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SPECIES COMPOSITION, STAND STRUCTURE, ESTIMATION OF BIOMASS AND CARBON CONTENT IN MANGROVE ECOTOURISM AREA, ANGKE KAPUK, JAKARTA

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Abstract

Mangrove forests have high carbon storage capacity and potential in climate change mitigation efforts. This study aimed to analyze the species composition, stand structure, biomass, carbon storage, and carbon dioxide absorption of mangrove stands in the Pantai Indah Kapuk (PIK) Mangrove Ecotourism Area, DKI Jakarta. This research method uses stratified random sampling and calculates the number of observation plots using the Slovin formula. Biomass estimation was carried out using the allometric equations. From the results of vegetation analysis, there are ten species of mangroves, namely *Rhizophora mucronata*, *Avicennia marina*, *Sonneratia caseolaris*, *Excoecaria agallocha*, *Cerbera manghas*, *Terminalia catappa*, *Rhizophora apiculata*, *Calophyllum inophyllum*, *Morinda citrifolia*, and *Nypa fruticans*. Total biomass, carbon storage, and carbon dioxide absorption by mangroves in the study area are 253, 18 tons ha^{-1}, 119 tons ha^{-1}, and 436, 71 tons ha^{-1}, respectively. Environmental factors influence the value of carbon storage and carbon dioxide absorption by mangroves in the planting area.

Keywords: Biomass, Carbon, Mangrove, Pantai Indah Kapuk.

INTRODUCTION

Indonesia has the largest mangrove forest area in the world. Based on national mangrove mapping in 2021, the current mangrove area is 3.364.080 ha, with a potential mangrove habitat area of 756.183 ha (KLHK 2021). Mangrove forests are ecosystems located between land and sea, and under suitable conditions, mangroves will form extensive and productive forests. The term mangrove is defined as a species or community of plants that live in tidal areas. Most of the vegetation in mangrove forests is dominated by mangrove species, or brackish forests because these forests grow on the land constantly inundated with brackish water (Dasril and Kamal, 2023).

Mangrove forests have many ecological functions for humans or marine organisms. One of the environmental functions of mangrove ecosystems is carbon storage in climate change mitigation efforts (Pravitha *et al*., 2022). Mangrove forests can store more carbon than other forest types, so if there is a decrease in the area of mangrove forests, it will significantly affect carbon absorption and storage to reduce CO_2 levels in the air. The importance of estimating the carbon storage potential of mangrove stands as a mitigation of global warming is a cue to conserve mangrove ecosystems (Dinilhuda *et al*. 2018).

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DKI Jakarta Province is one of the regions in Indonesia with mangrove forest areas spread in the Tegal Alur-Angke Kapuk mangrove forest area and around the Kepulauan Seribu. Based on the results of the boundary demarcation in the field and the Minutes of the Boundary Demarcation signed on July 25, 1994, and appointed by the decision of the Governor of the DKI Jakarta Regional Head, it is known that the forest that is maintained is 327,70 ha (Febriyanto 2020). One of the DKI Jakarta mangrove areas is used as a mangrove ecotourism area, namely the Pantai Indah Kapuk Mangrove Ecotourism Area, North Jakarta, with an area of 95,50 ha. Mangrove planting in this area took place in 2007 and continues. This study aims to analyze the species composition, stand structure, biomass content, carbon storage, and carbon dioxide absorption in mangrove stands in the Pantai Indah Kapuk (PIK) Mangrove Ecotourism Area, DKI Jakarta.

METHODS

Time and Place

The research was conducted in September-October 2023 in the Pantai Indah Kapuk (PIK) Mangrove Ecotourism Area, Kapuk Muara, Penjaringan District, North Jakarta City, DKI Jakarta Province (Figure 1).

Figure 1: Research Area

ISSN 1533-9211

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Tools and Materials

The tools used in this study include roll meter, measuring tape, compass, hygrometer, refractometer, digital pH meter, tally sheet, stationery, mangrove identification book, Avenza Maps application, and ArcGIS 10.8 software, Microsoft Word, and Microsoft Excel.

The materials used in this research are mangrove stands in the Pantai Indah Kapuk Mangrove Ecotourism Area, DKI Jakarta, and Sentinel 2A imagery in 2023.

Research Procedure

1. Creation of Vegetation Cover Classification Map Using NDVI

Vegetation density classification was analyzed using the Normalized Difference Vegetation Index (NDVI). The data is from the download of Sentinel 2A Band 4 and Band 8 images recorded on August 17, 2023, at the Sentinel Hub.

Data processing was carried out with ArcGIS 10.8 software using the NDVI method for three levels of canopy density: low, medium, and high. NDVI classification values range from -1 to 1. The criteria for mangrove canopy density levels used are according to Hendrawan *et al*. (2018) (Table 1). NDVI values close to 1 indicate high vegetation density, while NDVI values close to -1 indicate low or no vegetation density (Figure 2). The following equation calculates the NDVI value using red and infrared channel values (Philiani *et al*. 2016).

$$\text{NDVI} = \frac{\text{NIR-Red}}{\text{NIR+Red}}$$

Description:

NDVI = Normalized Difference Vegetation Index

NIR = Reflectance value of infrared channel (Band 8)

Red = Reflectance value of red channel (Band 4)

Table 1: Criteria for Mangrove Canopy Density Level

Canopy Density Level	NDVI
Low	0,37 - 0,61
Medium	0,61 - 0,76
High	0,76 - 1,00

ISSN 1533-9211
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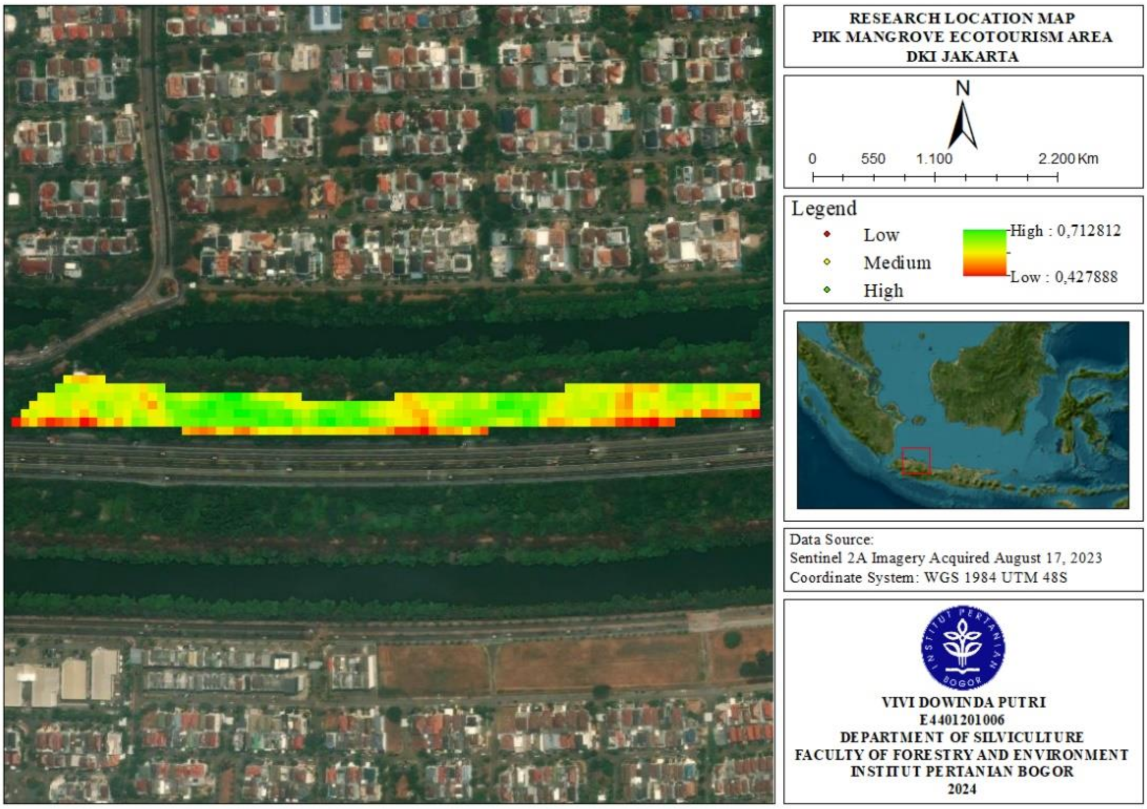

Figure 2: Map of Mangrove Vegetation Density using Sentinel 2A imagery

2. Vegetation Survey

The method used for vegetation data collection is stratified random sampling, which is a way of sampling by dividing the population into several strata and selecting samples by simple randomization in each stratum (Azora 2021). Vegetation surveys were carried out by making square-shaped observation plots with a distribution based on the density class of mangrove stands at the research site. The number of observation plots based on stand density class was obtained using the Slovin formula. The Slovin formula is a formula used to calculate the population size of an object whose characteristics are not explicitly known. According to Slovin, the sample size is determined based on the following formula (Narendra *et al*. 2021).

$$n = \frac{N}{1 + N e^2}$$

Description:

n = Sample size

N = Population size

e = Percent allowance for sampling error that is still tolerable or desirable.

ISSN 1533-9211
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The determination of sample size using the Slovin formula with an error rate of 20% resulted in a total of 41 observation plots with a distribution, namely 14 plots in the high-density class, 17 plots in the medium-density class, and ten plots in the low-density class. Mangrove vegetation was analyzed with the categories of seedling vegetation with a height ≤ 1.5 m and a stem diameter ≤ 2 cm, sapling vegetation with a height ≥ 1,5 m and a stem diameter of 2 - ≤ 10 cm, and tree vegetation with a stem diameter > 10 cm (Widiarti 2022). The vegetation survey observation plot is presented in Figure 3.

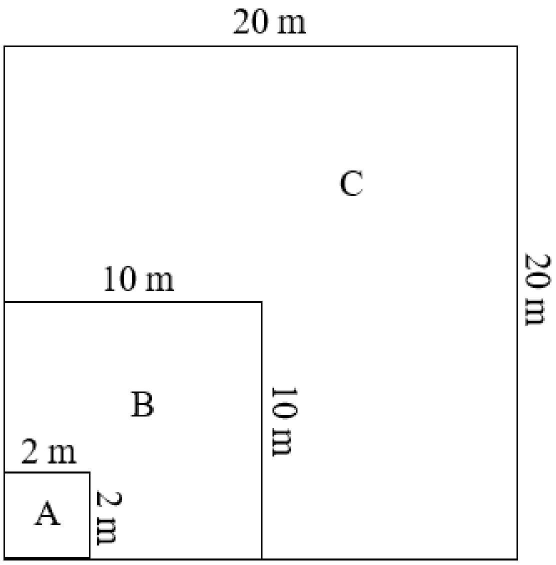

Figure 3: Research Plots for Vegetation Analysis

3. Measurement of Aquatic Environmental Condition Parameters

Parameter measurements of aquatic environmental conditions were carried out on each observation plot. The parameters measured were air temperature, air humidity, soil temperature, salinity, and pH. Measurement of air temperature and humidity using a hygrometer. Measurement of salinity or salt content using a refractometer. Measurement of soil temperature and pH using a digital pH meter. Soil sampling with a 0-20 cm depth for soil texture analysis and soil chemical properties in the form of soil C-organic content and soil NPK content at the IPB Soil Laboratory.

4. Data Analysis

Importance Value Index (IVI)

The plant importance index is a parameter that can show the role of plant species in the community. IVI is the sum of the relative density of species (KR), relative frequency of species (FR), and relative dominance of species (DR). The formulas for obtaining IVI are as follows (Curtis and Mcintosh 1950).

$$\text{Density of Species (K) (ind ha}^{-1}\text{)} = \sum \frac{\text{Individuals of a species}}{\text{-area of sample plot (ha)}}$$

The Seybold Report
ISSN 1533-9211
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Relative Density (KR) (%) $= \frac{\text{Density of a species}}{\text{Density of all species}} \times 100\%$

Frequency of Species (F) $= \sum \frac{\text{Subplot species found}}{\text{number of plots}}$

Relative Frequency (FR) (%) $= \frac{\text{Frequency of a species}}{\text{frequency of all species}} \times 100\%$

The dominance of Species (D) (m^2 ha^{-1}) $= \frac{\text{Base plane area of a species}}{\text{-area of sample plot (ha)}}$

Relative Dominance (DR) (%) $= \frac{\text{Dominance of a species}}{\text{dominance of all species}} \times 100\%$

IVI (%) = KR + FR (seedling growth rates)

IVI (%) = KR + FR + DR (sapling and tree growth rates)

Species Diversity Index (H')

The species diversity index was calculated using the Shannon-Wiener equation (1998) with the following formula:

$$H' = \sum_{i=1}^{S} \frac{ni}{N} \ln\left(\frac{ni}{N}\right)$$

Description:

H' = Shannon-Wiener Species Diversity Index
S = Number of species found
ni = number of i-th individuals
N = Total number of individuals

The species diversity index, according to Shannon-Wiener (1998), is defined as follows:

1. H' value < 1 indicates low species diversity.
2. H' value of $1 < H' \leq 3$ indicates a medium level of species diversity.
3. H' value > 3 indicates a high level of species diversity.

Species Evenness Index (E)

The species evenness index was calculated using the following formula (Ludwig and Reynolds 1988):

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

Description:

E = Species Evenness Index
H' = Species Diversity Index
S = Number of species found

The Seybold Report
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The species evenness index is defined as follows (Magurran 1988):

1. E value < 0,3 indicates low species evenness.
2. E values between 0,3-0,6 indicate moderate species evenness.
3. E value > 0,6 or close to 1 indicates high species evenness.

Species Richness Index (R)

The species richness index is calculated using the following formula:

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

Description:

R = Species Richness Index

S = Number of species found

N = Total number of individuals

Species richness values are divided into three categories: low with R < 3,5, medium with 3,5 < R < 5,0, and high with R > 5,0 (Magurran 1988).

Species Dominance Index (C)

The species dominance index was calculated using the dominance index formula from Misra (1980) as follows:

$$C = \sum_{i=1}^{n} \left(\frac{ni}{N}\right)^2$$

Description:

C = Species Dominance Index

ni = density of the i-th species

N = Total species density

Species dominance values range from $0 \leq C \leq 1$ and are divided into three categories: low if $0 \leq C \leq 0,5$; medium if $0,5 \leq C \leq 0,75$; and high if $0,75 \leq C \leq 1$.

Estimation of Biomass Content and Carbon Reserves

Carbon calculations are carried out by non destructive sampling (not damaging individual mangroves) with allometric formulas established by other researchers before. This allometric formula estimates the biomass content in the tree or above-ground biomass (Nuraini *et al*. 2021). The allometric equations and wood density of mangroves used to calculate the biomass of mangrove stands are presented in Table 2 and Table 3.

ISSN 1533-9211

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Table 2: Tree Biomass Allometric Equation Model

Species	Allometric Formula	Reference
Rhizophora mucronata	$B = 0{,}128*D^{2,60}$	Komiyama *et al*. (2008)
Avicennia marina	$B = 0{,}308*D^{2,11}$	Komiyama *et al*. (2008)
Sonneratia caseolaris	$B = 0{,}258*D^{2,287}$	Kusmana *et al*. (2018)
Rhizophora apiculate	$B = 0{,}235*D^{2,42}$	Ong *et al*. (2004)
Nypa fruticans	$B = 0{,}54*D_{pel}^{0,63}*P_{pel}^{0,31}$	Lukman (2020)
Common equation	$B = 0{,}168*\rho*D^{2,47}$	Clough & Scott (1989)

ρ = wood density (g cm^{-2}), B = biomass (kg m^{-2}), D = diameter (cm), D_{pel} = midrib diameter (cm), P_{pel} = midrib length (m).

Table 3: Wood Density of Some Mangrove Trees

Species	Wood Density (g cm^{-2})	Reference
Excoecaria agallocha	0,4288	CIFOR-ICRAF (2023)
Terminalia catappa	0,5404	CIFOR-ICRAF (2023)
Cerbera manghas	0,4400	CIFOR-ICRAF (2023)
Morinda citrifolia	0,6460	CIFOR-ICRAF (2023)
Calophyllum inophyllum	0,6583	CIFOR-ICRAF (2023)

According to IPCC (Intergovernmental Panel on Climate Change) (2006), the value of carbon contained in organic matter is 47% of the total biomass, so to find out the amount of carbon stored can be calculated by the following equation:

$$Cn\ (ton\ ha^{-1}) = Biomass\ (ton\ ha^{-1}) \times 47\%$$

The estimation of CO_2 absorption is calculated using the ratio of the relative atomic mass of C (12) to the relative molecular mass of CO_2 (44) with the following formula (Kemenhut 2013 in Oktavianto *et al*. 2015).

$$CO_2\ (ton\ ha^{-1}) = 3{,}67 \times Cn\ (ton\ ha^{-1})$$

RESULT AND DISCUSSION

1. Vegetation Structure

a. Importance Value Index

The importance index is obtained from the sum of relative frequency, relative density, and relative dominance. The importance index data is presented in Table 4.

The Seybold Report
ISSN 1533-9211
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Table 4: Importance value index of mangrove species

Canopy Density Level	Species	Seedling			Sapling				Tree			
		K (ind ha-1)	F	IVI (%)	K (ind ha-1)	F	D (m² ha-1)	IVI (%)	K (ind ha-1)	F	D (m² ha-1)	IVI (%)
Low	*Rhizophora mucronata*	11.250	0,50	117,08	2.580	0,90	64.560,51	271,68	120	0,40	15.614,45	73,74
	Avicennia marina	-	-	-	-	-	-	-	82,50	0,50	32.293,59	84,36
	Sonneratia caseolaris	-	-	-	-	-	-	-	77,50	0,60	37.493,23	93,20
	Excoecaria agallocha	-	-	-	30	0,30	1.434,71	28,32	10	0,10	1.300,56	9,48
	Cerbera manghas	750	0,10	22,92	-	-	-	-	25	0,20	7.905,25	26,03
	Terminalia catappa	-	-	-	-	-	-	-	5	0,20	1.570,06	13,19
Total		12.000	0,60	200	2.610	1,20	65.995,22	300	320	2	96.177,15	300
Medium	*Rhizophora mucronata*	8.088,24	0,53	122,56	1.800	1	40.670,19	283,29	150	0,76	21.666,82	70,39
	Avicennia marina	-	-	-	-	-	-	-	102,94	0,35	42.022,88	59,70
	Sonneratia caseolaris	-	-	-	-	-	-	-	111,76	0,65	54.187,20	79,23
	Excoecaria agallocha	441,18	0,06	9,68	-	-	-	-	97,06	0,59	29.636,80	58,64
	Cerbera manghas	2.058,82	0,18	35,37	-	-	-	-	4,41	0,18	1.853,81	8,08
	Terminalia catappa	882,35	0,18	25,24	5,88	0,06	29,97	5,40	11,76	0,29	4.494,54	15,26
	Rhizophora apiculata	-	-	-	-	-	-	-	11,76	0,12	3.644,62	8,72
	Calophyllum inophyllum	147,06	0,06	7,15	5,88	0,06	56,67	5,46	-	-	-	-
	Morinda citrifolia	-	-	-	11,76	0,06	84,77	5,85	-	-	-	-
Total		11.617,65	1	200	1.823,53	1,18	40.841,61	300	489,71	2,94	157.506,67	300
High	*Rhizophora mucronata*	25.000	0,79	180,51	2.000	0,93	41.050,96	224,20	232,14	0,93	39.673,57	127,07
	Avicennia marina	-	-	-	7,14	0,07	205,30	4,33	76,79	0,50	35.475,29	69,79
	Sonneratia caseolaris	-	-	-	7,14	0,07	81,89	4,07	8,93	0,14	4.820,86	11,67
	Excoecaria agallocha	-	-	-	35,71	0,21	792,77	14,02	37,50	0,43	10.444,30	33,86
	Cerbera manghas	1.071,43	0,14	19,49	7,14	0,07	511,83	4,98	7,14	0,21	2.621,42	11,58
	Terminalia catappa	-	-	-	28,57	0,14	388,42	9,26	37,50	0,64	9.738,40	40,51
	Rhizophora apiculata	-	-	-	14,29	0,07	180,28	4,60	1,79	0,07	2.786,62	5,52
	Calophyllum inophyllum	-	-	-	21,43	0,14	248,52	8,64	-	-	-	-
	Morinda citrifolia	-	-	-	28,57	0,21	1.286,97	14,75	-	-	-	-
	Nypa fruticans	-	-	-	64,29	0,07	2.194,25	11,15	-	-	-	-
Total		26.071,43	0,93	200	2.214,29	2	46.941,17	300	401,79	2,93	105.560,45	300

K = Density, F = Frequency, D = Dominance, IVI = Importance Value Index

The Seybold Report
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Rhizophora mucronata species has the highest density and frequency values. The range of density values of *Rhizophora mucronata* species at each vegetation level, namely, 8.088,24-25.000 ind ha^{-1} (seedlings), 1.800-2.580 ind ha^{-1} (saplings), and 120-232,14 ind ha^{-1} (trees). The range of frequency values of *Rhizophora mucronata* species at each vegetation level is 0,50-0,79 (seedlings), 0,90-1 (saplings), and 0,40-0,93 (trees). Another species with the highest frequency value is *Sonneratia caseolaris* at the tree vegetation level in the observation plot, which has a low canopy density level of 0,60.

Rhizophora mucronata species had the highest dominance value at the sapling vegetation level at each canopy density level (40.670,19-64.560,51 m^2 ha^{-1}), as well as at the tree vegetation level in plots with high canopy density levels (39.673,57 m^2 ha^{-1}). The highest dominance value at the tree vegetation level was *Sonneratia caseolaris*, with values of 37.493,23 m^2 ha^{-1} (low canopy density level) and 54.187,20 m^2 ha^{-1} (medium canopy density level). *Rhizophora mucronata* species had the highest IVI values at the seedling (122,56-180,51%) and sapling (224,20-283,29%) vegetation levels at each canopy density level, as well as at the tree vegetation level in plots with high canopy density levels (127,07%). The highest IVI at the tree vegetation level were *Sonneratia caseolaris* species, with values of 93,20% (low canopy density level) and 79,23% (medium canopy density level). The *Rhizophora mucronata* species has the highest IVI at the seedling and sapling vegetation level because the seeds used in the rehabilitation activities of the PIK Mangrove Ecotourism Area are *Rhizophora mucronata* species. *Sonneratia caseolaris* species has the highest IVI at the tree vegetation level because each species competently obtains nutrients and sunlight. *Sonneratia* spp. is an intolerant pioneer species that can grow quickly and competently on various substrates (Nurjanto *et al*., 2021). Species with the highest IVI indicate the critical role of a species in their respective communities and their ability to adapt to environmental factors (Wahyuningsih *et al*. 2019). The species with the highest IVI in the PIK Mangrove Ecotourism Area are *Rhizophora mucronata* and *Sonneratia caseolaris*. The results of the IVI species *Rhizophora mucronata* and *Sonneratia caseolaris* greatly influence the ecosystem, significantly impacting ecosystem stability if these two species are lost or disturbed.

b. Index of Diversity, Evenness, Richness, and Dominance of Species

Index of species diversity, evenness, richness, and dominance are some methods used to measure and analyze the composition and diversity of plant species in an area. The index values are listed in Table 5.

Table 5: Index of Diversity, Evenness, Richness, and Dominance of Species

Vegetation Level	Canopy Density Level											
	Low				Medium				High			
	H'	E	R	C	H'	E	R	C	H'	E	R	C
Seedling	0,23	0,34	0,26	0,88	0,93	0,58	0,92	0,52	0,17	0,25	0,20	0,92
Sapling	0,06	0,09	0,18	0,98	0,08	0,06	0,52	0,97	0,51	0,22	1,57	0,82
Tree	1,43	0,80	1,03	0,27	1,57	0,81	1,03	0,23	1,26	0,65	1,11	0,39

H'= Species diversity index, E = Evenness diversity index, R = Species Richness index, C = Species dominance index

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The value of the species diversity index at the seedling and sapling vegetation level is low (0,06-0,93) due to the dominance of *Rhizophora mucronata* as rehabilitation seedlings. The species diversity index at the tree vegetation level is moderate (1,26-1,57) due to the natural growth of other mangrove species. Generally, mangrove forests have less species diversity than other forest types (Kusmana and Azizah 2021).

The species evenness index value at the tree vegetation level is high (0,65-0,80), saplings are low (0,06-0,22), while seedlings are low to moderate (0,25-0,58). According to Kusmana and Azizah (2021), the higher the evenness index, the more stable the species diversity. The species richness index is low at all vegetation levels (0,18-1,57). The higher the value of species diversity and the area of the observation plot, the higher the species richness (Kusmana and Azizah 2021).

The species dominance index was classified as medium and high at the seedling vegetation level (0,52-0,92). The sapling vegetation level showed a high species dominance value (0,82-0,98). Moderate and high dominance values at the seedling and sapling vegetation levels occur because the diversity value at these levels is low due to the dominance of *Rhizophora mucronata* species at the beginning of growth. The tree vegetation level is low (0,23-0,39) due to the natural development of other mangrove species.

c. Biomass, Carbon Content, and CO_2 Sequestration

Biomass is the total amount of living matter of a tree above and below the surface with units in the form of dry weight tons per unit area (Brown 1997). The biomass, carbon content, and CO_2 sequestration values of each mangrove species are presented in Table 6.

Table 6: Biomass, Carbon Content, and CO_2 Sequestration Values of Each Mangrove Species

Mangrove Classification		Species	Biomass (ton ha^{-1})	Carbon Content (ton ha^{-1})	CO_2 Sequestration (ton ha^{-1})
True Mangrove	Major	*Rhizophora mucronata*	70,80	33,28	122,13
		Sonneratia caseolaris	82,80	38,92	142,83
		Avicennia marina	61,68	28,99	106,39
		Rhizophora apiculata	8,14	3,83	14,04
		Nypa fruticans	0,05	0,02	0,08
	Minor	*Excoecaria agallocha*	16,48	7,74	28,42
Mangrove Association		*Terminalia catappa*	7,84	3,68	13,51
		Morinda citrifolia	0,13	0,06	0,22
		Calophyllum inophyllum	0,02	0,01	0,04
		Cerbera manghas	5,25	2,47	9,05
Total			253,18	119,00	436,71

The total biomass at the study site was about 253,18 tons ha^{-1}. The mangrove species with the highest biomass value is *Sonneratia caseolaris* species at 82,80 tons ha^{-1} and higher than *Rhizophora mucronata* biomass at 70,80 tons ha^{-1}. According to Rachmawati *et al*. (2014), the value of mangrove biomass content is influenced by species density and diameter of mangrove

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stands. *Rhizophora mucronata* has a smaller stem diameter (2,2-29,9 cm) than *Sonneratia caseolaris* (3,8-43 cm).

The higher the biomass value in a stand, the higher the carbon storage (Suryono *et al*. 2018). *Sonneratia caseolaris* species has the highest carbon storage value, 38,92 tons ha^{-1}. In comparison, the lowest carbon storage is *Calophyllum inophyllum* species at 0,01 tons ha^{-1} because the number of individual stands found is only a few with sapling vegetation level, so the stem diameter is also not too large.

Sonneratia caseolaris is the mangrove species with the highest CO_2 uptake, at 142,83 tons ha^{-1}, while *Calophyllum inophyllum* is the mangrove species with the lowest CO_2 uptake, at 0,04 tons ha^{-1}. The greater the CO_2 uptake by vegetation, the greater the biomass stored in it. A comparison of biomass, carbon storage, and CO_2 uptake values at each canopy density level in the study site is presented in Figure 4.

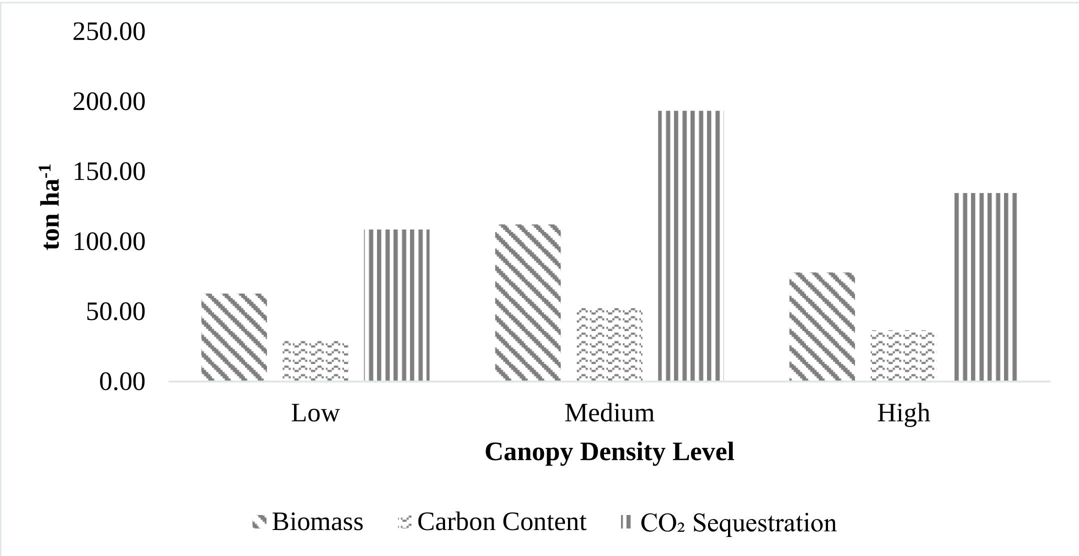

Figure 4: Biomass, Carbon Content, Dan CO_2 Sequestration of Mangrove Vegetation at each Canopy Density Level

The comparison diagram shows that observation plots with medium canopy density have higher biomass, carbon content, and CO_2 uptake values than those with other canopy density levels. According to Rachmawati *et al*. (2014), the density and diameter of mangrove species can affect the biomass content of a mangrove stand. The value of species density at each level of canopy density at the research site amounted to 2.930 ind ha^{-1} (low canopy density level), 2.313,24 ind ha^{-1} (medium canopy density level), and 2.616,07 ind ha^{-1} (high canopy density level). The average value of stem diameter at each canopy density level at the research site was 8,99 cm (low canopy density level), 12,06 cm (medium canopy density level), and 9,90 cm (high canopy density level). Areas with medium canopy density levels have the highest average stand diameter values because they tend to be dominated by the *Sonneratia caseolaris* species at the tree vegetation level. According to Surahmat *et al*. (2023), *Sonneratia caseolaris* has a

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larger tree diameter than other mangrove species. These results also show that observation plots with high canopy density levels do not necessarily have higher biomass, carbon content, and carbon dioxide sequestration values than those with medium or low canopy density levels.

Enviromental Factors

Optimal environmental factors can help improve plant growth and development. The results of the ecological factor parameters measured at the research site are presented in Table 7.

Table 7: Environmental Factor Parameter Data

Canopy Density Level	Parameter					
	Air temperature (°C)	Air humidity (%)	pH	Soil temperature (°C)	Salinity (ppt)	Substrate type
Low	32,76	54,77	6,50	27,50	0	Silt
Medium	32,65	55,76	6,21	26,76	0	Silt
High	32,41	56,83	5,61	27,00	0	Silt

Air temperature in the PIK Mangrove Ecotourism Area ranged from 32, 41-32,76 °C, and air humidity ranged from 54,77-56,83%. According to Lahabu *et al*. (2015), a natural mangrove forest has an ambient temperature ranging from 21-30 °C, and a suitable temperature for mangrove growth is not less than 20 °C. This statement shows that the air temperature at the research site is still considered ideal for mangrove growth.

The pH value or degree of acidity ranges from 5, 61-6, 50. Bachtiar *et al*. (2023) stated that soil pH ranging from 6, 0-7, 0 is the optimal pH for mangrove growth, while the optimal pH for mangrove growth *Rhizophora* sp. ranges from 4, 6-6, 5. Soil temperature at the research site ranged from 26, 76-27, 50 °C. Chrisyariati *et al*. (2014) stated that the range of suitable soil temperature for the growth of *Rhizophora* sp. and *Excoecaria* sp. ranged from 26-28 °C, while *Avicennia* sp. ranged from 18-20 °C.

The water salinity measurements showed a salinity value of 0 ppt in all observation plots. The optimum salinity mangroves need to grow well ranges from 10-30 ppt (Lahabu *et al*. 2015). Data collection was carried out during the dry season, which caused the mangrove area in the study site to dry out, and the manager wet the mangrove area with lake water, which is classified as fresh water. Mangrove species can still live in 0 ppt water salinity conditions because the types of mangroves that grow in the study site are adaptable to low salinity conditions.

The research site's observations of soil substrate types showed that the *Rhizophora mucronata* species grew on thick silt substrate types and not much sand. *Rhizophora* sp. mangrove plants can grow well in deep silt. *Rhizophora* sp. can grow better on silt substrates rich in organic matter, while other mangrove species, such as *Avicennia* sp. and *Sonneratia* sp., will grow well on sandy silt substrates (Tefarani *et al*. 2019). The suitability of other environmental factor parameters, such as soil chemical properties, can also affect the growth of mangrove stands. Soil chemical properties, namely soil NPK content and soil C-organic content, were analyzed in this study. The results of the analysis of soil chemical properties at the research site are presented in Table 8.

The Seybold Report
ISSN 1533-9211
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Table 8: Results of soil chemical analysis at IPB University Soil Laboratory

Canopy Density Level	Parameter			
	N-total (Kjeldahl) (%)	P (Bray I) (ppm)	K (Flame photometer) (ppm)	C-organik (Walkley & Black) (%)
Low	0,28	15,40	502	3,80
Medium	0,24	16,70	609	3,17
High	0,33	11,60	834	4,84

The content of soil N and P elements at the research site is classified in the medium category, so it is good for the growth of mangroves in the location. The element Nitrogen (N) functions in improving the vegetative growth of plants (Nursin *et al*. 2014), while the element Phosphorus (P) is helpful for the formation of flowers, fruits, seeds, root development, and to strengthen the stem so as not to collapse (Asnindar *et al*. 2019). The K element content is classified in the high to very high category. The K element strengthens cell walls and increases resistance to certain diseases. However, excess K can also poison plants and inhibit growth because it binds the N-K element, which makes nitrogen absorption difficult and causes plants to lack Mg and Ca nutrients (Wirayuda *et al*., 2023).

The C-organic content is classified as a high category, and the water condition is classified as healthy due to the abundance of organic matter that will be decomposed as a food source for soil microorganisms (Nursin *et al*. 2014). The high C-organic content is due to the type of soil substrate at the research site, which is quite thick in mud. According to Barus *et al*. (2020), soil substrates with finer sizes absorb organic carbon more easily than substrates with larger/rougher sizes.

The measurement of environmental factors in the PIK Mangrove Ecotourism Area shows that the area can support mangrove growth optimally. This can occur because the values of ecological factor parameters, such as air temperature, air humidity, pH, soil temperature, and substrate type, are by the criteria for environmental factors for mangrove stand growth. In addition, the chemical properties of the soil at the research site, such as nitrogen (N) and phosphorus (P) content, are classified as moderate. In contrast, soil C-organic content is classified as high, ideal for mangrove growth. The dry condition of the study site caused a salinity value of 0 ppt (freshwater) and a very high Potassium (K) content. However, it did not show any adverse effect on mangrove growth due to other environmental factors that are still suitable for mangrove growth and adaptability in the face of drought.

CONCLUSION

Mangrove Ecotourism Area Pantai Indah Kapuk (PIK), DKI Jakarta, managed by the Department of Parks and Urban Forests of DKI Jakarta Province, has an area of about 4 ha. *Rhizophora mucronata* dominates for seedling and sapling vegetation levels at all levels of canopy density with a range of IVI between 122,56-180,51% (seedlings) and 224,20-283,29% (saplings). *Sonneratia caseolaris* species dominated the tree vegetation level in areas with low and medium canopy density levels, with IVI reaching 93,20% (low canopy density level) and 79,23% (medium canopy density level). The estimated biomass stored in mangrove stands in

The Seybold REPORT
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the PIK Mangrove Ecotourism Area is 253,18 tons ha^{-1} and has a carbon storage value of 119 tons ha^{-1} and CO_2 absorption of 436,71 tons ha^{-1}. Environmental factors suitable for mangrove growth in the PIK Mangrove Ecotourism Area cause mangroves to grow optimally so that carbon storage and carbon dioxide absorption by mangrove stands are high.

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