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VEGETATION ANALYSIS OF SUNGAI TEMBILUK SUNGAI AIR MATA MANGROVE FOREST: A PROPOSED SITE OF KETAPANG BOTANICAL GARDEN IN WEST KALIMANTAN

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Abstract

The mangrove forest of Sungai Tembiluk−Sungai Air Mata is a High Conservation Value (HCV) area composed of native plants of Ketapang Regency, West Kalimantan, which is proposed as Ketapang Botanical Garden. This study aims to analyze the vegetation composition, Important Value Index (IVI), species richness, diversity, and evenness in the mangrove forest of Sungai Tembiluk−Sungai Air Mata that could be used as the basis of sustainable management practices. Thirtyone plots of 10x10 m laid down along the transect and 10 mangrove species were identified. Seedlings were dominated by *Bruguiera gymnorhiza* (IVI = 109.83%), while sapling and tree were dominated by *Rhizophora apiculata* (IVI = 160.79% and 163.28%, respectively). The Margalef Richness Index (D) was 1.11 (low), the Shannon Diversity Index (H') was 1.08 (moderate), and the Pielou Evenness Index (J') was 0.47 (moderate). The horizontal structure was an L−form, which meant as the diameter class getting bigger and the number of species was becoming fewer. The vertical structure had four canopy layers, namely stratum B, C, D, and E. The plant diversity information of this region is essential as a starting point for the development of Ketapang Botanical Garden in order to maintain and improve the initial environmental conditions and native plant species composition.

Key words: Botanical garden, Vegetation analysis, Mangrove forest, Ketapang Regency.

Introduction

The mangrove forest is one of the unique coastal ecosystems, a transition between land and sea ecosystem that is affected by tidal cycles of the sea (Noor *et al*., 2012). Mangrove ecosystem has a great carrying capacity for the environment, ecologically, and economically (Giesen *et al*., 2006). Mangroves are generally found on protected beaches of bay areas, where no big waves that allow mud and sand sedimentation. The sediment is the primary substrate for mangrove species to grow (Dahuri *et al*., 1996).

Mangrove forests are widely distributed throughout the tropics and subtropics. The estimated total area of mangrove forests in Indonesia is 4.25 million ha, which represents about 20% of the world's mangroves. However, 2.94 million ha are stretched along the coastal line of Papua and still relatively pristine and unexploited (Choong *et al*., 1990). On the other hand, mangrove forests in Indonesia are experiencing a very high rate of degradation. In 1980-2000, Indonesia lost one-third of mangrove forests for agriculture, aquaculture, tourism, settlement, and excessive exploitation (Campbell & Brown, 2015).

The role of mangrove forests is vital for humans; hence it is urgent to conserve the mangrove forests. In order to manage a sustainable mangrove forests, it is necessary to conduct plant analysis and floristic studies. The result of these studies will be a significant contribution and likely to be incorporated into the conservation policy by the stakeholders and policymakers. There are 202 mangrove species recorded in Indonesia, but there are differences in the diversity of mangrove species on the main island, namely 166 species found in Java, 157 species in Sumatra, 150 species in Kalimantan, 142 species in Papua, 135 species in Sulawesi, 133 species in Maluku and 120 species in the Lesser Sunda Islands (Noor *et al*., 2012). There are some studies of vegetation analysis of mangrove forests in Indonesia especially in the main island and surrounding islands, i.e., in Sumatra (Onrizal & Kusmana, 2008, Yuliana *et al*., 2019), Java (Syawala, 2013, Susilo, 2017, Hariyanto *et al*., 2019), Kalimantan (Heriyanto & Subiandono, 2016, Hariphin *et al*., 2016, Warsidi & Endayani, 2017, Kartika *et al*., 2018, Muharamsyah *et al*., 2019), Sulawesi (Usman *et al*., 2013, Momo & Rahayu, 2018), Lesser Sunda Islands (Syarifuddin & Zulharman, 2012, Widiatmaka *et al*., 2016), Maluku (Serosero *et al*., 2020), and Papua (Suhardjono, 2014, Tanjung *et al*., 2015, Sianturi & Choesin, 2018). Research on vegetation analyses and floristic studies of mangrove forest were also conducted in other countries such as India (Ragavan *et al*., 2016), Singapore (Sheue *et al*., 2005), Sarawak (Shah *et al*., 2015), Papua New Guinea (Robertson *et al*., 1991), and Taiwan (Hsueh & Lee, 2000).

The mangrove forest of Sungai Tembiluk Sungai Air Mata is established as a High Conservation Value (HCV) area based on Decree of the Regent of Ketapang No. 29 in 2011. Vegetation analysis in the area is essential, especially since this location will be developed into a botanical garden soon. According to Wyse Jackson and Sutherland (2000), a botanical garden is an institution holding documented collections of living plants for scientific research, conservation, display, and education. This ex situ plant conservation area is artificially developed in order to meet the requirement of a botanical garden. Therefore, some changes will occur, including the development of landscape and infrastructure according to the botanical garden masterplan. It is expected that some impacts will occur, i.e., changes in environmental conditions and the disruption of native vegetation. Hence, it is crucial to do identification, characterization, and measurements of any possible effected parameters such as environmental values, species richness, and diversity, and the ecosystem (Witono *et al*., 2020).

Vegetation analysis was carried out to complete Ketapang Botanical Garden's masterplan, as the basis of sustainable management practices by minimizing any reversed impacts and maintain the initial environment condition and native species of this area. This research aims to analyze the vegetation composition, Important Value Index (IVI), species richness, diversity, and evenness in the mangrove forest of Sungai Tembiluk–Sungai Air Mata.

Materials and Methods

Study area: The study was conducted in November 2019 at the mangrove forest of Sungai Tembiluk Sungai Air Mata, is located in Sungai Awan Kanan Village, Muara Pawan sub-district, Ketapang Regency, which covers 504.40 ha (Fig. 1). The elevation is about 0–23 m above sea level, topography dominantly flat (0–8%). The soil type is dominantly composed of entisols that are formed by the early deposit (alluvial), pH 5.32, and the C-organic was 16.67%. Based on the climatic classification of Schmidt Fergusson, the mangrove forest of Sungai Tembiluk – Sungai Air Mata belongs to type A (very wet) with rainfall 2926 mm/year and air temperature between 21.2–35.5^{0}C (Safarinanugraha *et al*., 2019).

Sampling method: The sampling was conducted using a transect method with systematic plot placement, and 10x10 m plots were measured along the transect. The transect line followed the line from the sea boundary to inland (Fig. 1). The distance between plots was 20 m apart, and 31 plots were used. The vegetation was categorized based on its stage; the trees were measured its DBH (diameter at breast height) in 10x10 m plots, sapling (2 cm ≤ DBH < 10 cm) were measured in 5x5 m subplots and seedling species (DBH < 2 cm) were counted in 1x1 m subplots (Fig. 2). The species inside plots and subplots were identified, counted, and measured its height and DBH except for seedlings, which only identified and counted. All samples herbarium were taken for further identification in Herbarium Bogoriense (BO) and Herbarium Hortus Botanicus Bogoriense (BOHB).

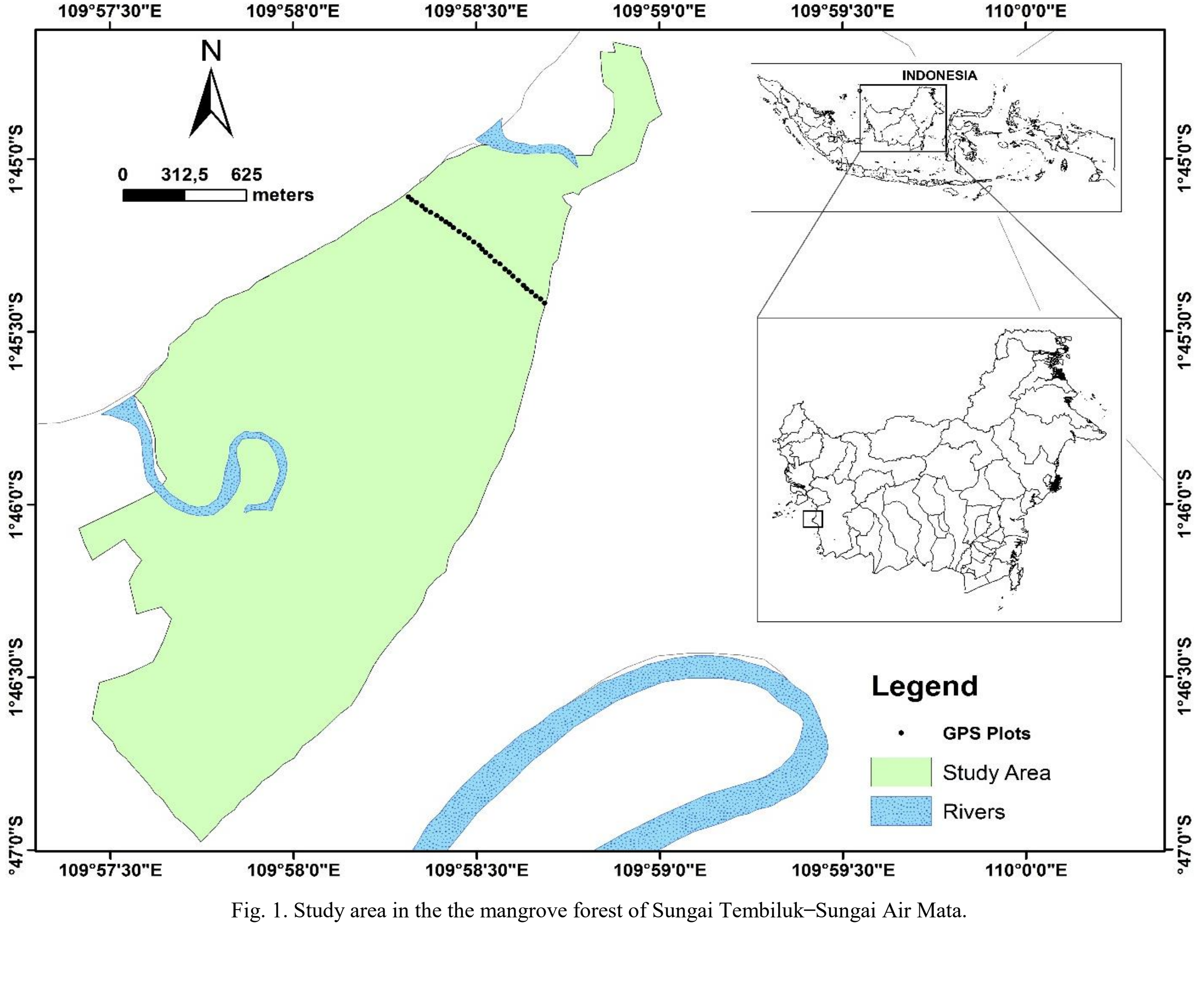

Fig. 1. Study area in the the mangrove forest of Sungai Tembiluk–Sungai Air Mata.

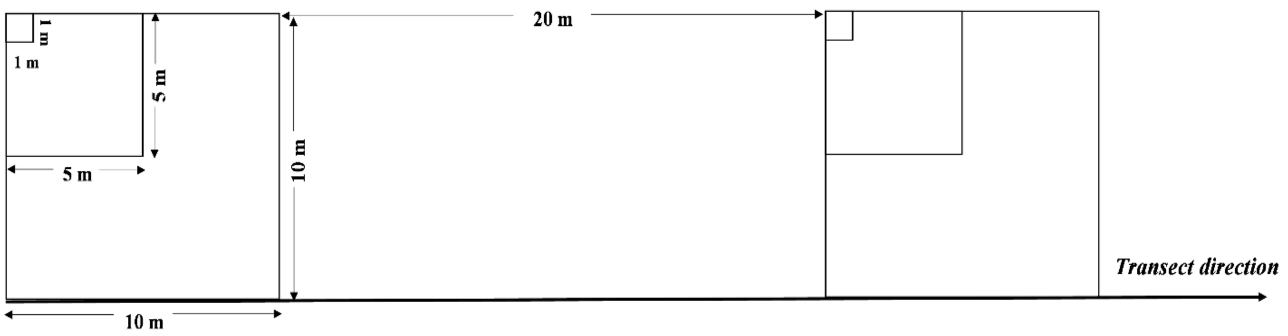

Fig. 2. The vegetation analysis plots.

Following habitat parameters including altitude, pH, organic carbon, total nitrogen, P_2O_5, and K_2O were analysed. The altitude was noted on each plot using GPS. Four sediment samples were taken with 150 m distance between samples. Sediment samples were taken at a depth of 0 - 2 meters and were mixed (composite). pH, organic carbon, total nitrogen, P_2O_5, and K_2O were determined at the Environmental Biotechnology Laboratory, Bogor.

Data analysis: Analysis of mangrove forest vegetation consisted of the value of important value index (IVI), species richness, diversity, and evenness. The IVI of seedling was calculated by summing the relative density and relative frequencies, while sapling and tree were calculated by summing the value of relative density relative frequencies and relatively dominancy (Curtis & McIntosh, 1950). Analysis of the plant community mangrove forest of Sungai Tembiluk – Sungai Air Mata was used a cluster analysis similarity Bray-Curtis of the species abundance data at the tree level. The relationship between habitat characteristics and abundance of mangrove plant species using Canonical correspondence analysis). Prior to the Canonical correspondence analysis, the value of habitat characteristics and abundance of mangrove species were transformed in the form of log 10 (X + 1), where X = habitat characteristics/species abundance. Cluster analysis similarity Bray-Curtis and Canonical correspondence analysis **were** using the PAST software (PAleontological STatistics) version 4.0 (Hammer *et al*., 2001).

The species richness was calculated using the Margalef Richness Index (D), and the species diversity was calculated based on Shannon Diversity index (H'), the species evenness was calculated using Pielou Evenness Index (J') (Magurran 2004) with the following equation:

$$D = \frac{(S-1)}{\ln(N)}$$

$$H' = -\sum_{i=1}^{n}\left[\left(\frac{n_i}{N}\right)\ln\left(\frac{n_i}{N}\right)\right]$$

$$J' = \frac{H'}{\ln(S)}$$

where:
D: Margalef Richness Index
H': Shannon Diversity Index
J': Pielou Evenness Index
NI: Number of individual of-i
N: Total number of individuals
S: Number of species

There are three categories of Margalef Richness Index (D): low (< 3.5), moderate (3.5−5), and high (>5) (Haneda & Panggabean, 2019). Shannon Diversity Index (H') has three categories: low (>1), moderate (1−3), and high (≥3). Pielou Evenness Index (J') also has three categories: low (<0.4), moderate (0.4−0.6) and high (≥0.6) (Fitrian *et al*., 2017).

Results

Vegetation composition: There were 10 mangrove species found on the mangrove forest of Sungai Tembiluk Sungai Air Mata, 8 species were identified as true mangrove species, namely: *Rhizophora apiculata* Blume, *Bruguiera gymnorhiza* (L.) Lam., *Avicennia marina* Vierh., *Sonneratia alba* Sm., *Xylocarpus granatum* K.D. Koenig, *Heritiera littoralis* Aiton, *Excoecaria agallocha* L., and *Acrostichum aureum* L. and the remaining two species were associated mangrove species, i.e., *Hibiscus tiliaceus* L., and *Planchonella obovata* Pierre. Mangrove vegetation in the research site belonged to 8 families, i.e., Rhizophoraceae (2 species), Malvaceae (2 species), Euphorbiaceae, Acanthaceae, Lythraceae, Sapotaceae, Meliaceae and Pteridaceae (1 species).

Bray-Curtis cluster analysis of mangrove community at the level of the similarity value of 0.5 showed that the mangrove forest of Sungai Tembiluk Sungai Air Mata consisted of three population groups, i.e. (1) *A. marina*−*S. alba* group, (2) *E. agallocha*−*P. obovata* group, and (3) *R. apiculata*−*B. gymnorhiza* group (Fig. 3).

Important value index (IVI): The seedlings of mangrove forest of Sungai Tembiluk–Sungai Air Mata were abundant with 8387.10 ± 21716.17 individuals ha^{-1}, the highest density was recorded 5483.87 ± 18809.52 individual ha^{-1} for *B. gymnorhiza*. The mangrove species density in area was decreasing however, growing rate was increasing, i.e., sapling density was 1445.16 ± 951.34 individuals ha^{-1} and tree was 690.32 ± 316.59 individuals ha^{-1}. *R. apiculata* was found to have the highest density on sapling stages (722.58±756.35 individual ha^{-1}), and tree stages were 445.16±348.12 individuals ha^{-1} (see Tables 1−3).

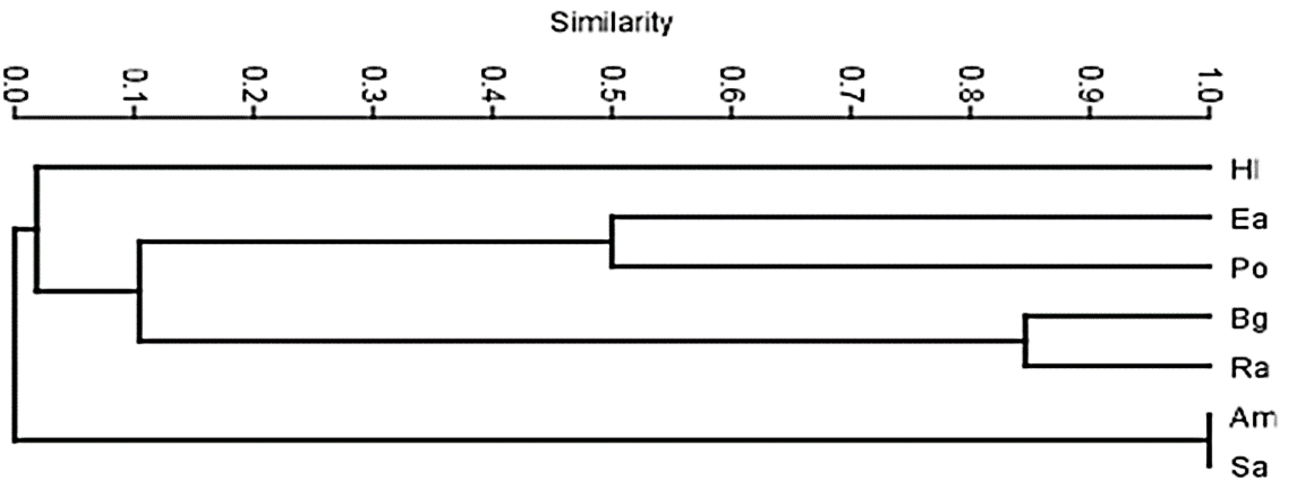

Fig. 3. Bray-Curtis cluster analysisof mangrove community in the mangrove forest of Sungai Tembiluk–Sungai Air Mata. Hl = *Heritiera littoralis, Ea = Excoecaria agallocha, Po = Planchonella obovata, Bg = Bruguiera gymnorhiza, Ra = Rhizophora apiculata, Am = Avicennia marina, Sa = Sonneratia alba.*

Table 1. Number of seedlings and frequency of seedling stage in the mangrove forest of Sungai Tembiluk - Sungai Air Mata.

No.	Species	Family	No.of seedlings (ha^{-1})	Frequency
1.	*Bruguiera gymnorhiza* (L.) Lam.	Rhizophoraceae	5483.87 ± 18809.52	0.13
2.	*Rhizophora apiculata* Blume	Rhizophoraceae	967.74 ± 2956.50	0.10
3.	*Acrostichum aureum* L.	Pteridaceae	1612.90 ± 8834.23	0.03
4.	*Excoecaria agallocha* L.	Euphorbiaceae	322.58 ± 1766.85	0.03
	Total		8387.10 ± 21716.17	

Table 2. Number of saplings, diameter, basal area and frequency of sapling stage in the mangrove forest of Sungai Tembiluk - Sungai Air Mata.

No.	Species	Family	No.of saplings (ha^{-1})	Diameter (cm)	Basal area (m^2 ha^{-1})	Frequency
1.	*Rhizophora apiculata* Blume	Rhizophoraceae	722.58 ± 756.35	5.44 ± 2.37	2.08 ± 1.67	0.65
2.	*Bruguiera gymnorhiza* (L.) Lam.	Rhizophoraceae	658.06 ± 790.58	4.14 ± 0.71	1.06 ± 0.99	0.61
3.	*Xylocarpus granatum* J.Koenig	Meliaceae	38.71 ± 155.91	4.09 ± 1.75	0.06 ± 0.05	0.07
4.	*Excoecaria agallocha* L.	Euphorbiaceae	12.90 ± 70.67	4.93 ± 0.00	0.03 ± 0.00	0.03
5.	*Hibiscus tiliaceus* L.	Malvaceae	12.90 ± 70.67	3.34 ± 0.00	0.01 ± 0.00	0.03
	Total		1445.16 ± 951.34		3.24 ± 2.91	

Table 3. Number of trees, diameter, height, basal area and frequency of tree stage in the mangrove forest of Sungai Tembiluk - Sungai Air Mata.

No.	Species	Family	No.of trees (ha^{-1})	Diameter (cm)	Height (m)	Basal area (m^2 ha^{-1})	Frequency
1.	*Rhizophora apiculata* Blume	Rhizophoraceae	445.16±348.12	18.82±6.33	17.46±4.28	13.88±10.41	0.84
2.	*Bruguiera gymnorhiza* (L.) Lam.	Rhizophoraceae	203.23±202.38	22.20±12.09	15.70±4.44	10.16±12.51	0.84
3.	*Excoecaria agallocha* L.	Euphorbiaceae	16.13±57.34	16.93±2.89	9.16±3.41	0.37±0.12	0.10
4.	*Avicennia marina* (Forssk.) Vierh.	Acanthaceae	12.90±70.67	20.16±3.99	6.80±1.80	0.64±0.23	0.03
5.	*Heritiera littoralis* Aiton	Malvaceae	6.45±35.34	13.21±1.13	6.10±1.56	0.09±0.02	0.03
6.	*Sonneratia alba* Sm.	Lythraceae	3.23±17.67	26.10±0.00	8.20±0.00	0.17±0.00	0.03
7.	*Planchonella obovata* (R.Br.) Pierre	Sapotaceae	3.23±17.67	14.01±0.00	8.80±0.00	0.05±0.00	0.03
	Total		690.32±316.59			25.36±27.31	

The IVI analysis showed that the seedlings of *B. gymnorhiza* had the highest relative frequency value (44.44%), the highest relative density value (65.38%), and resulted in the IVI of 109.83%. On the sapling stage, *R. apiculata* had the highest value of relative frequency (46.51%), relative density (50.00%), relative dominancy (64.28%), and resulted to the highest IVI (160.79%). *R. apiculata* on tree stage had the highest value of relative frequency (44.07%), relative density (64.49%), relative dominancy (54.72%), and IVI (163.28%). *B. gymnorhiza* was on the second rank of the highest values of IVI at the sapling stage (122.50%) and tree stage (113.58% (see Tables 4–6).

Richness index, diversity index and evenness index: Margalef Richness Index (D) of mangrove forest of Sungai Tembiluk-Sungai Air Mata fell into low category (1.11), Shannon Diversity Index (H') belonged to category moderate (1.08), and Peilou Evenness Index (J') was moderate (0.47). Based on growth stages, mangrove forest of HCV Sungai Tembiluk–Sungai Air Mata had a low category on Margalef Richness Index (D) (0.85–

1.12), Shannon Diversity Index (H') (0.89–0.97) and moderate to a high category on Pielou Evenness Index (J'), i.e., 0.46–0.70 (Fig. 4).

Vegetation structure and composition: The highest density on diameter class was recorded for diameter class below 5 cm (<5 cm) with a number of abundance 9355 individual ha^{-1}. While the density in the highest class (>50 cm) with a number of abundance 13 individual ha^{-1}. Horizontal structure of mangrove forest of Sungai Tembiluk-Sungai Air Mata tended to shape an L– form, which meant when the diameter class became bigger, the number of species was found to be lesser (Fig. 5). This result indicated that the population of vegetation in the area tended to be normal, where the vegetation regeneration of trees and saplings sustainability could be well assured.

Diameter at Breast Height (DBH) of trees of mangrove forest of Sungai Tembiluk – Sungai Air Mata were between 10–57.10 cm, the average diameter was 19.76 cm. The basal area of trees in this site was 25.36 ± 27.31 m^2 ha^{-1}. The most significant basal area was found in *R. apiculata* (13.88 ± 10.41 m^2 ha^{-1}), followed by *B. gymnorhiza* (10.16 ± 12.51 m^2 ha^{-1}). Trees height in the mangrove forest of Sungai Tembiluk–Sungai Air Mata was 4.20–29.40 m, with the average height was 16.36 m (Table 3).

Based on the vegetation composition and structure, the mangrove forest of HCV Sungai Tembiluk – Sungai Air Mata was dominated by *R. apiculata* and *B. gymnorhiza,* with the DBH value up to >50 cm. Therefore mangrove forest of Sungai Tembiluk–Sungai Air Mata is categorized as the old mangrove forest.

Table 4. Relative frequency, relative density, and importance value index of the seedling stage in the mangrove forest of Sungai Tembiluk - Sungai Air Mata.

No.	Species	Relative frequency (%)	Relative density (%)	Importance value index (%)
1.	*Bruguiera gymnorhiza* (L.) Lam.	44.44	65.38	109.83
2.	*Rhizophora apiculata* Blume	33.33	11.54	44.87
3.	*Acrostichum aureum* L.	11.11	19.23	30.34
4.	*Excoecaria agallocha* L.	11.11	3.85	14.96
	Total	100.00	100.00	200.00

Table 5. Relative frequency, relative density, relative dominance and importance value index of sapling stage in the mangrove forest of Sungai Tembiluk - Sungai Air Mata.

No.	Species	Relative frequency (%)	Relative density (%)	Relative dominance (%)	Importance value index (%)
1.	*Rhizophora apiculata* Blume	46.51	50.00	64.28	160.79
2.	*Bruguiera gymnorhiza* (L.) Lam.	44.19	45.54	32.78	122.50
3.	*Xylocarpus granatum* J.Koenig	4.65	2.68	1.80	9.13
4.	*Excoecaria agallocha* L.	2.33	0.89	0.78	4.00
5.	*Hibiscus tiliaceus* L.	2.33	0.89	0.36	3.58
	Total	100.00	100.00	100.00	300.00

Table 6. Relative frequency, relative density, relative dominance and importance value index of tree stage in the mangrove forest of Sungai Tembiluk - Sungai Air Mata.

No.	Species	Relative frequency (%)	Relative density (%)	Relative dominance (%)	Importance value index (%)
1.	*Rhizophora apiculata* Blume	44.07	64.49	54.72	163.28
2.	*Bruguiera gymnorhiza* (L.) Lam.	44.07	29.44	40.07	113.58
3.	*Excoecaria agallocha* L.	5.08	2.34	1.47	8.89
4.	*Avicennia marina* (Forssk.) Vierh.	1.69	1.87	2.52	6.08
5.	*Heritiera littoralis* Aiton	1.69	0.93	0.35	2.98
6.	*Sonneratia alba* Sm.	1.69	0.47	0.68	2.84
7.	*Planchonella obovata* (R.Br.) Pierre	1.69	0.47	0.20	2.36
	Total	100.00	100.00	100.00	300.00

Table 7. Habitat characteristics in the mangrove forest of Sungai Tembiluk - Sungai Air Mata.

Habitat characteristics	Unit	Min - Max	Mean ± Standard deviation
Altitude	m	0.00–11.10	9.20 ± 2.46
pH H_20	-	4.58–6.03	5.32 ± 0.60
Organic Carbon	%	5.80–30.64	16.66 ± 10.62
Total Nitrogen	%	0.12–0.83	0.39 ± 0.31
P_2O_5	mg/100g	11.72–20.26	16.93 ± 4.07
K_2O	mg/100g	74.46–221.46	144.49 ± 66.12

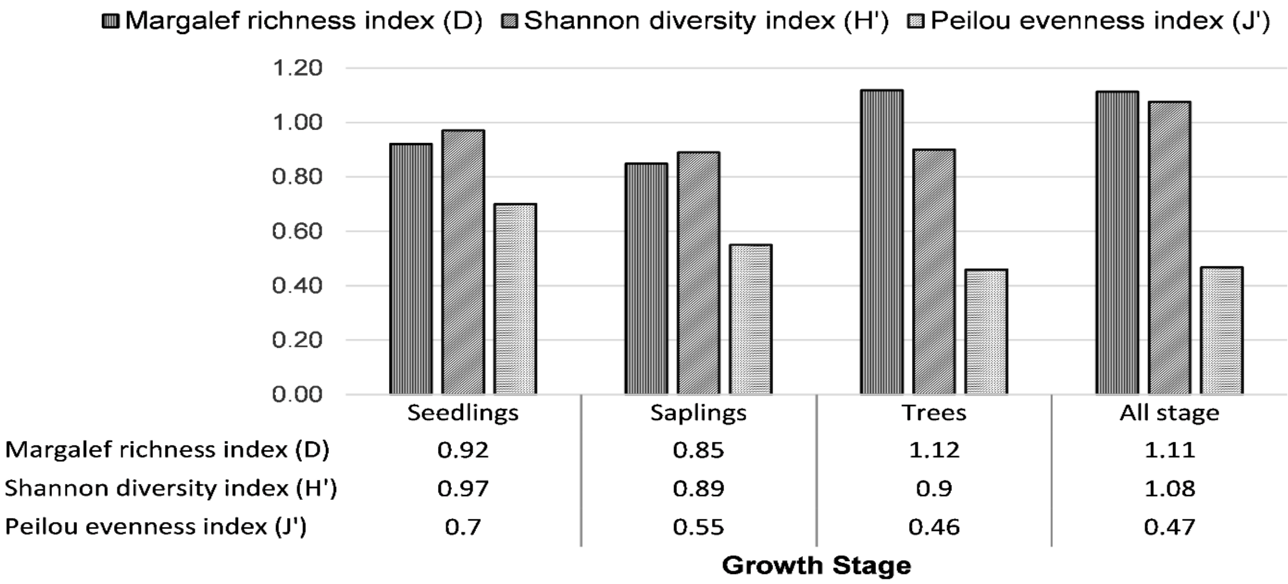

Fig. 4. Margalef richness index, Shannon diversity index, Peilou evenness index on growth stages.

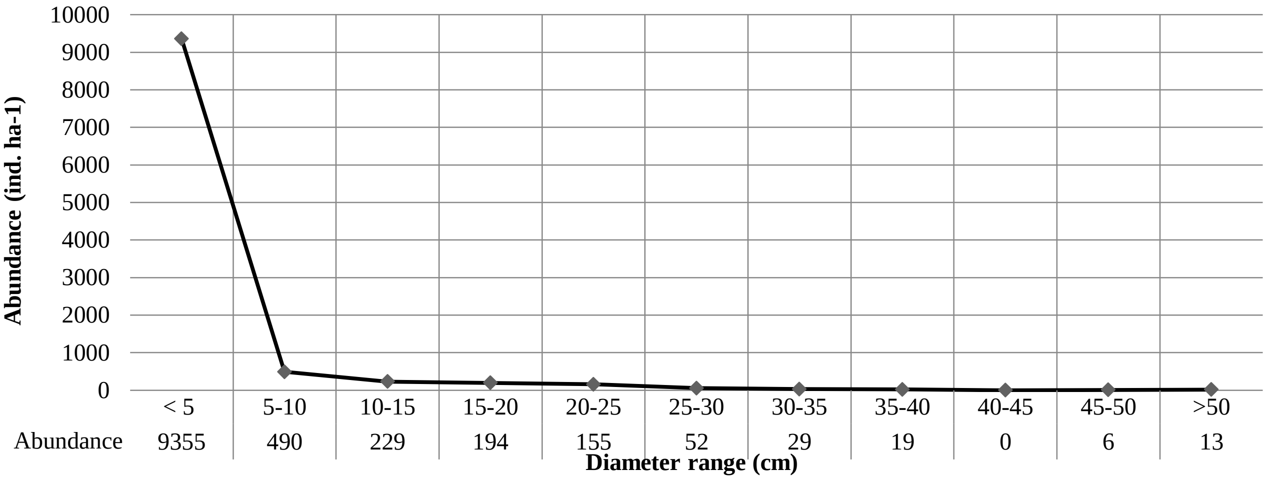

Fig. 5. Horizontal structure of vegetation in the mangrove forest of Sungai Tembiluk–Sungai Air Mata.

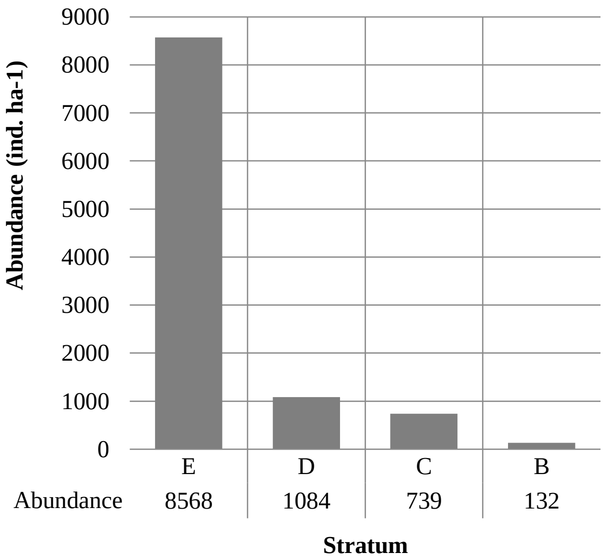

Fig. 6. Vertical structure of vegetation in the mangrove forest of Sungai Tembiluk–Sungai Air Mata.

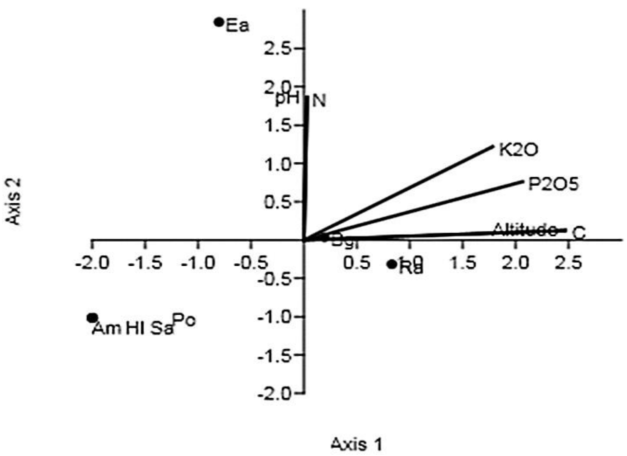

Fig. 7. Ordination of the relationship between mangrove plant species and habitat characteristics in the mangrove forest of Sungai Tembiluk– Sungai Air Mata. Hl = *Heritiera littoralis, Ea = Excoecaria agallocha, Po = Planchonella obovata, Bg = Bruguiera gymnorhiza, Ra = Rhizophora apiculata, Am = Avicennia marina, Sa = Sonneratia alba, C = organic Carbon, N = total Nitrogen.*

Habitat characteristics: The altitude of the measurement plots in the mangrove forest of Sungai Tembiluk–Sungai Air Mata is 0.00–11.10 meters above sea level. Based on the assessment criteria of the soil analysis results (Soil Research Institute 2005), habitat characteristics in the mangrove forest of Sungai Tembiluk– Sungai Air Mata has a soil with pH of 4.58–6.03. The research site has high organic carbon (5.80–30.64%), low to high total nitrogen content (0.12–0.83%), very low phosphorus content (11.72–20.26 mg $100g^{-1}$) and very high potassium content (74.46–221.46 mg $100g^{-1}$).

The abundance of each mangrove that grows in the mangrove forest of Sungai Tembiluk – Sungai Air Mata is influenced by different habitat characteristics. *Rhizophora apiculata* and *Bruguiera gymnorhiza* which were the most dominant species in the mangrove forest of Sungai Tembiluk – Sungai Air Mata, in the ordination diagram were located near the center point of the ordination diagram., meaning that *Rhizophora apiculata* and *Bruguiera gymnorhiza* had a wide tolerance to altitude, pH, organic carbon, total nitrogen, phosphorus, and potassium. However, the abundance types of *Rhizophora apiculata* and *Bruguiera gymnorhiza* were influenced by high altitude, organic carbon, phosphorus, and potassium. The species *Avicennia marina*, *Heritiera littoralis, Sonneratia alba,* and *Planchonella obovata* with relatively low abundance of each species were more influenced by low altitude, organic carbon, phosphorus, and potassium. Whereas the abundance of *Excoecaria agallocha* generally grows in locations with high pH and total nitrogen (Fig. 7).

Discussion

The vegetation in a mangrove ecosystem is generally categorized into two large groups, i.e., the true mangrove and associated mangrove. True mangrove consists of plant species characteristic of a mangrove ecosystem that could not be found in any other ecosystem. The associated mangrove consists of plant species found in a mangrove ecosystem as well as other type ecosystems (Lacerda *et al*., 2002). Compared to other mangrove forests in Kalimantan, the number of mangrove species in Sungai Tembiluk-Sungai Air Mata was higher, for instance, the species number of mangrove forest on Bengkayang Regency (West Kalimantan) was 8 species (Nurrahman *et al*., 2012), Mempawah Regency (West Kalimantan) was 10 species (Marini *et al*., 2018). However, we recorded lesser number of species compared to Sungai Kunyit Subdistrict, Mempawah Regency (West Kalimantan) who reported 11 species (Muharamsyah *et al*., 2019).

The IUCN (The International Union for Conservation of Nature) Red List (2019) included eight species in the mangrove forest of Sungai Tembiluk–Sungai Air Mata *R. apiculata, B. gymnorhiza, A. marina, S. alba, X. granatum*, *A. aureum, E. agallocha,* and *H. littoralis* belonged to the least concern (LC) category. Even though those species belong to the lower category of conservation status, conservation efforts in species level and habitat of mangrove ecosystem need to be done as early as possible.

The community type analysis identified three community clusters. The first cluster dominated by *A. marina* and *S. alba* found at sites adjacent to the sea up to 30 m toward inland. The second cluster was dominated by *E. agallocha* and *P. obovata* found at the second layer behind the first cluster, 50 m toward inland. The third cluster was dominated by *R. apiculata* and *B. gymnorhiza,* which was the major community in the research site situated on the third layer behind the second cluster 800 m toward the inland. The dominant tree stage of *R. apiculata* in this site was supported by the same result from other research in the mangrove forest of Kalimantan and Sarawak. *R. apiculata* was reported as a dominant species with the IVI 121.75% in Kubu Raya Regency (West Kalimantan) (Heriyanto & Subiandono 2016), Balikpapan gulf (East Kalimantan) with IVI 177.63% (Warsidi & Endayani 2017), Bulungan Regency (North Kalimantan) with IVI 133.60% (Kartika *et al*., 2018), and Sibuti, Sarawak (Malaysia) with IVI 202.24% (Shah *et al*., 2015). However, in Sungai Raya Islands, Bengkayang Regency was dominated by *A. marina* and *A. alba* (Nurrahman *et al*., 2012), and the mangrove forest of Sungai Bakau Kecil Village, Mempawah Regency was dominated by *Avicennia marina* (Marini *et al*., 2018). Our contrary findings might be due to the different method of the sampling site. In the last two sites, the samplings were conducted along beach gradient, while our study, Kubu Raya Regency, Balikpapan gulf, Bulungan Regency, and Sarawak, Malaysia, were conducted from the coastal area to the inland.

Based on IVI, *R. apiculata* and *B. gymnorhiza* had the most dominant role in the ecosystem of mangrove forest of Sungai Tembiluk–Sungai Air Mata, since these species had the ability to adapt well in this site. *R. apiculata* showed a wide range of tolerance to salinity and soil condition. This species was able to grow in salinity of 8–26 ppt, clay soil to sand, mud sediment with high organic content, and aerobic to anaerobic soil (Duke, 2006). This ability is supported by root system *R. apiculata* with air roots protruding from the base of the stems, and it helps to establish the tree in the unstable mud substrate (Hariyanto *et al*., 2019). According to Giesen *et al*., (2006), the dominancy of *R. apiculata* is high, and it can dominate up to 90% of the vegetation in the mangrove forest. *B. gymnorhiza* also has a relatively wide tolerance range to shade, salinity, and soil conditions. This species may grow in both under the full sun and the seedlings able to grow under the canopy shade, up to 90% shade, clay and mud substrate with relatively high organic carbon levels, and able to grow salinity of 8–26 ppt (Allen & Duke, 2006).

A. aureum was found in higher frequency value (1612.90 ± 8834.23 individuals ha^{-1}) in the category of the seedling. Some ferns *Acrostichum aureum* and other associated mangrove species were found, and it is mostly grown in degraded mangrove forests or open area (Giesen *et al*., 2006). This species usually grows in clumps but sometimes found solitaire, reach up to 2 m (Sukardjo, 1984). *R. apiculata*, *B. gymnorhiza*, and *E. agallocha* were found at any level of growth. This species was able to grow in various types of vegetation up to 400 m above sea level (Giesen *et al*., 2006).

A. marina, *H. littoralis, S. alba,* and *P. obovata* were only found at the tree stage. The population of these species were relatively low, it was 12.90 ± 70.67

individuals ha^{-1} in *A. marina,* for *H. littoralis* it was 6.45 ± 35.34 individuals ha^{-1} and for *S. alba,* and *P. obovata* it was 3.23 ± 17.67 individuals ha^{-1} respectively. *A. marina* and *S. alba* belonged to true mangrove. Both species grow in the outermost of the mangrove forest adjacent to the sea, therefore its fruits were carried away through drifting.

The richness index, evenness index, and diversity index of the mangrove forest of Sungai Tembiluk Sungai Air Mata was lower compared to mangrove forests in Sarawak, Malaysia, and Bulungan Regency. According to Shah *et al.*, (2015), the mangrove forest in Sarawak had the Margalef Richness Index (D) of 1.41, the Shannon Diversity Index (H ') of 1.18, and Pielou Evenness Index (E) of 0.54. The mangrove forest of Salimbatu and Liagu, Bulungan Regency, had the Shannon Diversity Index (H ') of 1.68 (Kartika *et al.*, 2018). The differences of richness index, diversity index, and evenness index were affected by differences in the number of species and density which were impacted by soil quality (physical and chemical factors such as pH, nutrient, salinity, organic content, texture, and content) (Hossain & Nuruddin, 2016).

The stand's structure of mangrove forests consisted of horizontal and vertical structures. The horizontal structure was based on the association of diameter class and individual density, while the vertical structure was based on the number of canopy layers of mangrove forests (Ghufrona *et al.*, 2015). The basal area in the mangrove forest of Sungai Tembiluk–Sungai Air Mata was larger than the basal area of mangrove forest Bulungan Regency (North Kalimantan) which was 11.91 m^2 ha^{-1} (Kartika *et al.*, 2018) and smaller than the mangrove forest of Sebuku Island, South Kalimantan which was 31.76 m^2 ha^{-1} (Ghufrona *et al.*, 2015). Komiyama *et al.*, (2008) categorized mangrove forest based on basal area value, i.e., primary mangrove forest with minimal damages has the basal area usually bigger than 25 m^2 ha^{-1}; secondary mangrove forest with the basal area 10–25 m^2 ha^{-1}; and the disturbed mangrove forests with the basal area less than 10 m^2 ha^{-1}. Based on these criteria, the mangrove forest of Sungai Tembiluk Sungai Air Mata falls to the primary mangrove forest category where relatively small damage occurred. This result was supported by our observations in the field, where no sign of any stumps that indicate logging activity occurred in this area. It showed that the community around the forest did not do any logging activity and maintained the existence of the forest.

Based on the stand's height, the stratification of tropical forest in general consisted of five layers or strata, namely stratum A (emergent) is the highest with height above 30 m; stratum B (canopy), with heights reach 20-30 m; the stratum C (sub-canopy) with a height between 4-20 m; the stratum D (understorey) with a height of 1−4 m; and the stratum E (forest floor) with the least height of 0−1 m (Indriyanto, 2006). Based on the definition of vertical structure above, the mangrove forest of Sungai Tembiluk – Sungai Air Mata consisted of four layers of strata, i.e., B, C, D, and E (Fig. 6). This result was consistent with the finding in the mangrove forest of the Sebuku Island (South Kalimantan) which generally consisted of four canopy layers, namely stratum B, C, D, and E (Ghufrona *et al.*, 2015).

The old mangrove forest is a mangrove plant community that has reached the peak of its development (climax), where the balance has been reached, the species composition is relatively constant, and the change in species composition occurs only in the gap root (Sukardjo, 1984). The mangrove forest of Sungai Tembiluk – Sungai Air Mata indicated that the forest and its stands were well maintained and able to develop further for ecotourism, environmental education, and research site. However, the research site was relatively low in species richness and diversity. Therefore, it is necessary to increase the species richness and diversity by planting mangrove species, especially the native plant species and other mangrove species that could grow in the site with the environmental conditions.

Tropical mangrove forests have soil pH characteristics from acid to alkaline) of a value of 2.87-8.22 with organic carbon of 0.38 -13.31% and total nitrogen of 0.09-0.97% (Hossain & Nuruddin, 2016). The low soil pH in mangrove forest locations is due to the accumulation of high mangrove vegetation litter and the decomposition process of the litter by soil microorganisms, resulting in high carbon and larger H^+ ions (Pazi *et al.,* 2016). Soil pH, organic carbon, and total nitrogen in the mangrove forest of Sungai Tembiluk – Sungai Air Mata was higher than other mangrove forests on the island of Borneo. Apar Natural Reserve mangrove forest, East Kalimantan, Indonesia had soil pH 3.95–4.82, organic carbon 3.96–11.40% and total nitrogen 0.37–0.97% (Sukardjo, 1994), Sibuti Mangrove, Sarawak, Malaysia had soil Ph 3.34, organic carbon 12.18% and total nitrogen 0.22%. Awat-Awat Lawas Mangrove Sarawak, Malaysia had a soil pH 3.19 and organic carbon 9.38% and total nitrogen 0.15%. (Rambok *et al.*, 2010). Higher soil pH, organic carbon, and total nitrogen in the mangrove forest of Sungai Tembiluk – Sungai Air Mata strongly supported mangrove plant growth, especially due to the availability of nutrients.

The establishment of Ketapang Botanical Garden will be done by Ketapang Regency and supported by the Research Center for Plant Conservation and Botanic Gardens, Indonesian Institute of Sciences. This initiative is a solution to improve the ecological and economic values of the area. From the ecological point of view, the sustainability of the native species enriched with mangrove species introduced from other places in Indonesia will enhance the species diversity of plants as well as fauna. This is the opportunity for Ketapang Botanical Garden to be the center of mangrove conservation, research, and education in Indonesia. The garden could protect the mangrove habitat by owning or managing the site, or it can contribute to in situ conservation indirectly through research, advocacy, and outreach program (Havens *et al.*, 2006). From the economic point of view, the Ketapang Botanical Garden will become a new ecotourism destination and drive economic activities of the local community in surrounding areas as well as increase the revenue of Ketapang Regency (Safarinanugraha *et al.*, 2019).

However, it is necessary to take precautions in developing Ketapang Botanical Garden, to make sure that ecosystem condition balance and increase in quality. The first step is the Ketapang Botanical Garden Masterplan, where the infrastructures and the visitor activity center are designed to adjust with the initial environmental conditions, minimum use of the area for infrastructure construction, and restrictions on the number of visitors. The protection of the area is a better way to conserve and safeguard the species from the visitors. So both in-situ and ex-situ conservation is needed in the botanical gardens, mainly to conserve indigenous and local species (Witono *et al*., 2020).

Conclusion

The Mangrove forest of Sungai Tembiluk–Sungai Air Mata inhibits ten mangrove species, i.e., *Rhizophora apiculata, Bruguiera gymnorhiza, Avicennia marina, Sonneratia alba, Xylocarpus granatum, Acrostichum aureum, Excoecaria agallocha, Heritiera littoralis, Hibiscus tiliaceum,* and *Planchonella obovata.* The vegetation analysis showed that seedling stage was dominated by *Bruguiera gymnorhiza* with an IVI value of 109.83%, and *Rhizophora apiculata* dominated at the sapling stage (IVI = 160.79%) and tree stage (IVI =163.28%). In overall, Margalef Richness Index (D) in the mangrove forest of Sungai Tembiluk–Sungai Air Mata was 1.11 (low category), the Shannon Diversity Index (H') was 1.08 (moderate category), and the Pielou Evenness Index (J') was 0.47 (moderate category). The horizontal structure was L-form, and the vertical structure had four canopy layers, i.e. stratum B, C, D, and E.

The Mangrove forest of Sungai Tembiluk – Sungai Air Mata has a high potential and could be developed for ecotourism, environmental education, and research. The development of Ketapang Botanical Garden is a solution to improve the ecological and economic value of Ketapang Regency. A precaution in developing and constructing the Ketapang Botanical Garden is necessary for keeping ecosystem undisturbed.

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