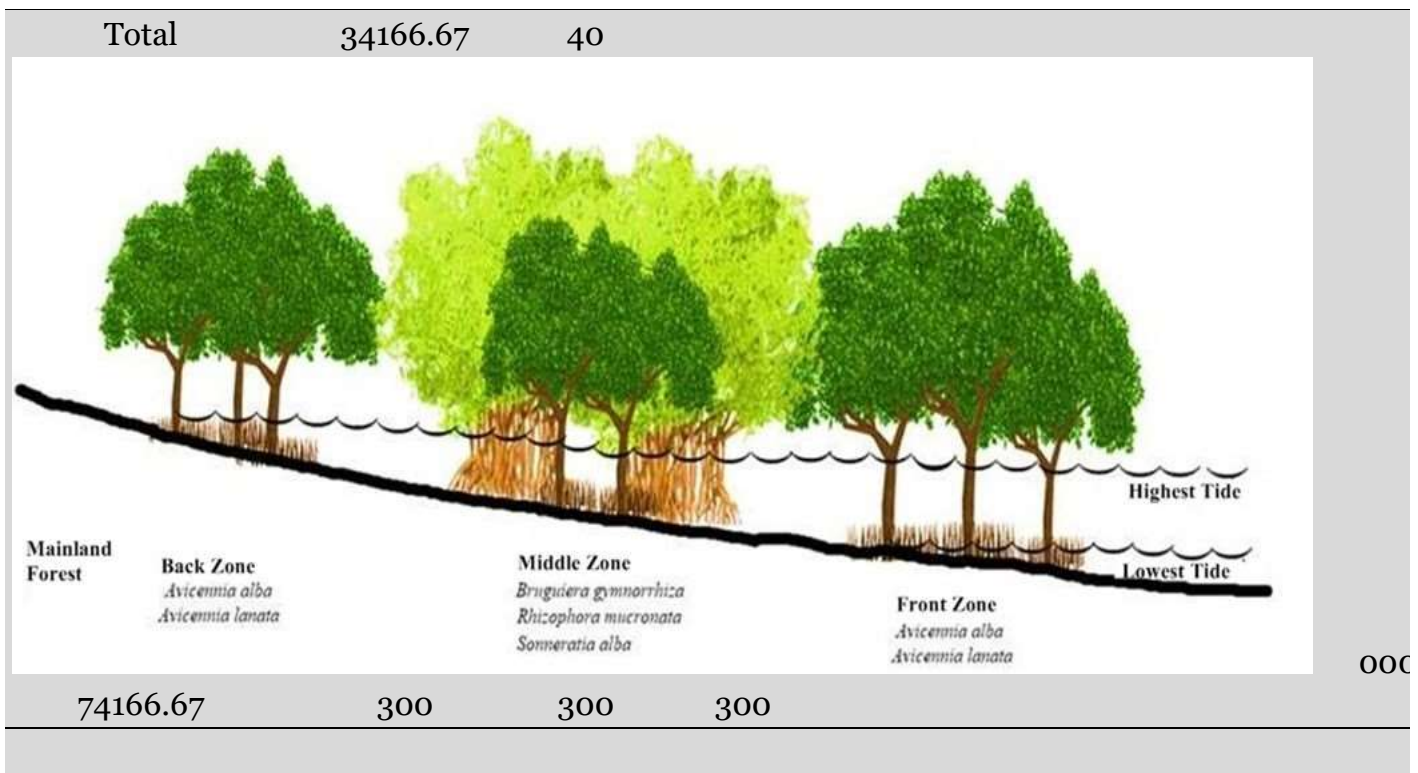
Figure 2. Mangrove vegetation distribution zone in Cut Mamplam Village, Lhokseumawe.

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Table 2. ordination, revealed a 60% similarity in mangrove density Density and IVI of mangrove vegetation in Cut Mamplam Village (232.16%), Lhokseumawe. , seedlings (average 102.40%), and saplings (average AA = *A. alba*; AL = *A. lanata*; BG = *B.* among species, categorized into two groups the first group *gymnorrhiza*; RM = *R. mucronata*; SA = *S. Alba*. 228.43%).). The highest IVI for *A. alba* in the tree and sapling

Species	Density (ind/ha)			IVI (%)		
	St. I	St. II	St. III	St. I	St. II	St. III
<i>Tree category</i>						
AA	616.67	341.67	383.33	214.25	245.44	236.78
AL	141.67	75	0	52.98	54.56	0
BG	33.33	0	41.67	13.12	0	29.23
RM	16.67	0	41.67	6.55	0	13.48
SA	33.33	0	50	13.1	0	20.51
Total	841.67	416.67	516.67	300	300	300
<i>Sapling category</i>						
AA	833.33	100	633.33	143.6	25.62	137.98
AL	33.33	0	0	17.93	0	0
BG	633.33	266.67	566.67	116.57	113.33	123.14
RM	100	266.67	100	12.02	85.12	19.36
SA	66.67	200	100	9.87	75.93	19.52
Total	1666.67	833.33	1400	300	300	300
<i>Seedling category</i>						
AA	25000	25000	66666.67	196.71	220.69	267.9
AL	6666.67	15000	3333.33	64.57	79.31	12.02
BG	2500	0	1666.67	38.72	0	9.44
RM	0	0	2500	0	0	10.64
SA	0	0	0	0	0	0



Comprising *R. mucronata*, *S. alba*, and *B. gymnorrhiza*, and the second group consisting of *A. alba* and *A. lanata* (Figure 3). The first group comprised species located on the mainland, but the second group was located directly facing the sea, consistently obstructing the waves. Furthermore, the Importance Value Index (IVI) of mangrove vegetation in Cut Mamplam Village indicates that the *A. alba* species exhibits the highest values relative to other species, across the tree category (average categories was recorded at Station II (245.44% and 267.90%), while the highest value for seedlings was observed at Station I (143.60%) (Table 2).

Basal area vegetation

The basal area of mangrove vegetation in Cut Mamplam Village shows that the vegetation stands of *A. alba* and *A. lanata* have higher values (280.61 and 266.03 m²/ha), while the basal area

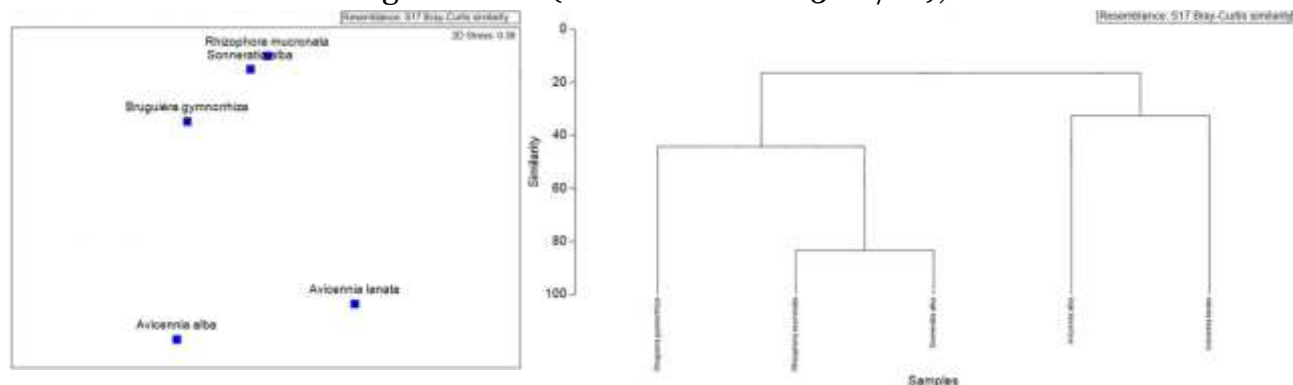


Figure 3. Dendrogram of density similarities among mangrove species in the coastal area of Cut Mamplam Village, Lhokseumawe. (a)

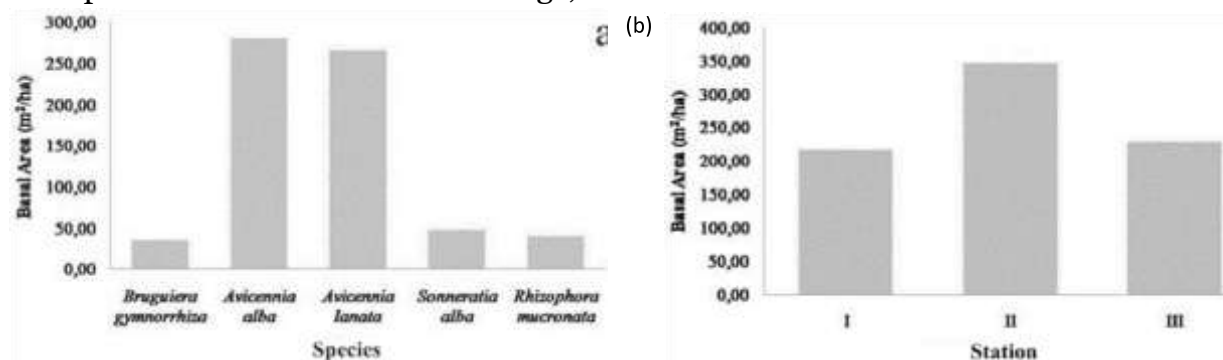


Figure 4. Basal area of mangrove vegetation in Cut Mamplam Village, Lhokseumawe. (a) between species; (b) between observation stations.

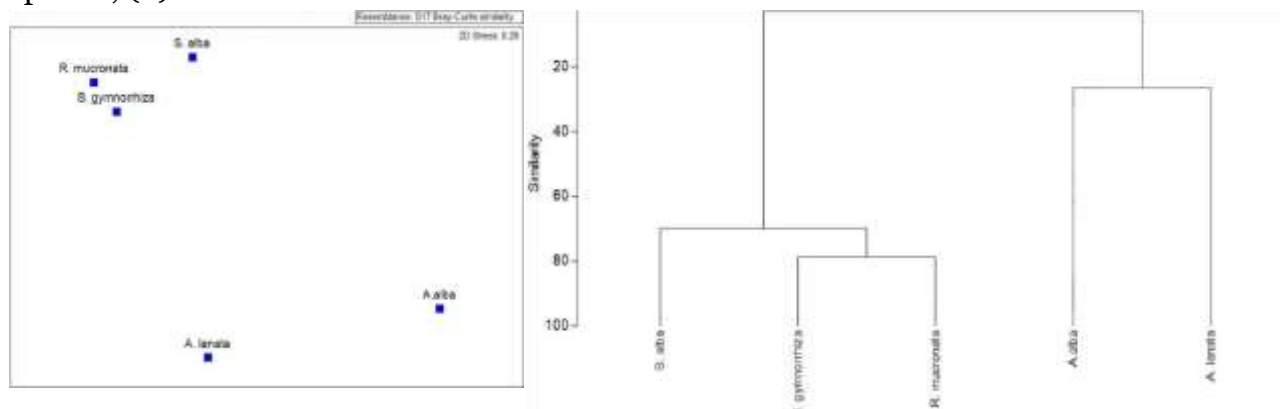


Figure 5. Dendrogram of basal area similarities among mangrove species in the coastal area of Cut Mamplam Village, Lhokseumawe.

between observation stations, the highest value was found at Station II (345.61 m²/ha) (Figure 4).

Figure 5 illustrates that the basal area cluster analysis of mangroves in Cut Mamplam Village, which was followed by MDS ordination, revealed a 20% similarity between the observed species, with the basal areas of the species grouped into two groups. The first group is comprised of *S. alba*, *B. gymnorrhiza*, and *R. mucronata*, which are classified as embryonic mangrove vegetation (juveniles). The second group is composed of *A. alba* and *A. lanata*, which are classified as mature mangrove vegetation. Additionally, the mangrove vegetation at Stations I and II is designated as more mature than that at Station III, as evidenced by the cluster analysis (Figure 6), which indicates that the similarity between the two observation stations is 80%.

Discussion

The *A. alba* species is a mangrove that exhibits salinity tolerance, capable of thriving in both high and low salinity environments, including freshwater locations. The growth and development of *A. alba* in high salinity regions necessitates robust root systems to endure the impact of waves during tidal events (Hamka et al., 2012). Bengen (2004) states that the coastal regions, frequently dominated by mangroves,

are primarily inhabited by the species *A. alba* and *A. lanata*, which typically coexist with *S. alba*. Inland, these areas consist of various stands of other mangrove species, including members of the genera *Rhizophora* and *Bruguiera*, as well as the species *Aegialitis annulata*.

On coastlines, the *A. alba* species can compete effectively for nutrients, its population is unaffected, and it is particularly tolerant of changing circumstances. This leads *A. alba* population and IVI to be greater in Cut Mamplam Village than other species, where a species' high density may be attributed to a suitable environment and strong adaptation (Lahabu et al., 2015). Meanwhile, a species' high value stems from its frequent occurrence (Syarifuddin & Zulharman, 2012), which causes a plant to dominate in each site. Araujo and Shideler (2019) defined basal area as the land area occupied by the cross-section of a plant's stem or trunk at the point of measuring diameter at stem (DBH). Basal area is also correlated with biomass (Araujo & Shideler, 2019), wood volume (ACES, 2010; Araujo & Shideler, 2019), and plant growth, making it a critical metric for forest management decisions, such as assessing forest regeneration needs and wildlife habitat requirements (ACES, 2010).

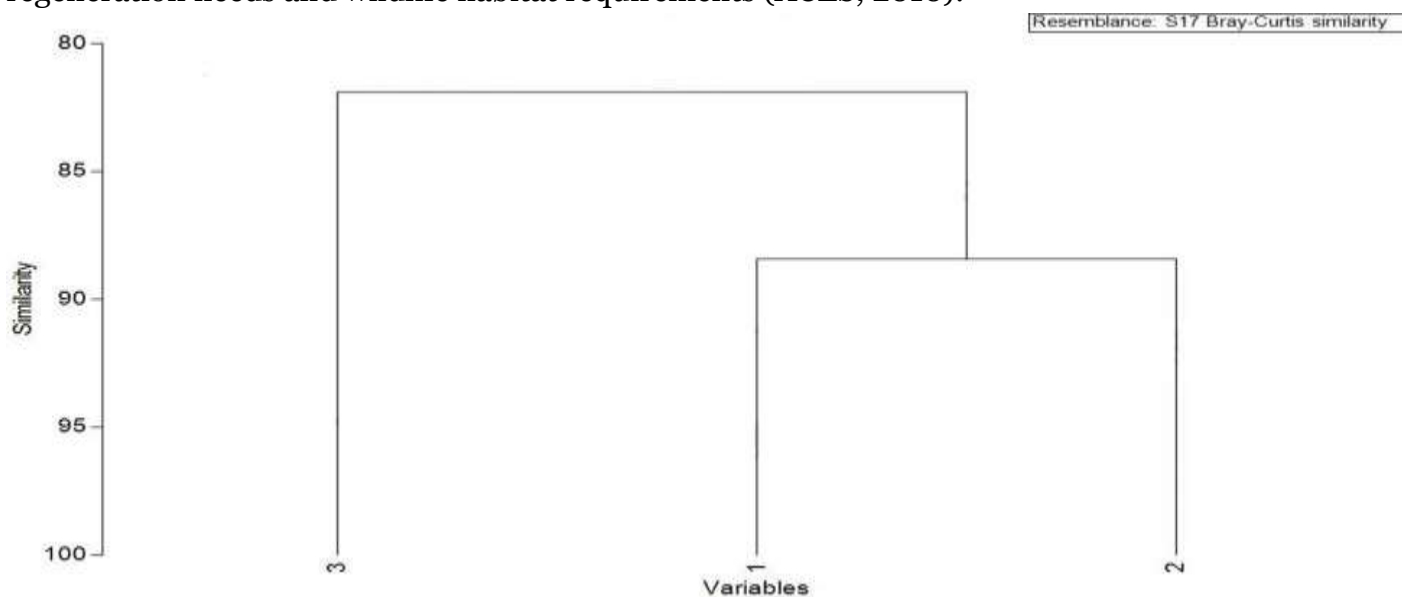


Figure 6. Basal area cluster diagram of mangrove observation stations based on Bray-Curtis similarity in Cut Mamplam Village,

Conclusions

The mangrove forest vegetation in Cut Mamplam Village consists of five species from three families. Members of the Acanthaceae family thrive in zones adjacent to the sea or bordering the land, while those of the Rhizophoraceae family are located in the central zone. Moreover, the greatest density and IVI of mangrove vegetation in Cut Mamplam Village were seen in *A. alba*, with comparable mangrove density across species categorized into two groups. In terms of basal area, the vegetation stands of *A. alba* and *A. lanata* exhibit the greatest values and demonstrate more maturity compared to other species, with the vegetation maturity at the observation station identified at Station II.

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Authorship contribution

Adinda Aulia Putri: Conceptualization, methodology, investigation, resources, sample processing and analysis, data curation, formal analysis, visualization, original draft preparation writing, review and editing. **Erlangga Erlangga:** Methodology. **Syahrial Syahrial:** Writing - review and editing, supervision. **Riri Ezraneti:** Conceptualization, methodology, formal analysis, writing - original draft preparation, writing - review and editing, supervision. **Hayatun Nufus:** Writing - review and editing. **Yusyam Leni:** Writing - review and editing. **Febrina Rolin:** Writing - review and editing. All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Data availability

Datasets generated during and/or analysed throughout the present study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest.

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