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RESEARCH REPORT

FISHPOND PRE-FEASIBILITY STUDY TOWARDS MAINTAINING CARBON STORAGE ON MANGROVE AREA:

A CASE STUDY IN COASTAL AREA OF SUKAMARA DISTRICT, CENTRAL KALIMANTAN, INDONESIA

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1. INTRODUCTION AND SCOPE OF THE PRE-FEASIBILITY STUDY

Mangrove ecosystems are faced with complex challenges encompassing social, ecological, and economic aspects. The National Mangrove Map, released by the Ministry of Environment and Forestry in 2021, shows that the total area of Indonesia's mangrove ecosystem reaches 3,364,076 Ha or 20.37% of the world's total mangrove area. However, vast expanses of these mangrove ecosystems have been converted to other uses or degraded.

Mangroves provide various ecosystem services, including coastal protection, fishery nursery habitats, and carbon sequestration. The potential of mangroves to store carbon is five times greater than that of tropical rainforests (Alongi, 2012). Mangroves are one of the most productive plants, with an average net primary production of 11.1 MgC/ha/year (Alongi, 2014). Alongi (2014) added that ecosystem-scale carbon stocks average 956 tC/ha, or the equivalent of a humid tropical evergreen forest. Murdiyarso et al. (2015) explained that the highest carbon stores in the mangrove ecosystem are found in the mangrove sediment. Mangrove sediment has the ability to store carbon that is higher than carbon storage in mangrove trees themselves (Murray et al., 2011).

The high service value and productivity of the mangrove ecosystem make it vulnerable to land conversion, especially for fishponds (aquaculture) (Pendleeton et al., 2012). Indonesia has lost mangrove forests of about 600,000 ha for shrimp farms (Ilman et al., 2016). This causes and influences carbon stocks and absorption (Rudianto et al., 2020).

Moreover, fish farms have to dismantle the soil in the mangrove ecosystem, even though most of the carbon stores are in the sediment (Alongi, 2014; Sidik, 2019). Carbon dioxide emissions from mangrove conversion or degradation are a contributor to global greenhouse gas (GHG) emissions because soil disturbance causes increased microbial activity when sediment C is unstable and exposed to oxygen (Lovelock et al., 2017; Pendleton et al., 2012). Thus, the strategy that needs to be implemented to mitigate climate change is to prevent mangrove loss and restore mangroves (Duarte et al., 2013; Pendleton et al., 2012).

Efforts to restore mangroves, especially for abandoned ponds, have had a large positive impact. Sidik et al. (2019) concluded that after ten years, restored mangroves began to achieve similar ecosystem functions and services compared to natural stands. However, restored mangrove forests have lower soil respiration than natural forests, but both restored mangrove forests and natural mangrove forests have similar NPP and soil C compositions – the differences are found in the sediment from fish farming ponds (Sidik et al. 2019). Therefore, carbon assessments in mangrove ecosystems and abandoned ponds need to be calculated to obtain the total value of an area. Apart from that, it is hoped that this study will be able to determine carbon storage in fishponds to determine the impact of existing utilization.

2. STATED DELIVERABLES

Deliverables from this study include:

1. Mangrove vegetation condition, including Important Value Index (IVI), dominance index, species richness index, species diversity index, and evenness index.
2. Carbon stock value on the mangrove ecosystem, including above-ground stock and sequestration, below-ground stock and sequestration, and soil.
3. Carbon stock on the pond, which measures the carbon stock in the soil.

3. APPROACH TO COMPLETE STATED DELIVERABLES (METHOD)

3.1. ENVIRONMENTAL CONDITION

Environmental conditions in this study were assessed by measuring the water quality at the study location. Water sampling was conducted to determine environmental quality at 13 plot points with details of 7 pond plots and 6 mangrove plots. The data taken were water salinity, potential Hydrogen (pH), dissolved oxygen (DO), and temperature.

The measured water samples were puddles of water located closest to the plot collection point (plot coordinate point). The tools used include a refractometer for measuring water salinity, a pH meter to measure the acidity level of water, and a DO meter to confirm dissolved oxygen levels in water. Water sampling activities were carried out from morning to evening (07.49 to 15.40).

3.2. MANGROVE CONDITION

The vegetation data collection locations were selected randomly to ensure regional representativeness and cover diversity. A drone analysis assessed the area's condition before the field survey. The drone imagery provided crucial information about land-use cover type, presence, location, extent, and vegetation density levels (Annex 1). Based on the insights gained from the drone photo analysis, specific vegetation sampling sites were designated.

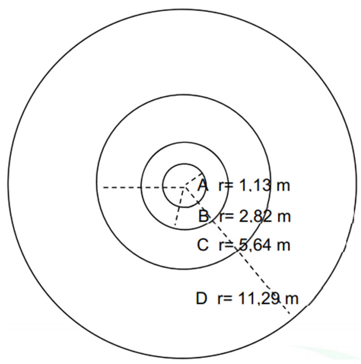
The vegetation data collection followed the methodology outlined by Soerianegara and Indrawan (2002), a recognized approach for assessing forest vegetation conditions. This method is designed to identify the composition, density, and diversity levels of forest vegetation, providing valuable insights into the overall ecosystem condition and stability.

In the field, data collection utilized a Global Positioning System (GPS) for accurate plot location marking, a camera for documentation, standard stationery supplies, plot marking rope, phi band or sewing tape for diameter measurements, and a flora data tally sheet. The process commenced with creating circular plots using raffia rope, which was subsequently subdivided for precise measurements at different growth stages. This included a circle radius of 1.13 meters for assessing seedlings, litter, and undergrowth, 2.82 meters for saplings, 5.64 meters for the pole level, and 11.29 meters for the tree level (refer to Figure 1).

For each growth stage—seedlings, saplings, poles, and trees—recordings were made of type, height, and diameter, following specific criteria established for each growth level:

- **Seedling:** Young tree with a diameter of less than 2 cm.
- **Sapling:** Young tree (wooden tree) with a diameter of 2 cm – less than 10 cm.
- **Pole:** Tree with a diameter of 10 cm – less than 20 cm.
- **Tree:** Tree with a diameter of ≥ 20 cm.

Figure 01. Example of a Circle Plot Shape



As, A is a subplot for seedlings, litter, and understorey, B is a subplot for saplings, C is a subplot for poles, and D is a subplot for trees.

3.3. MANGROVE AND FISH PONDS CARBON STOCK

The calculation of carbon reserves relied on assessing the biomass and organic material content across five carbon pools: above-ground biomass, below-ground biomass, dead wood, litter, and soil. This determination was conducted through a non-destructive method employing the allometric equation formula for accurate estimation. The data collection process was facilitated with the use of GPS, a tree diameter measuring tool (phi band), soil sampling equipment (soil drill, cool box, cap, plastic sampler, and rag), work maps, pruning shears, and writing implements.

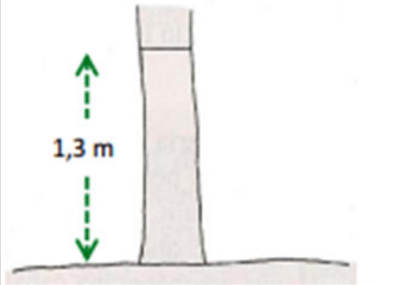
The sampling technique adopted was either stratified systematic sampling or simple random sampling, with a maximum acceptable sampling error of 20%. The minimum number of plots required is calculated by taking into consideration factors such as area size, average biomass, standard deviation of biomass, and plot dimensions. The sample plot shape utilized in this research conforms to the circular design (Figure 1), adapting to the specific field conditions.

Above-ground and below-ground biomass

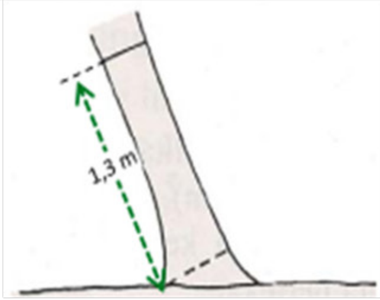
Biomass of vegetation

The process of measuring sapling, pole, and tree vegetation follows standard vegetation analysis procedures. This involves identifying the specific type of sapling, pole, or tree vegetation, measuring the diameter at breast height, and meticulously recording these values on a tally sheet. The measurement of the diameter at breast height for various levels of stakes, poles, and trees (excluding seedlings) in the field is detailed in Figure 2.

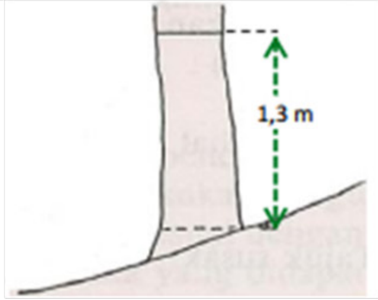
Figure 02. Measuring Diameter at Breast Height in Various Tree Conditions



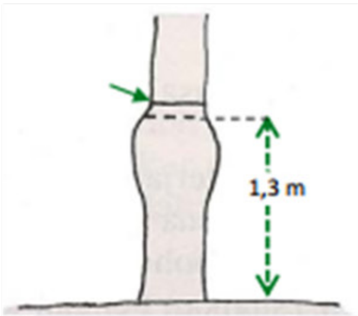
a. Normal tree: DBH is measured 1.3 meters from the ground.



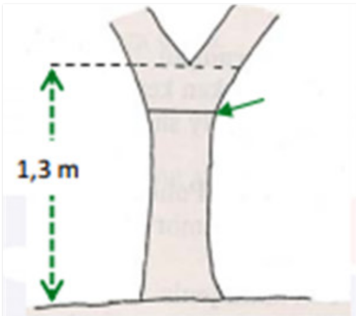
b. Slanted tree: DBH is measured 1.3 meters from the nearest ground level, or in the direction the tree is tilted.



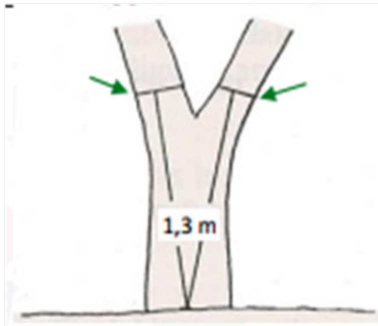
c. Normal tree: on sloping ground: DBH is measured 1.3 meters from the highest ground level.



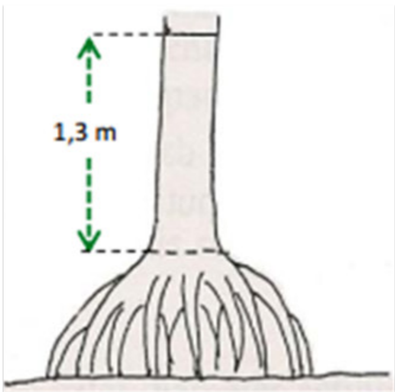
d. Deformed tree: If 1.3 meters is directly on the deformed (bloated) trunk, DBH is measured at the top of the normal starting part, at the top or bottom depending on which is closest.



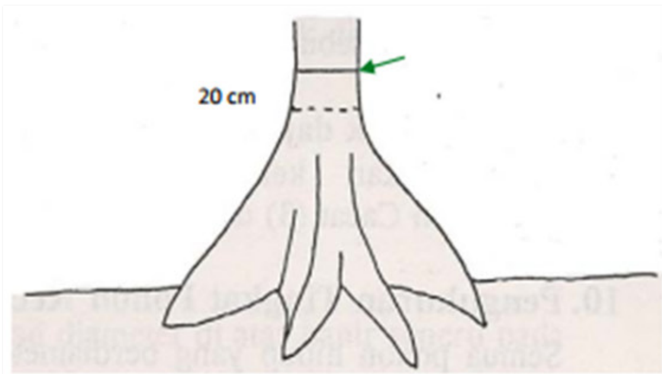
e. Branch tree: If 1.3 meters is accurately at the beginning of the branch, DBH is measured at the bottom of the branch, which is still normal.



f. Branch tree: If 1.3 meters is above the branch, measure the DBH on both branches and consider 2 trunks.



g. Trees with stilt-roots: DBH is measured 1.3 meters from the top of the supporting roots.



h. Trees with buttresses: DBH is measured 20 cm from the buttress limit.

(Source: SNI 7724, 2019)

Biomass of seedlings and understorey

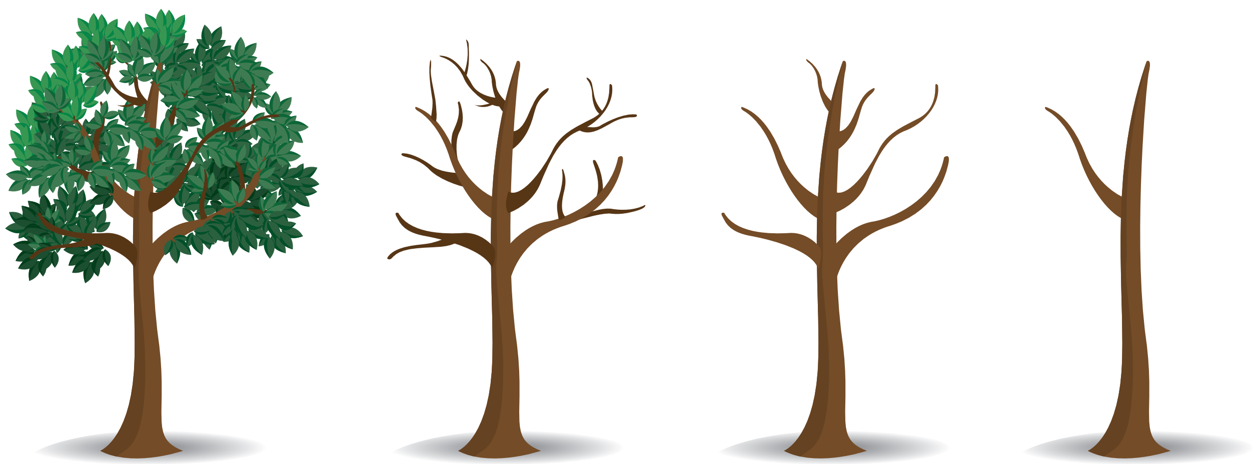
Carbon measurements in seedlings and understorey were conducted by measuring the wet weight of both seedlings and undergrowth. The total wet weight was then recorded, and samples weighing approximately ± 300 grams were selected for further analysis in the laboratory.

Necromass

Necromass are dead components of plants that come from litter, leaves, twigs, branches, roots, and the main trunk or dead tree. If a dead tree is found in the field, measurements are made of diameter at breast height, height of dead trees, and integrity of dead trees, then calculated by the allometric volume equation. The shape of the integrity of a dead tree can be seen in Figure 3.

Meanwhile, measurements of the diameter of the base and tip and the total length of deadwood are made for the measurement of dead wood that has collapsed. Furthermore, the volume of dead wood can be calculated with the Brereton formula. Small deadwood measurements were made by collecting all the dead wood on the measurement plot, weighing the total wet weight of all dead wood, and taking wet weight samples of ± 300 grams. The wet-weight sample was taken to the laboratory to be dried until it reached a constant weight, and the dry weight of the sample was weighed.

Figure 03.The Degree of Integrity of The Dead Tree



A. The Tree dies without leaves

B. Tree dies without leaves and Branches

C. The Tree dies without leaves, branches, and twigs

Criteria, A is the integrity level with an applied correction factor of 0.9; B is the integrity level with an applied correction factor of 0.8, and C is the integrity level with an applied correction factor of 0.7 (Source: SNI 7724, 2019).

Biomass of seedlings and understorey

Litter quantification entailed the collection of litter within designated plots, followed by the measurement of total wet weight and extraction of a representative sample weighing approximately 300 grams.

This procedure was conducted prior to the assessment of understory biomass. Notably, litter measurements were omitted in mangrove forest areas due to the influence of tidal factors, which resulted in an inaccurate representation of litter originating solely from the mangrove stands in that location.

Subsequently, the wet-weight samples were transported to the laboratory for thorough drying until a consistent weight was achieved, at which point the dry weight of the samples was recorded.

Soil Carbon

Soil carbon pools were collected at the 15 plots at each site (mangroves and fish/shrimp ponds). We measured the soil depth using an open-face peat auger of a 5 cm radius around the plot center. The soil C stocks were measured by collecting soil samples at the following depths: 0-15 cm, 15 131- 30cm, 30-50 cm, 50-100 cm and 100-200 cm, 200-300 cm, and 300-400 cm (Kauffman and Donato, 2012). A 5 cm sub-sample was collected at each depth interval for laboratory analysis of bulk density and carbon concentration.

Of all the samples collected, only samples from 3 plots from each land classification (dense mangroves, medium mangroves, low-density mangroves, and ponds) were analyzed, considering time and cost limitations.

3.4. DATA ANALYSIS

Environmental Condition

Environmental conditions are analyzed based on four water parameters: salinity, pH, dissolved oxygen levels, and water temperature. The results of water sample measurements are compared with the seawater quality standard values by Appendix VIII of the Republic of Indonesia Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management (Table 1).

Descriptive statistics tests are carried out by testing 16 measurement plots, as samples and aim to provide a statistical description or description of data that is seen starting from the minimum value, maximum value, average value (mean), and standard deviation of each variable.

Table 01. Sea Water Quality Standards for Marine Biota in Indonesia: Mangrove Habitat

Parameter	Units	Port	Marine Tourism	Marine Biota
Salinity	%	Natural	Natural	s/d 34
pH	-	6.5 – 8.5	7 – 8.5	7 – 8,5
Dissolved Oxygen	mg/L	-	>5	>5
Temperature	°C	Natural	Natural	28-32

Source: Attachment VIII to Republic of Indonesia Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management.

Mangrove Condition

Mangrove conditions in the study were analyzed using the vegetation analysis method. Plant species were initially identified using local names provided by local people. Subsequently, these identifications were confirmed by cross-referencing photographs or herbarium samples of leaves, stems, fruit, and flowers of the tree species encountered in the field with reference books on mangrove species introductions in Indonesia.

Important Value Index (IVI)

The Important Value Index (IVI) was used to determine species composition and the dominance of a species in a forest stand or vegetation. The IVI value is calculated by adding up the population's relative density (RA), relative frequency (RF), and relative dominance (RD) values (Soerianegara and Indrawan, 2002).

$$IVI = RA + RF + RD$$

Population density, dominance, relative density, relative dominance, and species importance values were calculated using the formula:

$$Density = \frac{Number\ of\ Individuals}{Total\ Area\ Sampled}$$

$$Relative\ Density\ (RA - \%) = \frac{Density\ of\ the\ Species}{Total\ Density\ of\ All\ Species}\ X\ 100$$

$$Frequency = \frac{The\ Frequency\ of\ Occurrence\ of\ a\ Species\ in\ the\ Plots}{The\ Frequency\ of\ Occurrence\ of\ a\ Species\ in\ All\ Plots}$$

$$Relative\ Frequency\ (RF - \%) = \frac{The\ Frequency\ of\ the\ Species}{The\ Frequency\ of\ All\ Species}\ X\ 100$$

$$Dominance\ (m^2 / ha) = \frac{Total\ of\ the\ Basal\ Area\ of\ Each\ Tree\ of\ a\ Species\ from\ All\ Plot}{Total\ Area\ of\ All\ the\ Measured\ Plots}$$

$$Relative\ Dominance\ (RD - \%) = \frac{Dominance\ of\ the\ Species}{Total\ Dominance\ of\ All\ Species}\ X\ 100$$

Dominance Index (D)

As described by Odum (1993), the dominance index is employed to assess the prevalence of species within a community, pinpointing areas of concentrated dominance. This index is calculated using the following formula:

$$D = \sum \left(\frac{n_i}{N}\right)^2$$

where, D is the dominance index, ni is the number of individuals per species, and N is the total number of individuals per study plot.

Species Richness Index Margalef (R)
To quantify species richness, the Margalef index is employed (Ludwigs and Reynold, 1988):

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

where, R is the species richness index Margalef, S is the number of species, and N is the total number of individuals. According to Magurran (1988), an R value below 3.5 indicates low species richness, while a value between 3.5 and 5.0 indicates medium species richness. An R value exceeding 5.0 indicates high species richness.

Species Diversity Index (H')
The Shannon–Wiener diversity index (H') is a widely utilized metric in community ecology for assessing species diversity. It provides valuable insights into species diversity within a given ecosystem (Ludwig and Reynold, 1988). The diversity index is calculated as follows:

$$H' = \sum_{i=1}^{s} \square \left[\left(\frac{n_i}{N}\right)\right] In\ In \left(\frac{n_i}{N}\right)$$

where, H' is Shannon-Wiener species diversity, s is the number of species, ni is the density of species-I, and N is total density.

In the analysis of the species diversity index, three criteria are applied. A value of H' < 2 categorizes it as low, while a value between 2 < H' < 3 places it in the medium category. If H' > 3, it is considered to be in the high category (Magurran, 2004).

Evenness Index (J')
The evenness index calculation uses the following equation:

$$J' = \frac{H'}{In\ (s)}$$

where, J' is the evenness index, H' is the species diversity index, and s is the number of species.

According to Magurran (2004), a J' value less than 0.3 suggests a low level of species evenness, while a value between 0.3 and 0.6 indicates moderate evenness, and a value greater than 0.6 signifies a high level of species evenness.

Carbon Stock Analysis

Measuring and calculating standing carbon adheres to the guidelines provided in the Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019), SNI 7724 (2019), Coastal Blue Carbon Method (2014), and Working Paper 86 (Kauffman and Donato, 2012).

The analysis of standing carbon stocks was computed for each stand or forest type, encompassing peat forest, lowland forest (comprising both natural and plantation forests), and mangroves within the study area. This analysis employs allometric equations to estimate biomass content both above and below the soil surface, encompassing aboveground biomass and belowground biomass.

Several allometric equations for mangrove types that can be used include the allometric equations of Dharmawan (2010), Komiyama et al. (2005), and Kusmana et al. (2018) and using wood density references from Komiyama et al. (2005). The allometric formula equation used in the study is presented in Table 2 and Table 3. Determining wood-specific gravity is conducted by referencing the ICRAF wood density database (Table 4). Each carbon pool in the mangrove study area was calculated by following the methods outlined in SNI 7729 (2019). The ecosystem carbon stocks were estimated by summing all carbon pools (IPCC, 2006; Eq. B.1).

Table 02. Allometric Equations for Estimating Above-Ground Biomass in Mangrove Area

Species	Allometric Equation	Source
Avicennia alba	$B = 0{,}251\ \rho\ (D)^{2{,}46}$	Komiyama et al. 2005
Sonneratia caseolaris	$AGB = 0.258\ (D)^{2.288}$	Kusmana et al. 2018

Note: B = biomass; ρ= wood density; D = Diameter at breast height (dbh); AGB = above-ground biomass.

Table 03. Allometric Equations for Estimating Below-Ground Biomass in Mangrove Area

Species	Allometric Equation	Source
Avicennia alba	$BGB = 0.199\ (\rho)^{0.899}(D)\ 2.22$	Komiyama et al. (2005)
Sonneratia caseolaris	$BGB = 0.230\,\rho\,(D^2H)^{0.740}$	Kusmana et al. (2018)

Note: BGB = above-ground biomass; ρ= wood density; D = Diameter at breast height (dbh); H = tree height.

Table 04. The Density of Mangrove Species

Species	Allometric Equation	Source
Avicennia alba	0.51	Komiyama 2005

4. TIMELINE OF ACTIVITIES

This study started with the development of research TOR and thereafter EcoNusa and PKSPL IPB finalized the TOR in August 2023. Using the Geographic Information System (GIS), in September 2023, the team classified spatial data in the research location and digitized land cover data covering an area of 27 ha resulting from aerial photography. The spatial data analysis also classified low-density mangroves, medium-density mangroves, dense mangroves, and ponds. As a result of the spatial data, the research team determined 30 sampling points covering an area of 13.34 hectares, respectively 15 sampling points in the pond area and in the mangrove area.

From 5 to 11 October, the research team collected samples in three carbon pools: above-ground biomass, below-ground biomass, and soil organic carbon. After this, post-fieldwork sample handling and preparation were conducted on 13 October, coordination and team meetings on 14-16 October, and continued sample delivery and analysis initiation on 18-23 October. Data processing, analysis, and report writing occurred from 13 October to the 3rd week of November.

5. RESULTS AND DISCUSSION

5.1. ENVIRONMENTAL CONDITION

In general, the water quality conditions at the study location are still in good condition and within the quality standard criteria; only a few stations do not meet the quality standards (Table 5 and Annex 2). For the salinity variable, the lowest value was 18, and the highest value was 38, with the average salinity of the 16 data at 29.44. The standard deviation value of salinity is 5.01, which is lower than the average value. The pH variable shows the smallest value of 6.52 and the largest value of 8.52, with an average of 7.54. The standard deviation value is 0.67, which is lower than the average. The dissolved oxygen variable has the smallest value of 3.5 and the highest value of 7.2, with an average of 5.44. The standard deviation value is 1.29, which is lower than the average value. The temperature variable has the smallest value of 28 and the highest value of 34.3, averaging 31.1. The standard deviation value is 2.25, which is lower than the average value.

Table 05. Water Quality in Study Location

Variable	Min	Max	Mean	Standard Deviation	Water Quality Standard of Sea Water
Salinity	18	38	29.44	5.01	± 34.00
pH	6.52	8.52	7.54	0.67	7.00 – 8.50
Dissolved oxygen	3.5	7.4	5.44	1.29	>5.00
Temperature	28	34.3	31.12	2.25	28.00-32.00

Compared to the standard seawater quality data outlined in Attachment VIII to the Republic of Indonesia Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management, certain plots in the study location do not meet the specified quality standards.

However, on the whole, the water quality at the study location meets the standards set for seawater. Salinity, pH, dissolved oxygen content, and temperature, on average, fall within the acceptable limits defined by the seawater quality standards, with values not exceeding the specified thresholds. This overall compliance indicates that the environmental conditions are relatively conducive to the life of mangroves. Nevertheless, it is recommended to address waterlogging for effective rehabilitation by adding water to optimize conditions.

5.2. MANGROVE CONDITION

There are several types of mangrove ecosystems in the Sungai Pasir found at the research location, consisting of four species of mangrove, api-api (*Avicennia alba*), nipah (*Nypa fruticans*), bakau (*Rhizophora mucronata*), and rambai (*Sonneratia caseolaris*).

There is an Important Value Index (IVI) used to determine a species' dominance or mastery. In addition, the vegetation data that has been obtained through measurements is then processed to obtain the Plant Species Diversity Index (H'), Plant Species Dominance Index (D), Plant Species Richness Index (R), and Species Evenness Index (J').

A comprehensive description of the dominant species found at the research location, encompassing the understory plant community and growth levels (seedlings, saplings, poles, and trees) across three types of land cover—dense mangroves, medium mangroves, and low-density mangroves—is presented in the following sub-chapter.

• MANGROVE COMPOSITION

The data collection results on different growth levels in dense mangrove land cover can be seen in Table 6. A species with high abundance is *A. alba* which is found at all growth stages from seedlings, saplings, poles, and trees. The IVI of *A. alba* for saplings is 200%, and the IVI for poles and trees is 300%. The most dominant species at the seedling level is *A. alba*, with an IVI value of 178.25%, which is higher than other species, *R. mucronata* and *A. speciosum*.

Similarly, *A. alba* continues to exhibit dominance within medium-density mangroves, particularly in sapling and pole, with 200% and 300% IVI values. The trend continues in seedlings, where *A. alba* dominates with an IVI value of 165.00%, surpassing the *N. fruticans* species. However, tree growth rates were not identified within medium-density mangrove cover.

In low-density mangroves, *A. alba* dominates across all growth levels, including seedling and sapling, while pole and tree are not observed. This is evident in the IVI value for *A. alba*, which is 162.82% for seedlings and 28.33% at the sapling level, surpassing the *S. caseolaris*.

- **OVERALL MANGROVE COMPOSITION**

This study also presents species dominance data by aggregating all types of high-density, medium-density, and low-density mangrove land cover. The objective is to assess the overall condition of the mangrove ecosystem (Annex 3).

The IVI values indicate that *A. alba* emerges as the most dominant species at each growth level. The Pole and tree level of *A. alba* marked an IVI of 300%, while the sapling category exhibits an IVI of 192.72%, highlighting its exceptional adaptability compared to *S. caseolaris* in the study location. Similarly, *A. alba* seedling showed an IVI of 175.55%, higher than other species such as *A. speciosum*, *N. fruticans*, *Rhizophora mucronata*, and *S. caseolaris* (see Table 6).

Table 06. Species Composition Values at The Seedlings Level in Dense Mangrove Land Cover

Mangrove classification	Growth level	Species	Family	Index	Index value
High-density mangrove	Tree	*Avicennia alba*	*Avicenniaceae*	RA (%)	100.00
				RF (%)	100.00
				RD (%)	100.00
				IVI	300.00
	Pole	*Avicennia alba*	*Avicenniaceae*	RA (%)	100.00
				RF (%)	100.00
				RD (%)	100.00
				IVI	300.00
	Sapling	*Avicennia alba*	*Avicenniaceae*	RA (%)	100.00
				RF (%)	100.00
				IVI	200.00
	Seedling	*Avicennia alba*	*Avicenniaceae*	RA (%)	98.25
				RF (%)	80.00
				IVI	178.25

Mangrove classification	Growth level	Species	Family	Index	Index value
High-density Mangrove	Seedling	*Rhizophora mucronata*	*Rhizophoraceae*	RA (%)	0.87
				RF (%)	10.00
				IVI	10.87
		Acrostichum speciosum	*Acanthaceae*	RA (%)	0.87
				RF (%)	10.00
				IVI	10.87
Medium-density Mangrove	Pole	*Avicennia alba*	*Avicenniaceae*	RA (%)	100.00
				RF (%)	100.00
				RD (%)	100.00
				IVI	300.00
	Sapling	*Avicennia alba*	*Avicenniaceae*	RA (%)	100.00
				RF (%)	100.00
				IVI	200.00
	Seedling	*Avicennia alba*	*Avicenniaceae*	RA (%)	90.00
				RF (%)	75.00
				IVI	165.00
		Nypa fruticans	*Arecaceae*	RA (%)	10.00
				RF (%)	25.00
				IVI	35.00
Low-density mangrove	Sapling	*Avicennia alba*	*Avicenniaceae*	RA (%)	96.15
				RF (%)	66.67
				IVI	162.82

Mangrove classification	Growth level	Species	Family	Index	Index value
Low-density mangrove	Sapling	*Sonneratia caseolaris*	*Sonneratiaceae*	RA (%)	3.85
				RF (%)	33.33
				IVI	37.18
	Seedling	*Avicennia alba*	*Avicenniaceae*	RA (%)	96.67
				RF (%)	75.00
				IVI	171.67
		Sonneratia caseolaris	*Sonneratiaceae*	RA (%)	3.33
				RF (%)	25.00
				IVI	28.33
	Tree		*Avicenniaceae*	RA (%)	100.00
Overall mangrove land cover		*Avicennia alba*		RF (%)	100.00
				RD (%)	100.00
				IVI	300.00
	Pole	*Avicennia alba*	*Avicenniaceae*	RA (%)	100.00
				RF (%)	100.00
				RD (%)	100.00
				IVI	300.00
	Sapling	*Avicennia alba*	*Avicenniaceae*	RA (%)	99.39
				RF (%)	93.33
				IVI	192.72

Mangrove classification	Growth level	Species	Family	Index	Index value
Overall mangrove land cover	Sapling	*Sonneratia caseolaris*	*Sonneratiaceae*	RA (%)	0.61
				RF (%)	6.67
				IVI	7.28
	Seedling	*Acrostichum speciosum*	*Acanthaceae*	RA (%)	0.74
				RF (%)	5.56
				IVI	6.30
		Avicennia alba	*Avicenniaceae*	RA (%)	97.77
				RF (%)	77.78
				IVI	175.55
		Nypa fruticans	*Arecaceae*	RA (%)	0.37
				RF (%)	5.56
				IVI	5.93
		Rhizophora mucronata	*Rhizophoraceae*	RA (%)	0.74
				RF (%)	5.56
				IVI	6.30
		Sonneratia caseolaris	*Sonneratiaceae*	RA (%)	0.37
				RF (%)	5.56
				IVI	5.93

Note: RA = Relative Density, RF = Relative Frequency, RD = Relative Dominance, IVI=Importance Value Index.

• MANGROVE DIVERSITY, RICHNESS, AND EVENNESS INDEX

The condition of mangrove vegetation in this study was also analyzed by calculating the value of the species diversity index (H'), dominance index (D), species evenness index (J'), and species richness index (R). Data on vegetation conditions for each type of mangrove land cover is shown in Table 7.

The values for diversity, evenness, and richness of all species showed low values (symbolized by c) for each type of land cover (low density, medium density, and dense mangroves) and at every growth level starting from seedlings, saplings, poles, and trees. Meanwhile, the dominance index (D) of each growth level of seedlings, saplings, poles, and trees shows a high value (a) with varying numbers ranging from 0.22 – 1.00, which means that the value indicates that there is a concentration of plant species in mangrove community that is not spread evenly.

The data showed that *A. alba* has the highest dominance index among other species, showcasing its exceptional adaptability compared to other types.

The species diversity index (H') at the seedling and understory level is calculated as 0.1365, placing it in the low category. Moreover, species richness (R) for seedlings and undergrowth is categorized as low, with an R-value of 0.715. The species evenness (J') figure stands at 0.0848, indicating a relatively low level.

• OVERALL MANGROVE DIVERSITY, RICHNESS, AND EVENNESS INDEX

The species diversity index (H'), richness (R), and evenness (J') at all growth levels fall into the low category, with a range from 0.00-0.14 for H', 0.00-0.72 for R, and 0.00-0.08 for J' (see Table 7). The dominance index of all growth stages ranges from 0.00 to 1.00, with *A. alba* recorded with the highest value among other species, indicating that this species dominates the ecosystem.

Table 07. Species Composition in Sungai Pasir Village Based on the Diversity, Richness, and Evenness Index

Mangrove classification	Index	Growth stage			
		Tree	Pole	Sapling	Seedling
Dense mangrove	H'	0.00[c]	0.00[c]	0.00[c]	0.1001[c]
	D	0.22[c]	1.00[a]	1.00[a]	0.9654[a]
	J'	0.00[c]	0.00[c]	0.00[c]	0.09[c]
	R	0.00[c]	0.00[c]	0.00[c]	0.368[c]
Medium-density mangrove	H'		0.00[c]	0.00[c]	0.33[c]
	D		1.00[a]	1.00[a]	0.82[a]
	J'		0.00[c]	0.00[c]	0.47[c]
	R		0.00[c]	0.00[c]	0.43[c]

Mangrove classification	Index	Growth stage			
		Tree	Pole	Sapling	Seedling
Low-density mangrove	H’			0.163[c]	0.1461[c]
	D			0.926[a]	0.9356[a]
	J’			0.24[c]	0.21[c]
	R			0.31[c]	0.294[c]
Overall mangrove land cover	H’	0.00[c]	0.00[c]	0.0372[c]	0.1365[c]
	D	1.00a	1.00[a]	0.9879[a]	0.9560[a]
	J’	0.00[c]	0.00[c]	0.0536[c]	0.0848[c]
	R	0.00[c]	0.00[c]	0.1961[c]	0.7150[c]

Note: a = high, b= moderate, c= low, H’ = species diversity index, D = dominance index, J’ = evenness index, R = species richness.

5.3. FISH POND CONDITION

The residents of Sungai Pasir became acquainted with pond cultivation in 1993 when ‘Javanese’ individuals, originally from Java Island, were introduced and settled in Sungai Pasir.

The ‘Javanese’ introduced ponds to the local community, prompting the residents to allocate a portion of their mangrove land for free to establish milkfish and shrimp ponds. Initially met with skepticism regarding the suitability of mangrove land for pond use, the community gradually recognized the promising prospects of pond business. Eventually, the local people embraced this venture, willingly converting their land into ponds.

Two types of ponds exist in Sungai Pasir: modern ponds and traditional ponds. The focus of this study is on traditional ponds constructed by the community. These ponds are situated along the beach in Sungai Pasir Village, established by clearing mangrove land located 150 meters from the coastline. The construction of one pond block involves a capital expenditure of approximately Rp. 60,000,000 covering the entire process, from clearing the pond location to making it operational. Pond operations have been ongoing year-round since 1993, and the pond is cleaned after each harvest by draining it and treating it with a solution, including poison from tuba roots, to prepare for seeding.

Each pond block ranges from 2 to 4 hectares with a central plains depth of 60 cm. An embankment surrounds each pond with a height of approximately 80 cm from the bottom of the pond. Additionally, a 1-2 meter wide ditch with a depth of 80 - 100 cm is constructed around the edges under the embankment. This design ensures water collection during extended dry seasons, especially at the pond edges where the depth is greater than the middle of the pond.

The cultivated commodities in these ponds are shrimp and milkfish. In traditional ponds, the majority of individuals cultivate milkfish, with only a small percentage engaged in tiger prawn cultivation due to its relative ease and higher yield. Vannamei shrimp, on the other hand, is predominantly cultivated in modern ponds referred to as vannamei shrimp ponds. A single milkfish harvest can yield up to 1 ton, with a selling price of Rp. 18,000 per kilogram. Meanwhile, a single tiger prawn harvest can reach 100 kg, with a selling price of Rp. 100,000 per kilogram. Both shrimp and milkfish are typically harvested twice a year, approximately every 4-5 months, and the produce is commonly sold to markets or middlemen.

Shrimp and milkfish seeds for cultivation are sourced from Java Island, with a purchase price of around Rp. 200 per individual. The number of seeds distributed in one pond varies from 6,000 to 10,000, depending on the pond's size. In addition to aquaculture, the community has implemented innovative practices by cultivating various vegetables such as chilies, pumpkins, corn, and watermelons along the pond embankments.

5.4. MANGROVE AND FISH PONDS CARBON STOCK

Mangrove Carbon Stocks

The growing awareness of forests as invaluable ecosystem services is closely tied to the increasing global concern over climate change, driven by escalating concentrations of greenhouse gasses in the atmosphere. Forests are crucial in providing oxygen and sequestering carbon dioxide, making them pivotal in mitigating greenhouse gas emissions. Carbon is stored in four main pools within a forest ecosystem: above-ground biomass, below-ground biomass, dead organic matter, and soil organic carbon. Notably, nearly 50% of forest vegetation biomass consists of carbon.

Mangrove forests emerge as particularly effective carbon stores, surpassing lowland tropical forests by three to five times (Kauffman and Donato, 2012). Moreover, they exhibit a heightened capacity for absorbing carbon elements from the atmosphere compared to other forest types (Imiliyana et al., 2012). Given their exceptional environmental service function, assessing the carbon storage potential of mangrove forests is imperative.

During the carbon calculation activities conducted in Sungai Pasir Village, four species of mangroves were identified: *A. alba*, *N. fruticans*, *R. mucronata,* and *S. caseolaris*, with *A. alba* being the dominant species. The calculations considered carbon stock across three carbon pools: above-ground biomass, below-ground biomass, and soil organic carbon. It is worth noting that in the mangrove ecosystem, litter and understorey were not factored into the calculations. Carbon storage assessments were performed for three land cover classifications: low-density mangroves, medium-density mangroves, and dense mangroves. The specific area coverage for each land cover type in the study location is detailed in Table 8.

Table 08. Mangrove Classification Area at The Study Location

Categories of land cover	Area (ha)
Low-density mangrove	1.49
Medium-density mangrove	0.34
Dense mangrove	2.41
Total	**4.24**

The carbon stock calculations for mangrove vegetation in Sungai Pasir Village, categorized into three mangrove cover types, reveal that this area boasts an average above-ground carbon stock stands at 18.18 ton C/ha, contributing to above-ground carbon sequestration of 66.72 tonCO2e/ha (Table 9). The results illustrate that the mangrove ecosystem at this location can store 18.18 ton C/ha within the trunk, branches, twigs, and leaves of the mangrove.

Among the various mangrove cover types, the highest carbon stock is identified in dense mangroves, registering at 27.98 tons of carbon per hectare. In contrast, low-density mangroves exhibit the lowest carbon stock, only 4.33 ton C/ha. The biomass in dense mangroves outpaces other densities due to a larger average diameter and a more significant number of individuals. It is worth noting that larger plant diameters correlate with increased biomass and, subsequently, greater carbon storage (Amira, 2008).

Table 09. Above-Ground Biomass Carbon Stock and Carbon Sequestration at Various Mangrove Densities

Categories of land cover	Above-ground carbon stock (ton C/ha)	Above-ground sequestration CO2 (ton CO2e/ha)
Low-density mangrove	4.41	16.19
Medium density mangrove	28.05	102.93
Dense mangrove	22.09	81.06
Average	18.18	66.72

Regarding below-ground mangrove vegetation carbon stocks, the average below-ground carbon stock is calculated to be 8.34 tons of carbon per hectare, contributing to a below-ground carbon of 30.61 tons of carbon dioxide equivalent per hectare (Table 10). The result indicates that within one hectare, the mangrove ecosystem at this location can store 8.34 tons of carbon per hectare in the roots of the mangroves. Much like above-ground biomass, the highest below-ground carbon stock is observed in dense mangroves, specifically at 12.52 tons of carbon per hectare. In contrast, mangroves with low density exhibit the lowest carbon stock.

Table 10. Below-Ground Biomass in Mangrove Area of Sungai Pasir Village

Categories of land cover	Above-ground carbon stock (ton C/ha)	Above-ground sequestration CO2 (ton CO2e/ha)
Low-density mangrove	2.40	8.82
Medium density mangrove	10.10	37.06
Dense mangrove	12.52	45.96
Average	8.34	30.61

The analysis of carbon stock in the mangrove ecosystem, based on its storage areas or carbon pools, serves the purpose of identifying the primary sources of carbon sequestration within each pool. This approach is crucial in minimizing carbon dioxide (CO_2) emissions into the atmosphere and safeguarding these vital carbon reservoirs.

Upon reviewing the calculated data for the two carbon pools, it is evident that the carbon storage above ground (AGB) generally surpasses that below ground (BGB). This phenomenon can be attributed to the substantial contribution of stems and branches to the above-ground biomass. The prevalence of these components leads to an overall higher above-ground biomass total.

In mature stands, root biomass typically constitutes around 15-17% of the above-ground biomass (Komiyama, 2008). However, in the case of Rhizophora species, it was observed that BGB exceeded AGB due to the supportive function of Rhizophora roots, resulting in a biomass almost equivalent to that of the branches.

The cumulative carbon storage value of AGB and BGB in the mangroves at this location averages 26.52 ton C/ha, equal to 97.34 ton CO2e/ha. Considering the mangrove area of 4.24 ha, the average carbon storage amounts to 112.46 ton C (412.72 ton CO2e).

It is worth noting that this calculation excludes soil carbon values. Compared to mangroves predominantly composed of A. marina in Kerala, India, which recorded a carbon storage of 117.11 ± 1.02 ton C/ha (Harishma et al., 2020), the findings from the Sungai Pasir study yield lower figures.

This trend is consistent with the research by Arifanti et al. (2020), affirming that the total carbon stock in the sampled ecosystem, dominated by *Avicennia spp*., is significantly lower ($P < 0.05$) compared to stands dominated by other genera (418 Mg C/ha compared to >900 Mg C/ha).

The lower carbon stock observed at the study site may be attributed to the relative youth of the stand and, subsequently, smaller average diameters, leading to reduced biomass.

Numerous factors influence carbon storage within mangrove biomass, encompassing primary production, respiration rates, hydrology, sedimentation rates, alterations in nutrient cycles, shifts in temperature and sea levels, as well as geographic location along the tidal gradient and species composition (Mcleod et al., 2011).

- ## SOIL CARBON STOCK IN MANGROVE

The parameters measured for calculating carbon stock in soil include bulk density and soil organic carbon content. The study conducted at Sungai Pasir reveals that at this location, bulk density tends to increase with soil depth in both ponds and mangroves (Figure 4).

In dense, medium, and low-density mangrove forests, bulk density increases at a depth of 0-100 cm. However, at a depth of 100-200 cm, bulk density decreases in low-density mangrove forests, increases again in medium-density mangrove forests, and decreases once more in high-density mangrove forests. Meanwhile, in high-density mangroves, bulk density decreases at a depth of 200-300 cm and increases again at a depth of 300-400 cm.

Regarding the soil organic carbon parameters, the organic carbon content in all three land classifications tends to decrease with soil depth. Additionally, Figure 5 illustrates that high-density mangroves exhibit higher organic carbon content compared to medium-density and low-density mangroves. The organic carbon values in high-density mangroves range from 7.24% to 13.42%, in medium-density mangroves from 2.24% to 11.80%, and in low-density mangroves from 1.41% to 11.20%.

The analysis results indicate average organic carbon values for high-density, medium-density, and low-density mangroves as 10.02 g/cm³, 8.30 g/cm³, and 7.91 g/cm³.

Soil carbon measurements in Sungai Pasir Mangrove at a depth of 400 cm resulted in the total soil carbon stock of 2,273.54 tonnes/ha in low-density mangroves, 2,320.91 tonnes/ha in medium-density mangroves, and 2,601.78 tonnes/ha in dense mangroves (Table 11), equivalent to carbon dioxide stock of 8,343.90 CO2e/ha, 8,517.74 CO2e/ha, and 9,548.55 CO2e/ha. The average carbon stock in the location is estimated to be 2,398.75 ton C/ha and 8,803.40 ton CO2e/ha.

The carbon stocks observed in this study surpass the average soil carbon stocks in the Mahakam Delta (879 tonnes C/ha; Arifanti et al., 2019), exceed the average carbon stocks in Indonesia (849 tonnes C/ha; Murdiyarso et al., 2015), and are higher than the average global carbon stock reported by the IPCC (2014) 471 tonnes C/ha. This notable difference is likely due to the deeper soil sampling in this study, reaching 400 cm, compared to the 300 cm depth in the Mahakam River Delta study.

Table 11. Soil Carbon Stock at Different Mangrove Land Cover

Categories of land cover	Above-ground carbon stock (ton C/ha)	Above-ground sequestration CO2 (ton CO2e/ha)
Low-density mangrove	2,273.54	8,343.90
Medium-density mangrove	2,320.91	8,517.74
Dense mangrove	2,601.78	9,548.55
Average	2,398.75	8,803.40

Figure 04. Soil Bulk Density (g/cm3) in Mangroves and Fish Ponds at Different Sampled Depths

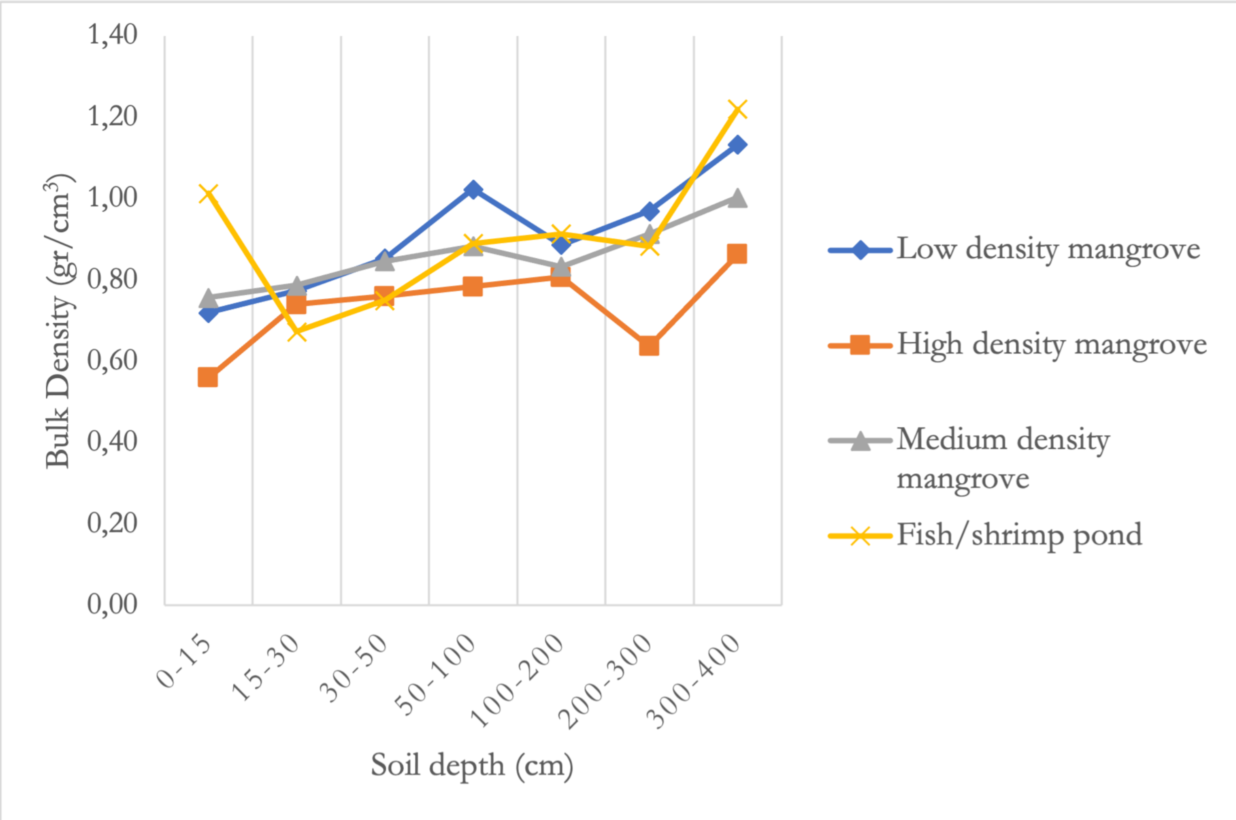
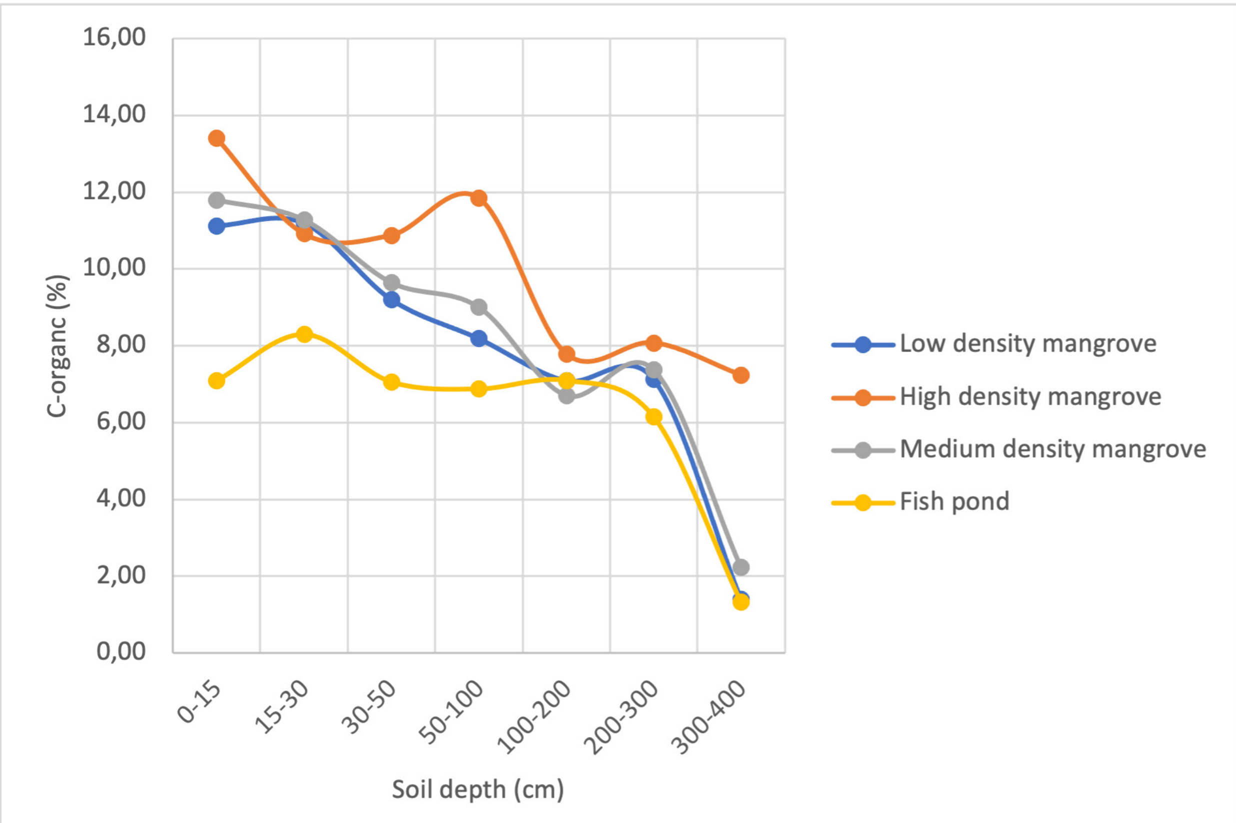


Figure 05. Soil Carbon Concentration (%) of Mangroves and Fish Ponds at Different Sampled Depths



- ## SOIL CARBON STOCK IN FISH POND

According to the analysis of drone images conducted, the pond area at the study location has been documented as 13 ha, larger than the existing mangrove area of 4.24 ha. In contrast to mangroves, fish/shrimp ponds exhibit elevated bulk density at a depth of 0-15 cm, reaching 1,013 g/ cm^3, followed by a decrease at 15-30 cm to 0.673 g/ cm^3. The density then gradually increases, reaching 1,220 g/cm^3 at a depth of 300-400 cm. The C-organic content in ponds is lower than that in mangroves, ranging from 1.34% to 8.31%, with an average C-organic content of 6.28%. The measurement of soil carbon in fish/shrimp ponds in Sungai Pasir Village at a depth of 4 meters resulted in a total soil carbon storage of 1,938.06 tons/ha (Table 12), equivalent to carbon dioxide storage of 7,112.68 CO2e/ha.

Table 12. Soil Carbon Stock at Existing Fish Ponds in Sungai Pasir Village

Categories of land cover	Soil Carbon Stock (ton C/ha)	Soil Carbon Stock (ton CO2e/ha)
Fish / shrimp pond	1,938.06	7,112.68

- ## TOTAL CARBON ECOSYSTEM

A distinction exists in the total carbon stock between the mangrove forest ecosystem and fish/shrimp ponds in Sungai Pasir Village. The average total ecosystem carbon stock in mangrove forests is 2,424.83 tonnes C/ha, ranging from 2,280.35 tonnes C/ha to 2,636.39 tonnes C/ha in three different land cover. However, the average ecosystem carbon stock for fish/shrimp ponds is 1,938.06 tonnes/ha (refer to Table 13). Soil carbon in mangrove forests and fish/shrimp ponds contributes 87% to 99% and 100% of the total ecosystem carbon stock.

Table 13. Carbon Stocks of Mangroves and Fish Ponds in Sungai Pasir Village

Categories of land cover	Above-ground carbon (ton C/ha)	Below-ground carbon (ton C/ha)	Total carbon from vegetation (ton C/ha)	Soil Carbon (ton C/ha)	Total Carbon Ecosystem (ton C/ha)
Low-density mangrove	4.41	2.4	6.81	2,273.54	2,280.35
Medium-density mangrove	28.05	10.1	38.14	2,320.91	2,359.05
Dense mangrove	22.09	12.52	34.61	2,601.78	2,636.39
Fish/shrimp ponds	0	0	0	1,938.06	1,938.06

6. CONCLUSION

Species of mangroves found in the study area include *Acrostichum speciosum, Avicennia alba, Nypa fruticans, Rhizophora mucronata,* and *Sonneratia caseolaris.*

The highest IVI value was 175.55 for the seedlings, 192.72 for the saplings, and 300 for the pole and tree. The composition of mangroves in Sungai Pasir shows high dominance of *Avicennia alba* and low diversity, richness, and evenness. The total area of mangroves reaches 4.24 ha, and fish/shrimp ponds reach 13 ha. The average above-ground carbon stock value is estimated to be 18.18 ton C/ha and CO2 sequestration of 66.72 ton CO2e/ha.

Meanwhile, the average below-ground carbon stock was 8.34 ton C/ha, and CO2 sequestration was 30.61 ton CO2/ha. The average soil carbon stock in the location is estimated to be 2,398.75 tons C/ha, corresponding to 8,803.40 tons CO2e/ha.

This results in an average total ecosystem carbon stock in mangrove forests of 2,425.27 tons C/ha, equivalent to 8,900.73 tons CO2e/ha. Additionally, the average ecosystem carbon stock for fish/shrimp ponds is estimated at 1,938.06 ton C/ha, with 100% of this value originating from soil carbon.

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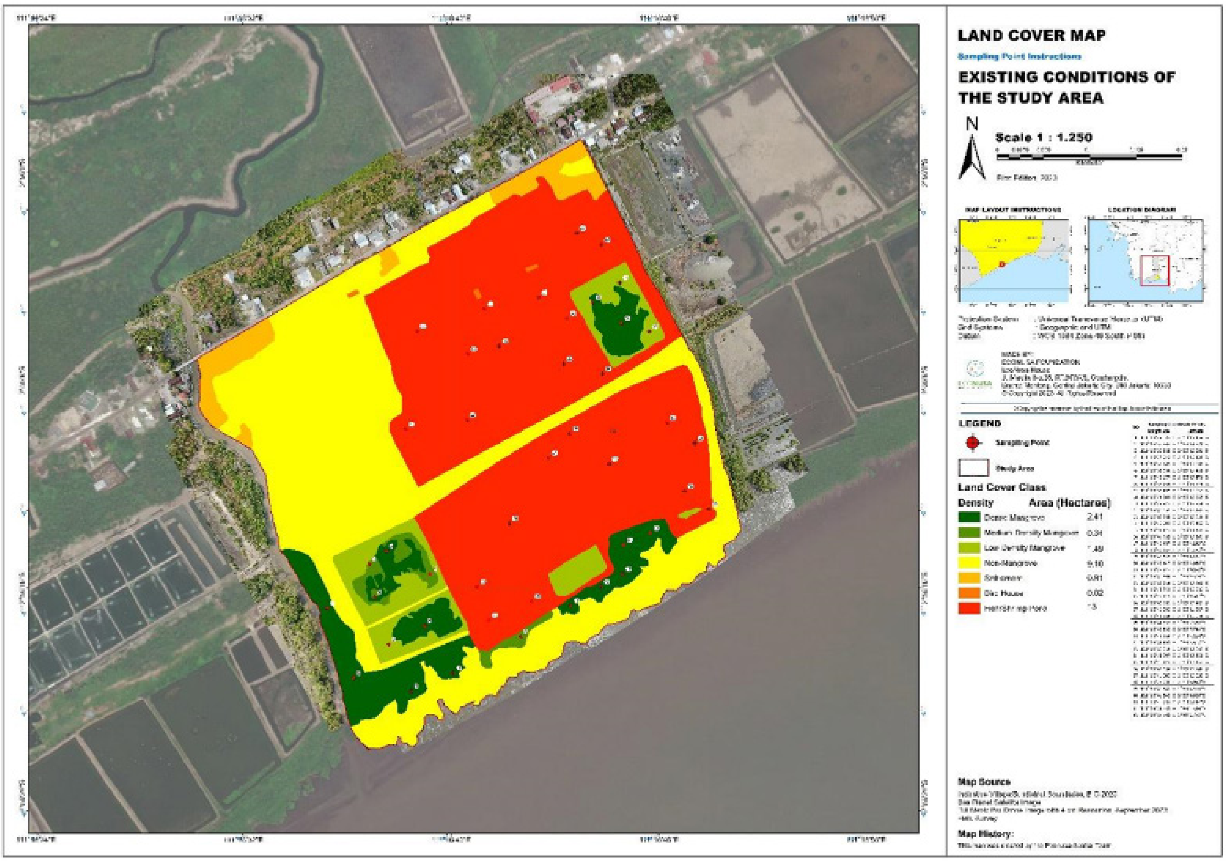
Annex 01. Maps of the study area




LAND COVER MAP
Sampling Point Instructions
EXISTING CONDITIONS OF THE STUDY AREA
N
Scale 1 : 1.250
LEGEND
Sampling Point
Study Area
Land Cover Class
Density
Area (Hectares)
Low Density Mangrove
Non-Mangrove
2.41
9.10
0.81
0.02
Map Source
Map History


ORTHOPHOTO MAP
Sampling Point Instructions
EXISTING CONDITIONS OF THE STUDY AREA
N
Scale 1 : 1.250
LEGEND
Sampling Point
Study Area
Map Source
Map History

Annex 02. Water Quality Data in Study Location

Plot No.	Coordinates	Time of Sampling	Salinity (%)	pH	DO (mg/L)	Temperature (°C)
T40	-2°56'07.11" S 111°16'42.01" E	07.49	26	6.71	5	30.8
T25	-2°56'09.17" S 111°16'48.17" E	08.40	28	7.70	5.4	30.8
T34	-2°56'12.15" S 111°16'49.05" E	08.49	32	7.65	4.9	34.1
T27	-2°56'11.18" S 111°16'46.20" E	09.12	35	8.52	7.2	33.2
T28	-2°56'10.09" S 111°16'44.51" E	09.21	38	8.51	7.2	32.9
T36	-2°56'16.62" S 111°16'43.13" E	09.58	33	8.24	4.2	33.7
T38	-2°56'06.00" S 111°16'38.54" E	10.31	33	7.99	7.4	34.3
M12	-2°56'18.6" S 111°16'40.1" E	14.54	26	6.93	3.8	30.5
M07	-2°56'17.8" S 111°16'42.6" E	15.40	18	7.65	5.4	29.4
M13	-2°56'15.9" S 111°16'45.8" E	12.52	30	7.42	6.3	28.0
M14	-2°56'15.5" S 111°16'46.6" E	12.55	28	7.41	5.8	28.8
M15	-2°56'14.6" S 111°16'46.7" E	13.03	30	6.52	4.6	29.0
M16	-2°56'13.7" S 111°16'47.9" E	13.13	26	6.73	3.5	29.0

Annex 03. Mangrove Structure and Composition Analysis

LOW DENSITY MANGROVE

SEEDLING

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J'
Api-api	*Avicennia alba*	24,167.00	96.67	75.00	171.67	0.93	0.03		
Rambai	*Sonneratia caseolaris*	833.00	3.33	25.00	28.33	0	0.11		
Total		25,000.00	100	100.00	200.00	0.94	0.15	0.29	0.21

SAPLING

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J'
Api-api	*Avicennia alba*	3,333.33	96.15	66.67	162.82	0.92	0.04		
Rambai	*Sonneratia caseolaris*	133.33	3.85	33.33	37.18	0.00	0.13		
Total		3,466.67	100	100	200	0.93	0.16	0.31	0.24

MEDIUM DENSITY MANGROVE

SEEDLING

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J'
Api-api	*Avicennia alba*	5,625	90	75	165	0.81	0.09		
Nipah	*Nypa fruticans*	625	10	25	35	0.01	0.23		
Total		6,250	100	100	200	0.82	0.33	0.43	0.47

SEEDLING

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J'
Api-api	*Avicennia alba*	4,000.00	100.00	100.00	200.00	1.00	0.00		
Total		4,000.00	100	100	200	1.00	0.00	0.00	0.00

POLE

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J'
Api-api	*Avicennia alba*	175.00	100.00	100.00	2.77	100.00	300.00		
Total		175	100	100	2.77	100	300	1.00	0.00

DENSE MANGROVE

SEEDLING

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J'
Api-api	*Avicennia alba*	70,313.00	98.25	80.00	178.25	0.97	0.02		
Bakau	*Rhizophora mucronata*	625.00	0.87	10.00	10.87	0.00	0.04		
Rumput piyai	*Acrostichum speciosum*	625.00	0.87	10.00	10.87	0.00	0.04		
Total		71,563.00	100.00	100.00	200.00	0.97	0.10	0.37	0.09

SAPLING

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J’
Api-api	*Avicennia alba*	4,900.00	100	100	200.00	1.00	0.00		
Total		4,900.00	100	100	200.00	1.00	0.00	0.00	0.00

POLE

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J’
Api-api	*Avicennia alba*	425.00	100	100	5.58	100.00	300.00		
Total		425.00	100	100	5.58	100.00	300.00	1.00	0.00

TREE

Local Name	Scientific Name	Density (ind/ha)	RA (%)	RF (%)	IVI	D	H'	R	J’
Api-api	*Avicennia alba*	6.25	100	100	0.22	100.00	300.00		
Total		6.25	100	100.	0.22	100.00	300.00	1.00	0.00

Note: RA = relative density, RF = relative frequency, IVI = important value index, D = dominance index, H’ = diversity index, R = species richness index, and J’ = evenness index.

Annex 04. Weight, Dry Weight, and C-Organic AGB of Mangrove Seedling

Categories of land cover	Total wet weight (gram)	Total dry weight (gram)	Wet weight sample (gram)	C-organik gravimetri/LOI (%)
Low-Density Mangrove	227.59 ± 34.64	67.47 ± 7.90	227.59 ± 34.64	44.77 ± 0.12
Medium Density Mangrove	196.69 ± 111.05	58.99 ± 39.11	196.69 ± 111.05	45.12 ± 4.18
Dense Mangrove	164.94 ± 119.77	41.85 ± 28.51	245.13 ± 19.68	45.40 ± 2.19
Grand Total	**196.50 ± 97.39**	**57.13 ± 32.23**	**213.69 ± 85.64**	**45.10 ± 2.19**

Annex 05. Soil Bulk Density and C Concentration

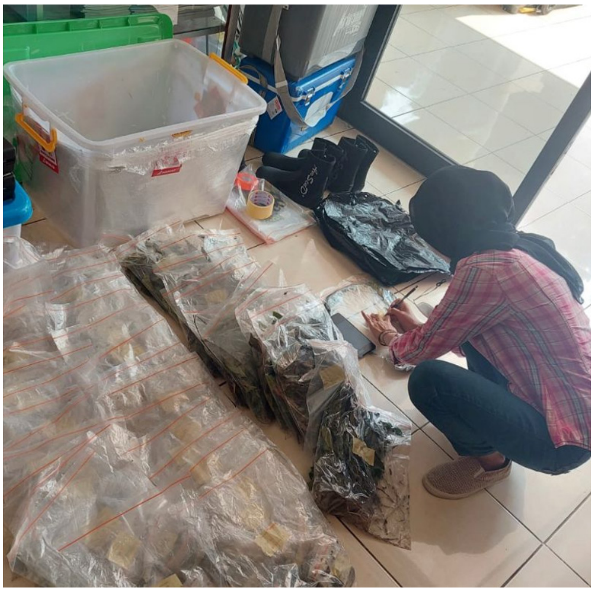
Mangrove land cover	Bulk density (g/cm3)	Average of C organic (%)
Low-Density Mangrove		
0-15	0.72 ± 0.24	11.13 ± 3.76
15-30	0.77 ± 0.21	11.20 ± 3.61
30-50	0.85 ± 0.08	9.21 ±3.04
50-100	1.02 ± 0.15	8.19 ± 1.93
100-200	0.89 ± 0.08	7.09 ± 1.56
200-300	0.97 ±0.00	7.14 ± 0.56
300-400	1.13 ± 0.21	1.41 ± 1.08

Mangrove land cover	Bulk density (g/cm3)	Average of C organic (%)
Medium-density mangrove		
0-15	0.76 ± 0.07	11.80 ± 1.26
15-30	0.79 ± 0.04	11.29 ± 0.98
30-50	0.85 ± 0.07	9.65 ± 1.19
50-100	0.88 ± 0.15	9.01 ± 0.31
100-200	0.83 ± 0.09	6.71 ± 2.11
200-300	0.91 ± 0.06	7.38 ± 0.68
300-400	1.00 ± 0.29	2.23 ± 1.83

Mangrove land cover	Bulk density (g/cm3)	Average of C organic (%)
Dense mangrove		
0-15	0.56 ± 0.04	13.42 ± 2.10
15-30	0.74 ± 0.03	10.92 ± 0.18
30-50	0.76 ± 0.10	10.88 ± 2.21
50-100	0.78 ± 0.11	11.85 ± 0.66
100-200	0.81 ± 0.13	7.79 ± 3.28
200-300	0.64 ± 0.05	8.08 ± 0.69
300-400	0.86 ± 0.08	7.24 ± 0.27

Annex 06. Documentation of Fieldwork Activities


7 Okt 2023 07.31.55
235° SW
Sungai Pasir
Kecamatan Pantai Lunci
Kabupaten Sukamara
Kalimantan Tengah



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