Jurnal Biolokus: Jurnal Penelitian Pendidikan Biologi dan Biologi
Vol. 8, Issue 2, December 2025
Pages: 276 – 287

p-ISSN: 2621-3702
e-ISSN: 2621-7538

Vegetation diversity of mangrove forest in Percut Village, Percut Sei Tuan District, North Sumatra

Edi Azwar[1*], Yusri Feviani[1], Bertaulina Haloho[1], Mhd. Rafi'i Ma'arif Tarigan[2]
[1]Department of Biology Education, Faculty of Teacher Training and Education, Universitas Islam Sumatera Utara, Jl. Sisingamangaraja, Teladan, Medan, North Sumatra, 20217, Indonesia
[2]STIT Hamzah Al-Fansuri Sibolga Barus, Jl. Sibolga-Barus No.100, Kedai Gedang, Central Tapanuli Regency, North Sumatra, 22564, Indonesia
*corresponding author: ediazwar@fkip.uisu.ac.id

ABSTRACT

This study aimed to analyze the vegetation diversity of mangrove forest in Percut Village, Percut Sei Tuan District, North Sumatra. A quantitative descriptive method with a field survey approach was employed, using purposively selected stations representing natural mangroves (Station I), mangroves adjacent to fishponds (Station II), and mangroves near an ecotourism area (Station III). Data were collected using 5 × 5 m^2 plots with 10 m spacing, including species identification, abundance measurements, and physicochemical parameter assessments (temperature, salinity, soil pH, and substrate texture). Vegetation characteristics were analyzed using the Shannon–Wiener diversity index (H'), evenness index (E), and Simpson's dominance index (D). Results showed that environmental parameters across stations remained within the optimal range for mangrove growth (temperature 18.6–19.7°C, salinity 16.5–19‰, and pH 7–8.5), though variations indicated differing levels of anthropogenic pressure. Eight true mangrove species were identified: *Sonneratia alba*, *Bruguiera cylindrica*, *Nypa fruticans*, *Acanthus ilicifolius*, *Rhizophora apiculata*, *Avicennia marina*, *Rhizophora mucronata*, and *Xylocarpus granatum*. Vegetation analysis revealed a strong dominance of *Rhizophora apiculata* and *Bruguiera cylindrica*, while *Xylocarpus granatum* and *Rhizophora mucronata* occurred in limited numbers. The Shannon–Wiener diversity index (H' = 0.8442) indicated low diversity and uneven species distribution, suggesting community instability linked to anthropogenic disturbances. These findings highlight the ecological impacts of land conversion and tourism activities on mangrove ecosystems and emphasize the need for conservation and rehabilitation efforts to maintain biodiversity and ecosystem services in the Percut Mangrove Forest.

Keywords: Conservation, mangrove diversity, Percut Sei Tuan, vegetation structure

INTRODUCTION

Mangroves are vegetation that grow in intertidal zones situated between marine and terrestrial ecosystems (Hilmi et al., 2021). Mangroves exhibit higher productivity compared to other ecosystems, making them vital for the survival of various living organisms. They also possess distinctive characteristics that set them apart from other forest types, particularly in terms of their habitat and biodiversity (Karimah, 2017). Typically, mangroves thrive in muddy coastal wetlands located in tropical and subtropical regions (Sholiqin et al., 2021). Moreover, mangroves can also flourish in lagoons and river estuaries that experience tidal flooding or remain dry during low tide. They are well adapted to high salinity levels and possess significant physical, ecological, and economic value (Alvareza & Leilani, 2020). In coastal regions, mangroves provide numerous benefits, including carbon sequestration, filtering harmful pollutants, reducing tsunami wave energy by up to 50%, protecting shorelines, enriching coastal waters as habitats for diverse flora and fauna, and offering ecotourism potential (Kurniawati et al., 2022). These multiple functions make mangroves essential in supporting biodiversity and sustaining life (Gunawan et al., 2025; Kasihiw et al., 2024).

Mangrove forests are vital ecosystems found in tropical and subtropical regions, with their global extent estimated at approximately 14.8 million hectares in 2020 (FAO, 2023). Mangrove forests occur in a relatively limited number of countries, with Indonesia, Brazil, Nigeria, Mexico, and Australia together accounting for roughly 47% of the world's total mangrove area (FAO, 2020). According to the most recent national mapping Kementerian Lingkungan Hidup dan Kehutanan (2023), Indonesia alone hosts about 3.39 million hectares of mangrove forest, representing a significant share of global mangrove coverage and underlining its role as one of the countries with the largest mangrove areas.

Mangrove areas cover about 16,530,000 hectares, with Indonesia recognized as one of the countries possessing the largest mangrove ecosystems, spanning approximately 3,489,140.68 hectares along 95,181 km of coastline (Akbaruddin et al., 2020; Tambunan, 2018). Indonesia's mangroves account for 23% of the world's total mangrove coverage and nearly 50% of Asia's mangrove resources (Junialdi et al., 2019). These forests are distributed across the Indonesian archipelago, from Sumatra to Papua, hosting around 202 mangrove species, including 89 tree species, 5 palm species, 19 climbers, 44 herbs, 44 epiphytes, and 1 fern species. Of these, 43 are classified as true mangroves, while the remainder are associated species (Khairunnisa et al., 2020). However, Majid et al., (2016) report that Indonesia's mangrove ecosystems are in a critical state, with an estimated 68% around 5.9 million hectares degraded. The mangrove forest area has decreased by an estimated 2.15 million hectares (Widiastuti et al., 2024).

The diversity of mangrove vegetation plays an important role in maintaining the balance of coastal ecosystems, serving as a habitat for various organisms, a natural barrier against coastal abrasion, and a carbon sink. However, the presence of mangrove vegetation in many coastal areas, including the Mangrove Forest Area of Percut Village, Percut Sei Tuan District, North Sumatra, is currently facing increasingly complex pressures. One of the main issues identified in this area is habitat degradation caused by the conversion of mangrove land into fishponds, settlements, and rapidly expanding industrial zones along the coast. Illegal logging of mangrove trees for firewood and construction materials has also been observed in several locations, contributing to the reduction of ecosystem coverage (Akram et al., 2023; Rudianto et al., 2020). In addition, environmental pollution from domestic waste and industrial activities along river flows that discharge into the mangrove area has decreased both water and soil quality, negatively impacting vegetation health (Mello et al., 2024 Soeprobowati et al., 2022). This problem is further exacerbated by increased sedimentation due to upstream erosion, which disrupts the natural regeneration process. Other anthropogenic pressures, such as overfishing of aquatic biota and coastal infrastructure development, also have significant impacts on the sustainability of mangrove vegetation in Percut Village.

Global climate change and sea-level rise also pose serious threats to this area. Changes in salinity and water temperature affect the distribution of mangrove species that are able to survive, while coastal erosion continuously reduces vegetated areas (Friess et al., 2022; van Hespen et al., 2023). In addition, the lack of updated inventories and recent research on mangrove species in the Mangrove Forest Area of Percut Village has resulted in insufficient scientific data to monitor the dynamics of vegetation diversity. Another threat comes from the potential introduction of invasive species that may displace native vegetation (Fazlioglu & Chen, 2020; Peng et al., 2022). The low level of public awareness regarding the ecological importance of mangroves for coastal ecosystems, coupled with limited community participation in rehabilitation and conservation activities, further worsens the situation (Arifanti et al., 2022; Tambunan et al, 2025). Therefore, an in-depth study of mangrove vegetation diversity in Percut Village is crucial as a basis for policy formulation and the development of sustainable management strategies.

METHODS

This study employed a quantitative descriptive method with a field survey approach to identify and analyze the diversity of mangrove vegetation in the Mangrove Forest Area of Percut Village, Percut Sei Tuan District, North Sumatra in Figure 1. Data were collected through direct field observations using a plot sampling technique. The research locations were determined purposively based on the representation of both relatively undisturbed mangrove ecosystems and those experiencing pressure from human activities. At each observation station, several square plots measuring 5 × 5 m^2 were established with a distance of 10 m between plots. Station I was located in the natural mangrove forest area (DMS: 3°42'53.4"N, 98°46'30.45"E; decimal: 3.7148333°, 98.7751250°). Station II was situated in the mangrove area adjacent to fishponds (DMS: 3°43'17.436"N, 98°46'48.216"E; decimal: 3.7215100°, 98.7800600°). Station III was positioned in the mangrove area near the ecotourism site (DMS: 3°43'4.458"N, 98°46'36.642"E; decimal: 3.7179050°, 98.7768450°). Within each plot, all mangrove vegetation species were identified, the number of individuals recorded, and environmental parameters such as salinity, temperature, soil pH, and substrate texture were measured.

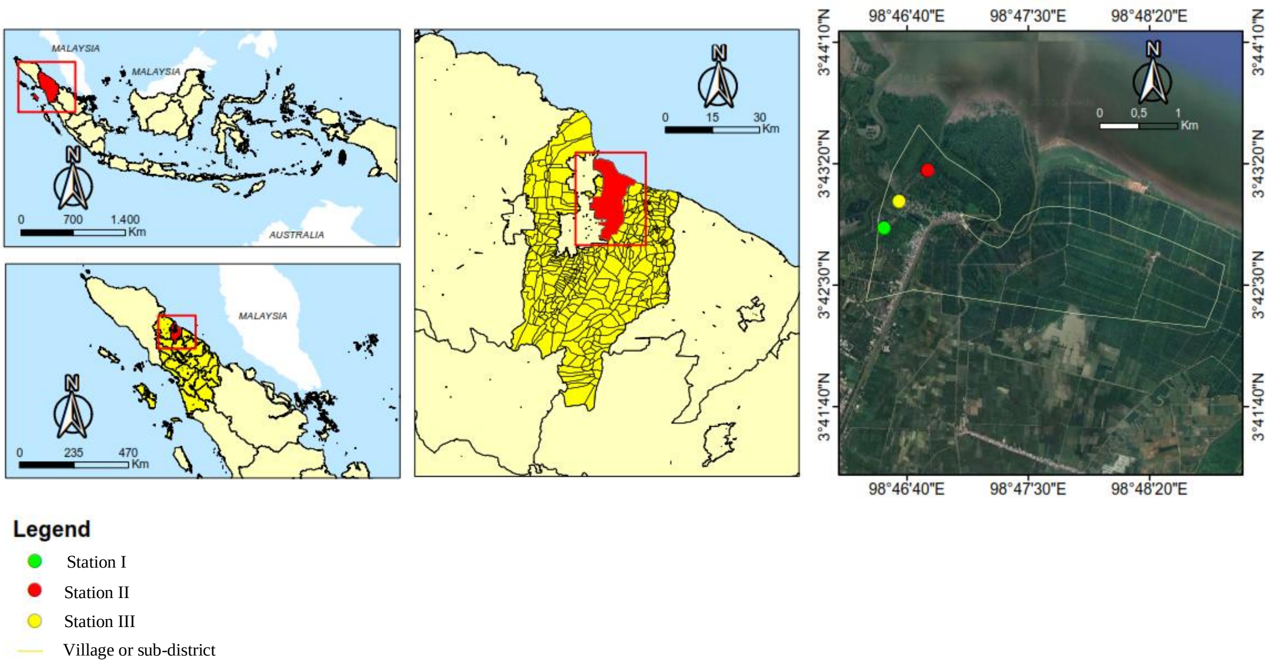

Figure 1. Map of Research Mangrove Forest Deli serdang Sumatera Utara.

This study utilized a variety of field instruments designed to facilitate observations and measurements at the research site. The tools used included a GPS (Global Positioning System) to determine the plot coordinates, a measuring tape to establish plot dimensions, raffia string and wooden stakes to mark plot boundaries, a mangrove identification guidebook to assist in species recognition, and a digital camera to document vegetation conditions. For measuring environmental parameters, a refractometer was used to measure water salinity, a digital thermometer to measure temperature, and a pH meter to determine soil acidity levels. In addition, writing tools, field boards, and sample bags were provided to collect and store substrate samples for further analysis. The primary materials in this study consisted of mangrove vegetation found at the research site, as well as water and substrate samples collected from each observation plot.

The research procedure began with a preliminary survey to purposively determine the study sites, taking into account the representation of diverse ecosystem conditions. Once the locations were established, observation stations were set up, and within each station, plots of specified sizes were laid out. In each plot, all mangrove vegetation was identified to the species level and the number of individuals was recorded. Species identification was carried out by comparing field morphological characteristics with identification guides by Noor et al. (2006) and Tomlinson (1986). Subsequently, environmental parameters were measured in each plot, including salinity using a refractometer, temperature using a digital thermometer, and soil pH using a pH meter. Substrate samples were collected and their texture was visually analyzed in the field. All observational data were systematically recorded on field sheets, then processed and analyzed using the Shannon-Wiener diversity index (H'), evenness index (E), and Simpson's dominance index (C) to provide an overview of the level of mangrove vegetation diversity in the Mangrove Forest Area of Percut Village. These formulas took into account the number of species recorded and the relative proportion of each species to the total number of individuals. The index values were then interpreted to assess the diversity level, where a high H' value indicates a more diverse and stable mangrove community, while a low H' value suggests dominance by one or a few species. The calculation of these indices was further complemented with dominance and evenness analyses to obtain a more comprehensive understanding of mangrove community structure in the study area.

The diversity index (H')

The diversity index (Shannon–Weiner index) of mangrove vegetation in the study area was determined using the following formula.

$$H' = - (\sum pi \ In \ pi)$$

Where: H' is the diversity index; Pi is the number of individuals of the i-th species (ni) to the total individuals (N): (ni/N); ni is the number of individuals of each species; N is the total number of individuals. According to Odum (1993), the Shannon-Wiener (H') diversity index divides fauna diversity into four categories, namely very high (H'>3.0), high (H' = 1.6-3.0), moderate (H'= 1.0-1.5), and low (H'<1).

The evenness index (E)

The evenness index was known by comparing the diversity index with the maximum value, expressed as follows:

$$E = \frac{H'}{In \ S}$$

Where: E is the evenness index, H' is the diversity index, and S is the number of individuals in a species. The Evenness index ranges from 0-1; hence, E=0 indicates low inter-species uniformity, meaning the individual richness of each species is very much different. Conversely, e=1 signifies uniformity between species, which is relatively even, meaning the number of individuals in each species is relatively the same.

Knowledge Richness Index (KRi)

The abundance or knowledge richness index (KRi) of mangrove vegetation in the study area was calculated using the following formula:

$$KRi = \left(\frac{ni}{N}\right) x \ 100\%$$

Where: KRi describes the knowledge richness index of mangrove vegetation, ni is the number of individuals of each species, and N is the total number of individuals of all species. KRi < 0.1 = rare, 0.1–2.0 = uncommon, 2.1-10.0 = often, 10.1-40.0 = common, and > 40.0 = abundant.

Dominance index (D)

The Simpson's dominance index (D) method was used to determine whether certain mangrove species are dominant. The D was calculated using the following formula:

$$D = \sum(pi)^2 = \sum\left(\frac{ni}{N}\right)_2$$

Where: D is the Simpson dominance index, Pi is the proportion of the i-th mangrove species in the community, ni is the number of individuals of the i-th mangrove species, and N is the total number of mangrove individuals. D ranges from 0-1; in this case, D = 0 indicates that no mangrove species dominate others or that the community structure is stable. Meanwhile, D = 1 indicates that certain mangrove species dominate others or that the community structure is unstable due to ecological pressure.

RESULTS AND DISCUSSION

Environmental Physico-Chemical Parameters

Physicochemical parameters were measured in the Mangrove Forest of Percut Sei Tuan Village, Percut Sei Tuan District, Deli Serdang Regency, during the research period. The research location was divided into three observation stations, each consisting of three plots. The stations were determined based on the panoramic characteristics of the area: Station I (natural area), Station II (fishpond area), and Station III (tourism area), as presented in Table 1 below.

Table 1. The physical-chemical parameters in the Mangrove Forest of Percut Sei Tuan Village, Percut Sei Tuan Subdistrict, Deli Serdang District.

Location	Station	Parameter			
		Temperature	Substrat	pH	Salinity
Mangrove Forest of Percut Sei Tuan Village	I (Natural area)	19°C	Fine Mud	8,5	17.80 ppmm
	II (Fishpond area)	18.6°C	Fine Sand Mud	7	19,00 ppmm
	III (Tourism area)	19.7°C	Sand mud	8	16.50 ppmm

Mangrove species found in the Mangrove Forest of Percut Sei Tuan Village

The mangrove species that have been found in the Percut Sei Tuan Village Mangrove Forest can be seen in Table 2 below.

Table 2. Mangrove species found in the Mangrove Forest of Percut Sei Tuan Village

No.	Spesies	Station			Total	Station			Total	Station			Total
		I	II	III		I	II	III		I	II	III	
1.	*Sonneratia alba*	6	3	-	9	3	-	3	6	-	-	4	4
2.	*Bruguiera cylindrica*	5	3	6	16	4	-	3	7	4	2	2	8
3.	*Nypa fruticans*	-	4	2	6	3	-	5	8	-	-	-	-
4.	*Acanthus ilicifolius*	-	3	3	6	2	2	-	4	2	2	-	4
5.	*Rhizophora apiculata*	6	5	6	17	4	2	4	10	-	-	-	-
6.	*Avicennia marina*	2	6	4	12	-	-	-	-	2	-	-	2
7.	*Rhizophora mucronata*	-	3	2	5	4	-	2	6	-	-	-	-
8.	*Xylocarpus granatum*	-	-	3	3	-	3	2	5	3	3	-	6
	Total	**19**	**27**	**26**	**74**	**20**	**7**	**19**	**46**	**11**	**7**	**6**	**24**

Table 3. Composition and Structure of Mangrove Vegetation at the Research Site.

No	Spesies	Station			AB	AF	RD	RF	IVI	SDR	Pi log pi
		I	II	III			%	%	%		
1.	*Sonneratia alba*	6	3	-	9	2	12.16	11.11	23.27	11.63	0.1136
2.	*Bruguiera cylindrica*	5	3	6	16	3	21.62	16.66	37.78	18.89	0.1438
3.	*Nypa fruticans*	-	4	2	6	2	8.10	11.11	19.21	9.60	0.0884
4.	*Acans llicifolius*	-	3	3	6	2	8.10	11.11	19.21	9.60	0.0884
5	*Rhizophora apiculata*	6	5	6	17	3	22.97	16.66	39.13	19.18	0.1467
6.	*Avicenniamarina*	2	6	4	12	3	16.21	16.66	32.37	16.18	0.1280
7.	*Rhizophora mucronata*	-	3	2	5	2	6.75	11.11	17.86	8.93	0.0790
8.	*Xylocarpus granatum*	-	-	3	3	1	4.05	5.55	9.6	4.8	0.0563
					74	**18**	**99.96**	**99.97**	**183.27**	**98.81**	**0.8442**

NB: AB (Absolute Density), AF (Absolute Frequency), RD (Relative Density), RF (Relative Frequency), IVI (Importance Value Index), & SDR (Summed Dominance Ratio).

Vegetation structure analysis was conducted to determine the species composition, density, frequency, and role of each mangrove species in the ecosystem at the research site. The results of vegetation parameter calculations, including KM, FM, KR, FR, INP, SDR, and Shannon-Wiener diversity index (Pi log pi), are presented in Table 3.

The physicochemical parameters recorded across the three stations reveal clear ecological gradients that shape mangrove species composition and vegetation structure in the Percut Sei Tuan mangrove ecosystem. As shown in Table 1, Station I (natural area) exhibits relatively stable conditions, characterized by fine mud substrates, slightly alkaline pH (8.5), and moderate salinity (17.80‰), which together provide optimal conditions for typical estuarine mangrove species. In contrast, Station II (fishpond area) displays a lower pH (7.0) and slightly higher salinity (19.00‰), reflecting anthropogenic influence from aquaculture activities that tend to alter water chemistry. Station III (tourism area) shows sandy-mud substrates and the lowest salinity (16.50‰), conditions commonly associated with higher hydrodynamic disturbance due to human activity and shoreline modification. These differences explain the variation in species distribution across stations, as presented in Table 2, where species such as *Rhizophora apiculata* and *Bruguiera cylindrica*—typically tolerant to a wide salinity range—dominate all stations, while substrate-specific taxa like *Sonneratia alba* and *Avicennia marina* are concentrated in areas with finer sediments and more stable tidal influences (Stations I and II).

The tabulated species abundance in Table 2 also shows that Station I supports a relatively balanced assemblage of pioneer and structural species, indicating an undisturbed ecotone with favorable physico-chemical conditions. Meanwhile, the higher presence of Nypa fruticans in Station II reflects the species' preference for brackish environments affected by freshwater input from pond effluents. Station III displays lower diversity, which corresponds with its more heterogeneous substrate and human pressure from tourism development. These ecological patterns are further validated by the vegetation structure metrics in Table 3. Species with the highest Importance Value Index (IVI) and Structural Dominance Ratio (SDR)—such as *Rhizophora apiculata* (INP 39.13%; SDR 19.18%) and Bruguiera cylindrica (INP 37.78%; SDR 18.89%)—are those capable of tolerating variations in salinity and substrate type, explaining their widespread presence across stations. In contrast, species with lower INP values like *Xylocarpus granatum* are restricted to specific microhabitats with suitable sediment stability.

Overall, the Shannon–Wiener diversity index (H' = 0.8442) calculated from Table 3 indicates a moderate level of community diversity, consistent with ecosystems experiencing varying degrees of human disturbance. Thus, the integration of data across the three tables demonstrates that physico-chemical parameters directly shape species abundance and vegetation structure by influencing physiological tolerances, competitive interactions, and habitat suitability across the mangrove landscape.

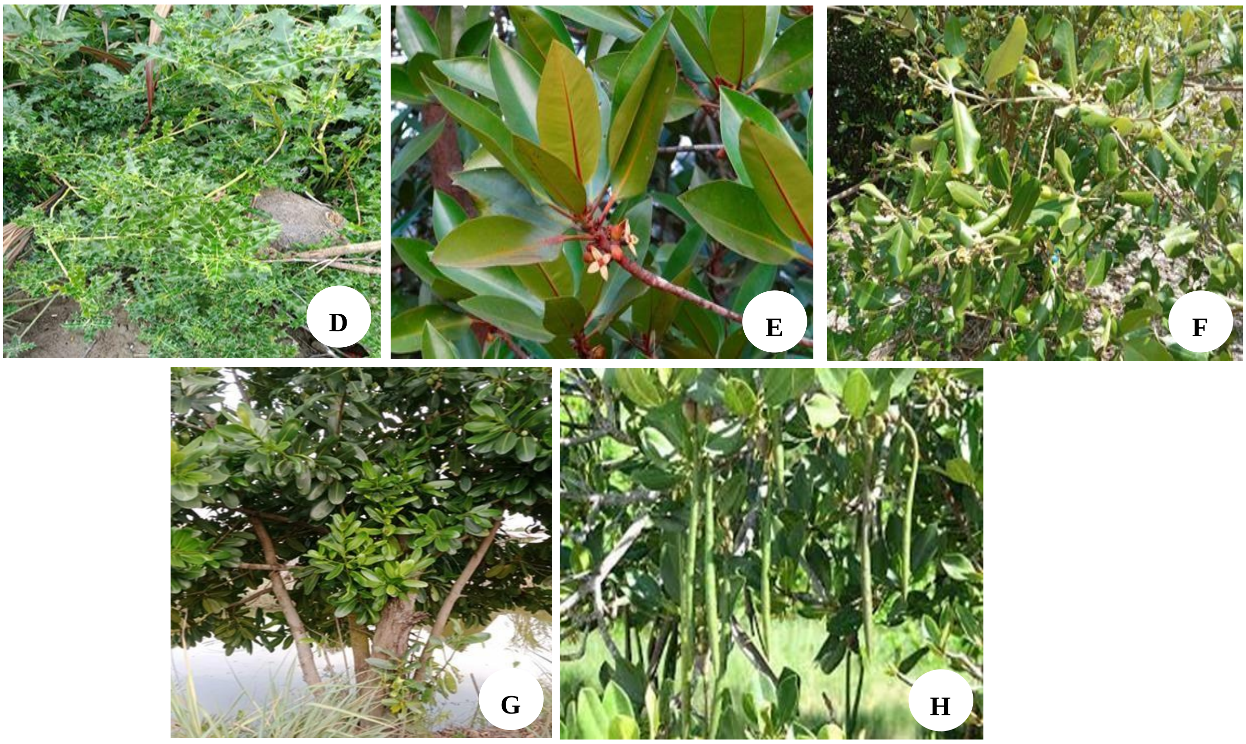

Figure 2. Mangrove species found in the Mangrove Forest of Percut Sei Tuan Village, North Sumtra: (A) *Sonneratia alba*; (B) *Bruguiera cylindrica*; (C) *Nypa fruticans;* (D) *Acanthus ilicifolius;* (E) *Rhizophora apiculata ;* (F) *Avicennia marina;* (G) *Xylocarpus granatum*; (H) *Rhizophora mucronata*
(Source: Photo taken by Edi Azwar)

Morphological parameters Mangrove

Table 4. Morphological parameters Mangrove

Species	Stem / Bark	Leaves	Flowers	Roots	Fruit
Sonneratia alba	Tree up to 15 m; erect trunk; pale whitish–gray bark, slightly rough with fine fissures.	Opposite, obovate, thick, glabrous; 5–12.5 × 3–9 cm; glossy dark green above; petiole 6–15 mm.	Large, solitary or 1–3; calyx 6–8 lobes, thick; petals white; many stamens; nocturnal blooming.	Cable roots with erect pneumatophores up to 25 cm.	Globose, 3.5–4.5 cm; indehiscent; 150–200 seeds.
Bruguiera cylindrica	Up to 15 m; gray–dark brown bark with lenticels.	Opposite, elliptic–oblong, coriaceous; 5–15 × 3–7 cm; underside with black dots.	Axillary; calyx tubular with 8 lobes; cream-white petals; explosive pollination.	Knee roots for gas exchange and support.	Cylindrical capsule 2–3 cm; viviparous; hypocotyl 10–15 cm.
Nypa fruticans	No above-ground trunk; creeping underground stem.	Pinnate, 4–9 m; leaflets 60–120 × 5–8 cm, lanceolate.	Monoecious; male in catkin clusters; female spherical at base of inflorescence.	Horizontal fibrous roots; no pneumatophores.	Large aggregate 25–50 cm; 30–60 fruits; individual fruits 10–15 cm; water-dispersed.
Acanthus ilicifolius	Shrub 1–2 m; green to woody stems with spines.	Opposite, ovate–elliptic; spiny margins; 5–15 × 3–8 cm.	Terminal spikes 10–30 cm; violet-purple corolla (4–5 cm).	Shallow fibrous roots; no aerial roots.	Spiny capsule 2–3 cm; explosively dehiscent; 2–4 seeds.
Rhizophora apiculata	10–30 m; gray–brown bark, fissured.	Opposite, elliptic–oblong; 8–15 × 4–8 cm; short apiculate tip; many black dots.	Axillary cymes (2–4 flowers); 4-lobed calyx; white petals.	Large stilt roots; horizontal cable roots.	Ovoid drupe 3–5 cm; viviparous; hypocotyl 20–50 cm.
Avicennia marina	5–15 m; gray to silvery bark; smooth to fissured.	Opposite, elliptic–oblong; 4–10 × 2–5 cm; silvery underside.	Small clusters; yellow-orange corolla; fragrant.	Pneumatophores 20–30 cm; cable roots.	Ovoid capsule 2–3 cm; often cryptoviviparous; 1 seed.

Species	Stem / Bark	Leaves	Flowers	Roots	Fruit
Xylocarpus granatum	8–15 m; buttressed base; mottled peeling bark.	Pinnate leaves with 2–4 pairs of leaflets; 5–12 × 3–7 cm.	Small, fragrant; axillary/terminal panicles.	Strong underground roots; no aerial roots.	Large woody capsule 10–25 cm; splits into 4–5 valves; large seeds.
Rhizophora mucronata	10–25 m; dark fissured bark; arching branches.	Opposite, elliptic–oblong; 8–20 × 4–8 cm; apex mucronate.	Axillary cymes (2–8); 4-lobed calyx; white petals.	Massive stilt roots; horizontal roots.	Ovoid drupe 4–7 cm; viviparous; hypocotyl 30–70 cm.

The results of the analysis of physico-chemical parameters and mangrove vegetation structure in the Percut Sei Tuan Village Mangrove Forest indicate that the environmental conditions across the three stations remain within tolerance ranges that support mangrove growth, including suitable salinity, pH, temperature, and substrate characteristics. However, despite these favorable environmental conditions, the diversity index was found to be low. This discrepancy suggests that factors other than natural physico-chemical conditions are influencing mangrove composition. The variation observed among stations reflects differing levels of anthropogenic pressure—such as settlement expansion, waste accumulation, wood harvesting, and changes in hydrological flow—which can selectively suppress the regeneration of sensitive species while allowing more tolerant species to dominate. Consequently, even though the abiotic environment is adequate for mangrove development, continuous human disturbances have reduced species richness and led to a simplified community structure, ultimately resulting in low diversity values. The measured water temperature ranged from 18.6 to 19.7°C, which is still optimal for supporting mangrove growth, in line with Alongi (2015) and Aljahdali et al., (2021) findings that the tropical temperature range is relatively stable for supporting mangrove metabolism. The slight differences between natural, pond, and tourist stations reflect an ecological gradient from relatively stable areas to areas that have undergone human intervention. The types of substrate found also vary, ranging from fine mud in natural stations, sandy mud in pond stations, to muddy sand in tourist stations. Fine mud substrates tend to be rich in organic matter and support species with pneumatophore roots such as Sonneratia and Avicennia, while sandier substrates support species with prop roots such as Rhizophora. This is in line with research by Dharmayasa et al., (2025) and Wintah et al., (2023), which confirms that the distribution of mangrove species is greatly influenced by substrate texture and organic content. The pH value of the water, which ranged from 7 to 8.5, was within the ideal range for mangrove growth (Dookie et al., 2024; Muttaqin et al., 2024), although the lowest pH at the pond station indicated the influence of cultivation activities that increased the decomposition of organic matter. Similarly, salinity ranging from 16.50–19.00‰ is still within the tolerance range of mangroves, with variations between stations influenced by factors such as seawater circulation, evaporation, and the inflow of fresh water from the mainland. These findings are in line with research in On the coast of Negeri Kaibobu West Seram, Maluku by Pietersz et al., (2025) , which shows that salinity, temperature, and pH that are still within the optimal range contribute to the sustainability of mangrove stands despite anthropogenic pressures.

In terms of species composition, there are eight true mangrove species, namely *Sonneratia alba*, *Bruguiera cylindrica*, *Nypa fruticans*, *Acanthus ilicifolius*, *Rhizophora apiculata*, *Avicennia marina*, *Rhizophora mucronata*, and *Xylocarpus granatum*. The presence of these various species indicates that this area still harbors significant diversity, although distribution between stations is uneven. Natural stations are dominated by *Rhizophora apiculata* and *Sonneratia alba*, which are suited to fine mud substrate conditions, while pond stations are mostly covered by *Avicennia marina* and *Nypa fruticans*, which are more tolerant of disturbance. On the other hand, tourist stations show a more even distribution but with relatively fewer individuals, including the presence of *Xylocarpus granatum*, which indicates the presence of older mangrove stands. These conditions can be compared with research in the In the coastal area of Mukomuko City, Mukomuko Regency, Bengkulu Province, which also found Rhizophora and Avicennia to be dominant in areas with human activity pressure, while species such as Sonneratia were more dominant in natural habitats with soft mud substrates (Zamdial et al., 2019).

Vegetation structure analysis shows the strong dominance of *Rhizophora apiculata* and *Bruguiera cylindrica*, each of which has the highest importance value and is known as a key species in stabilizing sediments and protecting the coast from abrasion. *Sonneratia alba* plays an important role in natural stations, but is no longer found in tourist areas, indicating habitat degradation in the riparian zone. Meanwhile, *Avicennia marina* plays a significant role in pond and tourist areas, which is in line with its adaptive nature to various environmental conditions, including fluctuating salinity. Other species such as *Xylocarpus granatum* and *Rhizophora mucronata* have low importance values, resulting in limited distribution and populations that are more vulnerable to disturbance. The structure of the mangrove community in the study area is supported not only by the low Shannon–Wiener diversity index (H' = 0.8442) but also by the evenness (E) and species richness (KRi) values, which clearly indicate an uneven distribution of individuals among species. The low evenness value shows that most individuals are concentrated in a few dominant species, particularly *Rhizophora apiculata* and *Bruguiera cylindrica*, while other species such as *Xylocarpus granatum* and *Rhizophora mucronata* occur in very limited numbers. This pattern is consistent with the KRi results, in which several dominant species fall into the “common” to “abundant” categories, whereas the remaining species are classified as “rare” or “uncommon,” indicating that the low diversity is not caused by a lack of species but by highly uneven species distribution due to strong dominance. Therefore, the combined interpretation of H’, E, and KRi provides clear evidence that the mangrove community in Percut Sei Tuan is ecologically unstable and shaped by significant anthropogenic pressure leading to low uniformity and simplified community structure. These findings are consistent with the research by Sholiqin et al., (2021) on the Pacitan Coast, East Java, which also noted low diversity with a dominance of Rhizophora due to tourism pressure and coastal activities.

These findings have important ecological implications. Natural stations exhibit relatively stable physical-chemical conditions and vegetation structure, while pond and tourist stations show signs of habitat degradation. Human activities such as land conversion and tourism development directly affect the composition and diversity of mangroves, which in turn has the potential to reduce the ecological functions of mangroves as coastal protectors, biota habitat providers, and carbon sinks. These findings are in line with the results of a study on Cilamaya Wetan District, Karawang Regency Kurniawansyah et al., (2023), which showed a decline in mangrove diversity in tourist areas compared to natural areas. Therefore, the results of this study emphasize the importance of mangrove conservation and rehabilitation efforts, especially in degraded areas, in order to maintain the sustainability of ecological functions and species diversity.

CONCLUSION

The study revealed that the physico-chemical conditions of the mangrove waters in Percut Sei Tuan Village remain within an optimal range to support mangrove growth, although variations among stations reflect different levels of anthropogenic pressure. Eight mangrove species were identified, with Rhizophora apiculata and *Bruguiera cylindrica* as the dominant species, while others such as *Sonneratia alba* and *Xylocarpus granatum* were more restricted to specific habitats. The low diversity index (H'=0.8442) indicates uneven species distribution and dominance by certain taxa. The natural station exhibited the most stable conditions, whereas the pond and tourism stations showed signs of habitat degradation due to human activities. These findings highlight the urgent need for mangrove conservation and rehabilitation efforts in degraded areas to maintain ecological functions, species diversity, and the sustainability of coastal ecosystems.

REFERENCES

Akbaruddin, I. P., Sasmito, B., & Sukmono, A. (2020). Analisis Korelasi Luasan Kawasan Mangrove Terhadap Perubahan Garis Pantai Dan Area Tambak (Studi Kasus: Wilayah Pesisir Kabupaten Demak). *Jurnal Geodesi Undip Maret*, *9*(2), 217–226. https://doi.org/10.14710/pilars.%25v.%25i.%25Y.%25p

Akram, H., Hussain, S., Mazumdar, P., Chua, K. O., Butt, T. E., & Harikrishna, J. A. (2023). Mangrove Health : A Review of Functions , Threats , and Challenges Associated with Mangrove Management Practices. *Forests*, *14*(9), 1–38. https://doi.org/10.3390/f14091698

Aljahdali, M. O., Alhassan, A. B., & Zhang, Z. (2021). Environmental Factors Causing Stress in Avicennia marina Mangrove in Rabigh Lagoon Along the Red Sea: Based on a Multi-Approach Study. *Frontiers in Marine Science*, *8*(May), 1–12. https://doi.org/10.3389/fmars.2021.646993

Alongi, D. M. (2015). The Impact of Climate Change on Mangrove Forests. *Current Climate Change Reports*, *1* (1), 30–39. https://doi.org/10.1007/s40641-015-0002-x

Alvareza, M., & Leilani, I. (2020). Community Structure of the Mangrove Forest in the Tourism Area of Pariaman City, West Sumatra. *Bioscience*, *4*(1), 62. https://doi.org/10.24036/0202041108192-0-00

Arifanti, V. B., Sidik, F., Mulyanto, B., Susilowati, A., Wahyuni, T., Yuniarti, N., Aminah, A., Suita, E., Karlina, E., Suharti, S., Turjaman, M., Hidayat, A., Rachmat, H. H., Imanuddin, R., Yeny, I., Darwiati, W., Sari, N., Hakim, S. S., Slamet, W. Y., & Novita, N. (2022). Challenges and Strategies for Sustainable Mangrove Management in Indonesia : A Review. *Forests*, *13*(5), 1–18. https://doi.org/10.3390/f13050695

Dharmayasa, I. G. N. P., Sugiana, I. P., & Anantanasakul, P. (2025). Mangrove species distribution across soil texture gradients in Benoa Bay and Nusa Lembongan, Bali Province, Indonesia. *Biodiversitas*, *26*(6), 2908–2915. https://doi.org/10.13057/biodiv/d260633

Dookie, S., Jaikishun, S., & Ansari, A. A. (2024). Soil and water relations in mangrove ecosystems in Guyana. *Geology, Ecology, and Landscapes*, *8*(3), 445–469. https://doi.org/10.1080/24749508.2022.2142186

FAO. (2020). *Global Forest Resources Assessment 2020 – Key findings* (1 ed.). Rome. https://doi.org/10.4060/ca8753en

FAO. (2023). *The world's mangroves 2000–2020*. Rome. https://doi.org/10.4060/cc7044en

Fazlioglu, F., & Chen, L. (2020). Introduced non-native mangroves express better growth performance than co-occurring native mangroves. *Scientific Reports*, *10*, 1–11.

https://doi.org/10.1038/s41598-020-60454-z

Friess, D. A., Adame, M. F., Lovelock, C. E., & Adams, J. B. (2022). Mangrove forests under climate change in a 2 C world. *Wiley Interdisciplinary Reviews: Climate Change*, *13*(May), 1–15. https://doi.org/10.1002/wcc.792

Gunawan, H., Basyuni, M., Subarudi, Suharti, S., Kustanti, A., Wahyuni, T., Arifanti, V. B., Yeny, I., Affandi, O., Sugiarti, Zuhriana, D., Lastini, T., Herawati, T., Riswati, M. K., & Effendi, R. (2025). Empowering conservation: the transformative role of mangrove education in Indonesia's climate strategies. *Forest Science and Technology*, *21*(4), 374–396. https://doi.org/10.1080/21580103.2025.2519475

Hilmi, E., Sari, L. K., Siregar, A. S., Sulistyo, I., Mahdiana, A., Junaidi, T., Muslih, Pertiwi, R. P. C., Samudra, S. R., & Prayogo, N. A. (2021). Tannins in mangrove plants in segara anakan lagoon, central java, indonesia. *Biodiversitas*, *22*(8), 3508–3516. https://doi.org/10.13057/biodiv/d220850

Junialdi, R., Yonariza, Y., & Arbain, A. (2019). Economic Valuation of Mangrove Forest At Apar Village Pariaman City of West Sumatra. *Jurnal Analisis Kebijakan Kehutanan*, *16*(2), 117–132. https://doi.org/10.20886/jakk.2019.16.2.117-132

Karimah. (2017). Peran Ekosistem Hutan Mangrove Sebagai Habitat Untuk Organisme Laut. *Jurnal Biologi Tropis, 17*(2), 51–58. https://doi.org/10.29303/jbt.v17i2.497

Kasihiw, P., Bawole, R., Marwa, J., Murdjoko, A., Wihyawari, A., Heipon, Y., Cabuy, R. L., Benu, N. M. H., Hematang, F., & Leftungun, N. Y. (2024). Mangrove distribution to support biodiversity management in Teluk Bintuni District, West Papua, Indonesia. *Biodiversitas*, *25*(2), 644–653. https://doi.org/10.13057/biodiv/d250223

Khairunnisa, C., Thamrin, E., & Prayogo, H. (2020). Keanekaragaman Jenis Vegetasi Mangrove Di Desa Dusun Besar Kecamatan Pulau Maya Kabupaten Kayong Utara. *Jurnal Hutan Lestari*, *8*(2), 325–336. https://doi.org/10.26418/jhl.v8i2.4007

Kurniawansyah, A., Susiloningtyas, D., & Manessa, M. D. M. (2023). Suitability of Mangrove Tourism Areas in Cilamaya Wetan District, Karawang Regency. *Forum Geografi*, *37*(1), 10–23. https://doi.org/10.23917/forgeo.v37i1.19852

Kurniawati, B., Sulistyaningrum, N., Nugroho, G., Sunarto, Kusumaningrum, L., Rahawarin, Y., Flores, A., Yap, C., & Setyawan, A. (2022). Mangrove conservation efforts with the ecotourism development in the Cengkrong Mangrove Ecotourism, Trenggalek District, East Java, Indonesia. *International Journal of Bonorowo Wetlands*, *12*(2), 75–81. https://doi.org/10.13057/bonorowo/w120203

Majid, I., Al Muhdar, M. H. I., Rohman, F., & Syamsuri, I. (2016). Konservasi Hutan Mangrove Di Pesisir Pantai Kota Ternate Terintegrasi Dengan Kurikulum Sekolah. *Jurnal Bioedukasi*, *4*(2). https://doi.org/10.33387/bioedu.v4i2.162

Mello, F. A. O., Ferreira, T. O., Bernardino, A. F., Queiroz, H. M., Mello, D. C., Menillo, R. B., & Cherubin, M. R. (2024). Soil Health and Ecosystem Services in Mangrove Forests: A Global Overview. *Water (Switzerland)*, *16*(24), 1–17. https://doi.org/10.3390/w16243626

Muttaqin, A. D., Soemarno, Purnomo, M., & Zakiyah, U. (2024). Analysis of the Mangrove Ecosystem Due to the Influence of Mount Bromo's Cold Lava Material on Permata Pilang Beach, Probolinggo. *Ecological Engineering and Environmental Technology*, *25*(4), 272–281. https://doi.org/10.12912/27197050/183918

Peng, D., Zhang, Y., Wang, J., & Pennings, S. C. (2022). The Opposite of Biotic Resistance : Herbivory and Competition Suppress Regeneration of Native but Not Introduced Mangroves in Southern China. *Forests*, *13*(2), 1–16. https://doi.org/10.3390/f13020192

Pietersz, J. H., Huliselan, N. V., Uneputty, P. A., & Tuapattinaja, M. A. (2025). Kondisi Eksisting Komunitas Mangrove di Pesisir Pantai Negeri Kaibobu Seram Bagian Barat, Maluku. *Jurnal Kelautan Tropis Juni*, *28*(2), 340–354. https://doi.org/10.14710/jkt.v28i2.26024

Rudianto, R., Bengen, D. G., & Kurniawan, F. (2020). Causes and E ff ects of Mangrove Ecosystem Damage on Carbon Stocks and Absorption in East Java , Indonesia. *Sustainability*, *12*(24), 1–17. https://doi.org/10.3390/su122410319

Sholiqin, M., Pramadaningtyas, P., Solikah, I., Febriyanti, S., Pambudi, M., Mahartika, S., Umam, A., Liza, N., & Setyawan, A. (2021). Analysis of the diversity and evenness of mangrove ecosystems in the Pacitan Coast, East Java, Indonesia. *International Journal of Bonorowo Wetlands*, *11*(2), 84–94. https://doi.org/10.13057/bonorowo/w110205

Soeprobowati, T. R., Anggoro, S., Puryono, S., & Purnaweni, H. (2022). Species Composition and Distribution in the Mangrove Ecosystem in the City of Bengkulu, Indonesia. *Water*, *14* (21). https://doi.org/10.3390/w14213516

Tambunan, M. I. H. (2018). Pengaruh Lingkungan Tempat Tinggal Terhadap Pengetahuan Siswa Tentang Ekosistem Hutan Mangrove di Kabupaten Deliserdang. *Jurnal Biolokus*, 1(1), 61. https://doi.org/10.30821/biolokus.v1i1.313

Tambunan, M. I. H., Iqbal, M., Efendi, Z., & Humayra, S. M. (2025). Program Konservasi Mangrove Melalui Penanaman Dan Penamaan Jenis Di Ekowisata Pantai Sujono. *Tepak Sirih: Jurnal Pengabdian Masyarakat Madani*, *4*(2), 140–150. https://doi.org/10.30606/jpmm.v4i2.3959

van Hespen, R., Hu, Z., Borsje, B., De Dominicis, M., Friess, D. A., Jevrejeva, S., Kleinhans, M. G., Maza, M., van Bijsterveldt, C. E. J., Van der Stocken, T., van Wesenbeeck, B., Xie, D., & Bouma, T. J. (2023). Mangrove forests as a nature-based solution for coastal flood protection: Biophysical and ecological considerations. *Water Science and Engineering*, *16*(1), 1–13. https://doi.org/10.1016/j.wse.2022.10.004

Widiastuti, T., Astiani, D., Roslinda, E., Ekyastuti, W., & Ekamawanti, H. A. (2024). Mangrove land cover changes in North Singkawang, West Kalimantan, Indonesia analyzed using Landsat 8 images. *Biodiversitas*, *25*(9), 3160–3167. https://doi.org/10.13057/biodiv/d250938

Wintah, Kiswanto, Hilmi, E., & Sastranegara, M. H. (2023). Mangrove diversity and its relationships with environmental conditions in Kuala Bubon Village, West Aceh, Indonesia. *Biodiversitas*, *24*(8), 4599–4605. https://doi.org/10.13057/biodiv/d240864

Zamdial, Z., Hartono, D., & Johan, Y. (2019). Struktur Komunitas Ekosistem Mangrove Di Kawasan Pesisir Kota Mukomuko Kabupaten Mukomuko Provinsi Bengkulu. *Jurnal Enggano*, *4*(1), 92–104. https://doi.org/10.31186/jenggano.4.1.92-104