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Estimation of Carbon Stocks in Mangrove Ecosystems as Blue Carbon Mitigation on the South Coast of Lombok Island

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Abstract: Mangrove ecosystems are globally recognized as major blue carbon sinks, yet site-specific evidence linking sediment carbon, nutrient availability, and community structure in sandy mangrove substrates remains limited, particularly along the south coast of Lombok Island. This study addresses that gap by examining how sediment carbon content relates to mangrove diversity, substrate texture, and nutrients across three stations namely Tanjung Luar, Kedome, and Poton Bako. A field survey using systematic line transects (10×10 m trees; 5×5 m saplings; 2×2 m seedlings) was combined with sediment coring (0–100 cm). Sediment carbon was measured by Loss on Ignition (LOI), while texture and nutrients (N, P, K) were analyzed in the laboratory. Mangrove communities showed moderate diversity (H' = 0.45–1.50). Poton Bako exhibited the highest diversity and evenness (H' = 1.50; E = 0.87), indicating a relatively stable stand compared with Tanjung Luar and Kedome. Sediment carbon varied by location and species, with the highest values associated with *Rhizophora apiculata*, *Rhizophora mucronata*, and *Sonneratia alba*, reaching up to 875.22, 825.45, and 665.55, respectively. Although sediments were predominantly sandy (>50%), finer fractions (silt-clay, ±5-47%) and relatively high nutrients in Rhizophora zones (N up to 4.28%; P up to 99.35 ppm; K up to 22.63 meq%) enhanced carbon retention. Environmental parameters were within optimal ranges (pH 5.7-6.2; salinity 34.5–35.5‰; temperature 27-29°C). These findings indicate that even sandy mangrove substrates can store substantial carbon when supported by favorable nutrient conditions and stable species composition, highlighting the blue carbon significance of South Lombok mangroves for ecosystem-based coastal management. Limitations include reliance on LOI for carbon estimation and the absence of seasonal measurements, which may influence carbon and nutrient dynamics.

Keywords: Blue Carbon; LOI; Mangrove; Sediment; South Coast of Lombok

Introduction

Mangrove ecosystems provide critical coastal services, including nursery habitat for marine fauna, shoreline protection from extreme events, and high primary productivity. (Vincentius et al., 2019; Husain et al., 2020; Al Idrus et al., 2023), provides protection against tropical storms (Zhang et al., 2022). Beyond these functions, mangroves are among the most effective blue carbon systems, capable of capturing atmospheric carbon and storing it long-term in biomass and, predominantly, in sediments. A substantial proportion of mangrove carbon (≈49–98%) is retained belowground within 0–3 m sediments, making sediment carbon the largest and most stable carbon pool and a key asset for climate-change mitigation. Indonesia also has considerable potential for carbon emissions, with a range of 10–100 Tg CO_2eq, compared to several other countries (de Paula et al., 2023).

Mangrove ecosystems are one of the richest *blue carbon* ecosystems in storing carbon in the world, so they have a significant contribution to ecological services as an effort to mitigate climate change through their ability to absorb carbon from the atmosphere and store it in biomass and sediment (Indrayani et al., 2021; Farhaby et al., 2024). Sediment is the largest carbon storage

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component in mangrove ecosystems because it is able to store 49–98% carbon at depth intervals of 0-3 m (Hatta et al., 2022; Donato et al., 2011; Alongi, 2020). Therefore, mangrove ecosystems mostly store carbon in their sediments and become a high-value ecological asset in climate change mitigation.

The potential of mangroves in absorbing and storing carbon has not been utilized to the fullest. In West Nusa Tenggara Province, data on carbon content in mangrove substrates are still limited and have only been reported from several locations, namely in Gili Meno, North Lombok (Rahman & Hadi, 2021), Teluk Lembar, West Lombok (Firman et al., 2023), as well as the latest research in Bagek Kembar, Sekotong (Hidayat et al., 2024). This condition shows that research related to mangrove carbon still needs to be carried out and further developed. Coastal blue carbon in mangrove ecosystems is generally analyzed based on vegetation biomass and soil organic carbon content. Globally, the carbon stock of mangrove ecosystems is reported to have an average value of around 702.5 Mg Corg ha^{-1} (Alongi, 2020).

The South Coast area of Lombok Island is an area that has a fairly large mangrove ecosystem, stretching from Tanjung Luar Village, Ketapang Raya Village (Keruak District) to Poton Bako Village and the Ekas area (Jerowaru District), with a total area of around 483 ha (Idrus et al., 2021). This area has two strategic economic locations, namely the Tanjung Luar Fish Landing Site (TPI) and the Bale Mangrove Poton Bako Ecotourism area. This coastline is socio-ecologically strategic due to intensive fisheries at Tanjung Luar and ecotourism at Poton Bako, activities that can alter nutrient inputs, sediment dynamics, and ultimately carbon burial through waste discharge and habitat disturbance (Widiawati et al., 2023). Prior studies here have examined seagrass structure, ecotourism potential, and aquatic fauna (Syukur et al., 2021; Husain et al., 2021), but have not investigated how nutrients, sediment texture, and mangrove community structure together influence sediment carbon storage.

Regional findings indicate that mangroves in nearby areas can store >400 Mg C ha^{-1}, with Rhizophora often contributing the highest biomass carbon (Noor et al., 2020; Hadi et al., 2019). However, it remains unclear whether high sediment carbon in Lombok mangroves is primarily driven by species dominance, nutrient enrichment, or substrate characteristics, particularly where sediments are predominantly sandy. Addressing this uncertainty is important because management and conservation strategies for blue carbon are often based on generalized global values (e.g., ~702.5 Mg Corg ha^{-1}; Alongi, 2020) rather than locally derived ecological controls.

The novelty of this study lies in examining a previously unreported blue-carbon landscape on the south coast of Lombok while integrating three determinants of sediment carbon simultaneously: substrate texture, nutrient content (N, P, K), and mangrove community structure. By focusing on sandy sediments, this research tests the assumption that such substrates are poor carbon sinks and evaluates how favorable nutrients and species composition may compensate for textural limitations. This integrated, site-specific approach provides ecologically grounded evidence needed for ecosystem-based coastal management and climate-mitigation planning in West Nusa Tenggara. Therefore, this study analyzes variation in sediment carbon across mangrove species and stations and relates it to substrate and nutrient characteristics along the south coast of Lombok Island.

Method

The research location was conducted at 3 stations. The first station is located in the Tanjung Luar mangrove area, which is near the Tanjung Luar Fish Landing Site (TPI), Keruak District, East Lombok. The second station is located in the Kedome Mangrove Area, Keruak District, Tanjung Luar which is a place for salt making and shrimp cultivation and Station 3 is located in the Poton Bako Ecotourism Area, Jerowaru District, East Lombok. Each coordinate point includes: Tanjung Luar: 8°46'21.43988-116°31'10.03212, Kedome: 8°46'19.37892-116°30'40.05756, Poton Bako 8°47'56.99472-116°30'14.77224. Details are shown in Figure 1.

Figure 1. Research Location

Mangrove vegetation data collection was carried out using *the line transect method* with a linear design, which is included in the *systematic sampling method*, where plot placement is carried out regularly from the sea to the mainland. This study consists of three observation stations based on the level of mangrove density (rare, medium, and dense). Each station has three transects, and in each transect there are five observation plots with a distance between transects and between plots of 20 m each. The plot size was adjusted to the mangrove vegetation measurement standard, which was 10 × 10 m for tree level, 5 × 5 m for stakes, and 2 × 2 m for seedlings, referring to the mangrove measurement protocol by (Al Idrus et al., 2023).

Sediment sampling was carried out at all research stations. On each plot, one sample point was taken in the center using a ground drill to a depth of 0–100 cm (Zhang et al., 2022; Bouillon et al., 2008). The entire sediment sample was stored in a plastic *zipper*, labeled, and stored in *a cool box* at ±4°C before further analysis. Analysis of substrate carbon content was carried out using *the Loss on Ignition* (LOI) method, and analysis of substrate type and nutrient content (N, P, and K) was carried out at the Soil Science Laboratory, Faculty of Agriculture, University of Mataram

Result and Discussion

Composition and Abundance of Mangrove Species

The mangrove ecosystem at the three research locations (Tanjung Luar, Kedome, and Poton Bako) is composed of 8 species of mangroves from 4 families, namely Acanthaceae, Rhizophoraceae, Meliaceae, and Lythraceae. However, not all species were found in every location, suggesting variations in the composition and spatial distribution of mangroves between study sites. Overall, the species with the highest abundance is *Rhizophora mucronata* with a total of 3808 individuals. The Composition and Abundance of Mangrove Species on the South Coast of Lombok is shown in Table 1.

Table 1. Composition and Abundance of Mangrove Species in Mangrove Ecosystems

Family	Species	Location			Total
		TL	K	PB	
Acanthaceae	*Avicennia marina*	884	275	30	1189
Acanthaceae	*Avicennia lanata*	0	1145	0	1145
Rhizophoraceae	*Rhizophora apiculata*	0	0	62	62
Rhizophoraceae	*Rhizophora stylosa*	1058	700	2050	3808
Rhizophoraceae	*Rhizophora mucronata*			2263	2263
Rhizophoraceae	*Bruguiera cylendrica*	0	125	0	125
Meliaceae	*Xylocarpus moluccensis*	358	1295	75	1728
Lythraceae	*Sonneratia alba*	6	5	1412	1423

Table 1 shows that Poton Bako is the richest location of individuals (5892 ind.), with large contributions from *Rhizophora stylosa* (2,050 ind.), *Rhizophora mucronata* (2263 ind.), and *Sonneratia alba* (1412 ind.). This shows that Poton Bako has environmental conditions that support the development of Rhizophora and Sonneratia species, usually the front to middle intertidal area with suitable sediment supply and tidal conditions.

The mangrove ecosystem in Kedome also showed significant abundance (3545 ind.), dominated by *Avicennia lanata* (1145 ind.) and *Xylocarpus moluccensis* (1295 ind.). The strong presence *of A. lanata* only in the Kedome indicates typical microhabitat conditions (e.g., specific substrates, salinity, or minimal disturbance) that favor this species. Meanwhile, in the Tanjung Luar mangrove ecosystem, there are fewer individuals than the other two locations (2306 ind.), but it still has a wide range of species including *Avicennia marina* (884 ind.) and *Rhizophora stylosa* (1058 ind.), which shows a relatively balanced zoning between coastal zoning and more protected parts. Furthermore, the presence of *Sonneratia alba* (the majority in Poton Bako) is often associated with the frontmost zone which is often flooded and more exposed to seawater. The dominance *of Rhizophora* (*stylosa* and *mucronata*) in Poton Bako indicates intertidal conditions suitable for support roots (stilt roots/pneumatophore) and relatively stable sediments. Avicennia species (*A. marina* and *A. lanata*) tend to be tolerant of high salinity and are often found in higher/drier zones relative to Sonneratia; *A. lanata* which is only found in the Kedome indicates a special microhabitat there.

Community Structure Mangrove Ecosystem in the South Lombok Coast

The structure of the mangrove community based on the growth rate (trees, stakes, and seedlings) at three research locations, namely Tanjung Luar, Kedome, and Poton Bako is shown in Figure 2.

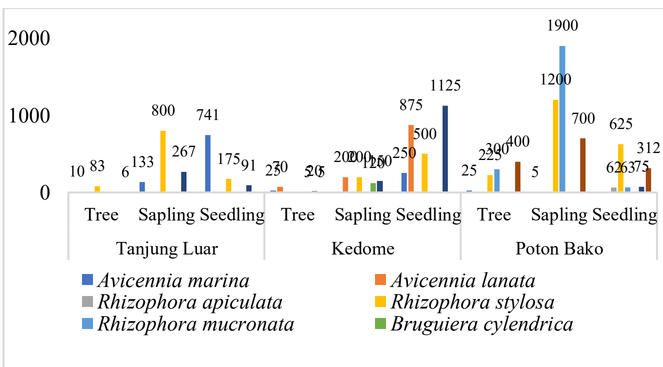

Figure 2. Community Structure Mangrove Ecosystem in the South Lombok Coast

Variations in composition and abundance at each growth rate show differences in regeneration status, ecosystem stability, and mangrove succession dynamics between locations. In general, the high number of individuals in the seedling and stake phases compared to mature trees indicates that the mangrove ecosystem in the study area is still in an active regenerative phase, although the success rate varies by location and species.

Figure 2 shows that the structure of the mangrove community in Tanjung Luar is dominated by the pile and seedling phases, especially in *Avicennia marina* and *Rhizophora stylosa*. *A. marina* shows a very high number of seedlings (741 individuals) compared to its trees (10 individuals), which indicates strong natural regeneration but with a limited transition to the tree phase. This condition may reflect a high mortality rate in the advanced phase or the presence of environmental and anthropogenic pressures that inhibit growth to the adult phase.

Rhizophora stylosa, also showed a similar pattern, with the dominance of stakes (800 individuals) and seedlings (175 individuals) compared to trees (83 individuals). This pattern reflects the ongoing succession potential and the availability of substrates that support the early phase of growth, particularly in the middle intertidal zone.

The location of the Kedome shows a relatively more balanced and complex community structure, with significant contributions from *Avicennia lanata* and *Xylocarpus moluccensis*. *A. lanata* exhibits a high number of stakes (200 individuals) and seedlings (875 individuals) in the absence of mature trees, indicating that this area serves as a major recruitment area for the species. *Xylocarpus moluccensis* in the Kedome shows a presence at all growth rates, with a very high number of seedlings (1.125 individuals) compared to trees (20 individuals). This shows active regeneration in the back mangrove zone which is relatively stable, but with the growth of mature trees that are still limited or take longer. The presence *of Bruguiera cylindrica* which is limited to the stake and seedling phases also indicates that this species has a narrow ecological niche and high sensitivity to habitat changes.

Bako Poton displays the most complex and mature community structure, characterized by the strong dominance of *Rhizophora stylosa*, *Rhizophora mucronata*, and *Sonneratia alba* at all growth levels. *R. stylosa* shows a very high number of spikes (1,200 individuals) and seedlings (625 individuals), indicating continuous regeneration and very supportive habitat conditions. *R. mucronata* was found only in Poton Bako with a much higher number of stakes (1,900 individuals) than seedlings (63 individuals), indicating a successful previous regeneration phase, but the latest recruitment was relatively lower. *S. alba* dominates the tree (400 individuals), stake (700 individuals), and seedling (312 individuals) phases, indicating this area as a well-established mangrove front zone, with a good level of stability and ecosystem function.

INP Mangrove Ecosystem on the South Lombok Coast

The Index of Important Values (INP) reflects the degree of dominance and ecological role of mangrove species based on density, frequency, and relative closure. The results of the study showed that there was a variation in species dominance between locations and growth rates, which indicated differences in environmental conditions and dynamics of mangrove regeneration on the coast of South Lombok.

Table 2. Mangrove Important Value Index (INP) on the South Coast of Lombok

Location	Species	Tree	Sapling	Seedling
Tanjung Luar	*Avicennia marina*	33.78	30.11	118.41
	Avicennia lanata	-	-	-
	Rhizophora apiculata	-	-	-
	Rhizophora stylosa	240.97	127.67	31.64
	Rhizophora mucronata	-	-	-
	Bruguiera cylindrica	-	-	-
	Xylocarpus moluccensis	-	42.22	49.95
	Sonneratia alba	25.25	-	-
	Total	300	200	200
Kedome	*Avicennia marina*	52.70	-	35.01
	Avicennia lanata	135.78	40.00	56.82
	Rhizophora apiculata	-	-	-
	Rhizophora stylosa	-	35.00	42.26
	Rhizophora mucronata	-	-	-
	Bruguiera cylindrica	24.83	44.75	-
	Xylocarpus moluccensis	62.27	80.25	65.91
	Sonneratia alba	24.42	-	-
	Total	300	200	200
Poton Bako	*Avicennia marina*	15.95	-	-
	Avicennia lanata	-	-	-
	Rhizophora apiculata	-	-	22.22
	Rhizophora stylosa	50.85	92.58	90.89
	Rhizophora mucronata	60.14	69.00	22.22
	Bruguiera cylindrica	-	-	-
	Xylocarpus moluccensis	-	-	20.23
	Sonneratia alba	173.06	38.42	44.44
	Total	300	200	200

Table 2, shows that the Tanjung Luar mangrove INP, *Rhizophora stylosa* dominates the tree level (INP 240.97), showing its role as the main constituent of the adult stand structure. However, lower INP values at the stake and seedling levels indicate relatively limited regeneration. In contrast, *Avicennia marina* has a high INP at the seedling level (118.41), which indicates good early regeneration ability. A similar pattern was reported by Duke et al. (2014), who stated that *Avicennia* generally plays a pioneer species in mangrove zones with open sedimentary conditions and high tidal influence.

The INP of the Kedome mangrove, the dominance of *Avicennia lanata* at the stake level (INP 135.78) indicates habitat suitability for the intermediate regenerative phase, while *Xylocarpus moluccensis* plays an important role at the tree level. The continued presence *of Rhizophora stylosa* and *Bruguiera cylindrica* reflects the stability of the community with specific adaptations to substrates and hydrodynamic conditions (Noor et al., 2012)

Mangrove of Poton Bako shows a strong dominance *of Sonneratia alba* at the tree level (INP 173.06), reflecting its high adaptation to sandy substrates and open coastal environments. High INP *of Rhizophora stylosa* and *R. mucronata* at the stake and seedling levels indicates active regeneration and community sustainability. This pattern is consistent with the study Primavera et al. (2019) which confirmed the role *of Sonneratia* and *Rhizophora* in shoreline stabilization and natural mangrove restoration. Overall, the genera *Rhizophora*, *Avicennia*, and *Sonneratia* are the main constituents of South Lombok mangroves with complementary ecological roles at each stage of growth. INP variation between locations confirms the influence of environmental factors, especially sediment texture, salinity, and tidal dynamics. These findings show that the South Lombok mangrove ecosystem still has good regeneration power and structural stability, so it has the potential to support important ecological functions, including carbon storage.

Diversity Indices of Mangrove Communities in the South Lombok Mangrove Ecosystem

The biodiversity index is used to describe the structure of mangrove communities quantitatively through several parameters, namely the species diversity index (H'), the species richness index (R), the species equality index (E), and the species dominance index (D). These four indices provide a comprehensive picture of the complexity of mangrove communities, the distribution of individuals between species, and the degree of dominance of certain species at each study site.

Based on the calculation results, the value of the mangrove diversity index in the three study locations showed quite clear variations between locations (Tanjung Luar, Kedome, and Poton Bako), which indicated differences in ecological conditions and dynamics of mangrove communities on the coast of South Lombok.

Table 3. Species diversity index (H'), species richness index (R), species equality index (E), and species dominance index (D) of the South Lombok coastal mangrove ecosystem

Location	(H')	(R)	(E)	(D)
Tanjung Luar	1.25 (medium)	0.54 (low)	0.45 (low)	0.25 (low)
Kedome	0.45 (medium)	1.10 (low)	0.27 (low)	0.30 (low)
Poton Bako	1.50 (medium)	0.95 (low)	0.87 (height)	0.87 (height)

Table 3 shows that in Tanjung Luar, the diversity index value (H' = 1.25) indicates a moderate level of diversity, reflecting the presence of several mangrove species with an uneven distribution of individuals. The low species richness index (R = 0.54) indicates the limited number of species that make up the community. A low equality value (E = 0.45) indicates an inequality in the distribution of individuals between species, although a low dominance index (D = 0.25) indicates that dominance has not been extremely concentrated in a single species. This pattern describes mangrove communities with moderate structural stability and are still vulnerable to environmental disturbances. Mangrove ecosystems often have low functional redundancy, meaning that most functional entities are represented by a single species. This lack of redundancy increases their vulnerability to disturbances, as the loss of even a single species can disrupt ecosystem functionality (Alejandra et al., 2025).

Variability in mangrove forest structure is influenced by environmental factors such as soil salinity, water content, and organic matter. For example, forests with smaller trees and higher stem densities are associated with soils rich in organic matter and water, while larger trees with lower stem densities are found in areas with intermediate soil characteristics (Hill et al., 2021). This structural variability can moderate stability but also reflects sensitivity to environmental changes. me mangrove systems exhibit resilience through high community diversity and habitat suitability, even under stress. However, resilience is often uneven, with certain areas or species being more vulnerable to disturbances (Zhang et al., 2022).

The Kedome location had the lowest diversity value (H' = 0.45), reflecting a relatively simple community structure. Although the value of species richness (R = 1.10) was slightly higher than that of the Tanjung Luar, the low evenness (E = 0.27) indicated a highly unbalanced distribution of individuals, with the dominance of some specific species. A relatively low dominance value (D = 0.30) indicates that the dominance is spread over more than one species. This condition indicates that mangrove ecosystems are structurally less stable and more sensitive to environmental stress, in line with the findings of Kathiresan and Bingham (2001) and Noor et al. (2012). In contrast, the Bako Poton showed the highest diversity value (H' = 1.50) with a high level of evenness (E = 0.87), indicating a relatively balanced distribution of individuals between species. Although the species richness is relatively low (R = 0.95), the mangrove communities in this location are more complex. A high dominance value (D = 0.87) indicates the presence of key species that have a major influence on the structure of the community, but without eliminating the balance of individual distribution. This pattern is commonly found in more mature and ecologically stable mangrove ecosystems (Primavera et al., 2019; Tomlinson, 2016; Sugiana et al. (2024).

Overall, the diversity of mangroves on the coast of South Lombok is in the low to medium category, with relatively limited species richness. Variations in the value of evenness and dominance between locations reflect differences in local environmental conditions, regeneration dynamics, and the influence of anthropogenic factors. Poton Bako shows the most balanced community structure and has the potential to have higher ecosystem resilience, while Kedome requires more attention in management and conservation.

Environmental Factors in the Control of Mangrove Ecosystems in the South Coast, Lombok

The indicators of environmental factors observed are soil pH, water pH, DO (ppm), Salinity (‰) and Temperature (°C). In detail, environmental factors are shown in Table 4**.**

Table 4. Environmental Factors

Location	Soil pH	pH air	OD (ppm)	Salinity (‰)	Temperature (°C)
Tanjung Luar	5.8	7.6	6	34.5	29
Kedome	5.7	7.2	5	35	28
Poton Bako	6.2	6,8	5	35,5	27
Range	5.7-6.2	6.8-7.6	5-6	34.5-35.5	27-29

Table 4 shows the variation of the main environmental factors (soil pH, water pH, DO, salinity, and temperature) in three South Lombok mangrove locations, all of which are still within the range of tropical mangrove ecological tolerance. The condition of mangrove environmental factors in Tanjung Luar, Kedome, and Poton Bako generally reflects the character of the tropical mangrove ecosystem that develops in the open coastal zone. Relatively acidic to slightly acidic soil pH values (5.7-6.2) indicate the dominance of organic matter decomposition processes and sediment conditions that tend to be anaerobic, as widely reported in mangrove ecosystems in Southeast Asia and the Indo-Pacific region (Alongi, 2014; Mitsch & Gosselink, 2015). The pH of water in the neutral to slightly alkaline range (6.8–7.6) indicates a balance between the influence of seawater and freshwater input, a common condition in tidal mangroves with active hydrological dynamics (Tomlinson, 2016).

The dissolved oxygen (DO) content of 5–6 ppm is still good for coastal waters, but the slightly lower DO values in Kedome and Poton Bako indicate a high rate of decomposition of organic matter in sediments, a phenomenon that is also found in tropical mangroves with high litter accumulation and limited water circulation (Alongi, 2020). High salinity and relatively homogeneous (34.5–35.5‰) confirm the dominance of marine influences, in line with recent studies reports showing that mangroves on the open coast are generally subject to high salinity pressures and are dominated by salt-tolerant species such as *Rhizophora* and *Avicennia* (Reef et al., 2010; Donato et al., 2011).

Water temperatures ranging from 27–29 °C are in the optimal range for mangrove growth and support photosynthesis processes and biogeochemical cycles, consistent with global findings that indicate that tropical mangrove productivity increases significantly at temperatures above 25 °C (Alongi, 2014). Overall, the suitability of these environmental factors shows that the South Lombok mangrove ecosystem is still in relatively good ecological conditions and is able to support the main ecosystem functions, although high salinity pressure and the dominance of sandy sediments have the potential to limit the accumulation of organic matter and sedimentary carbon in the long term if not managed sustainably (Donato et al., 2011; Alongi, 2020).

Variations in Carbon Content in Sediment at Each Location in the South Coast Mangrove Ecosystem of Lombok

The variation in sediment carbon content in the South Lombok mangrove ecosystem shows clear differences between mangrove species and observation locations (Tanjung Luar, Kedome, and Poton Bako). These differences reflect the complex interactions between mangrove vegetation structures, sediment characteristics, and coastal environmental dynamics that affect the process of carbon accumulation and storage in sediments. In general, the highest sediment carbon content is found in locations and species that have high biomass, complex root systems, and effective ability to trap sediment and organic matter. The total average carbon content in mangrove ecosystems on the southern coast of Lombok is shown in Table 5.

Table 5. Total Average Carbon Content of Each Location

Mangrove Species	Total Carbon Footprint of Each Location		
	Tanjung Luar	Kedome	Poton Bako
Avicennia marina	400.38	458.66	0
Avicennia lanata	266.80	256.88	0
Rhizophora apiculata	850.59	0	875.22
Rhizophora stylosa	285,25	0	315.90
Rhizophora mucronata	0	0	825.45
Bruguiera cylendrica	0	365.76	0
Xylocarpus moluccensis	0	125.68	88.56
Sonneratia alba	576.98	665.55	625.30

The results of the analysis of carbon content in mangrove sediments in Table 5, show that the carbon content of mangrove sediments on the coast of South Lombok varies between locations and species, with the highest values consistently found in Rhizophora species (*R. apiculata and R. mucronata*) and *Sonneratia alba*. In Tanjung Luar and Poton Bako, *R. apiculata* recorded the highest sediment carbon content (>850), while in Kedome the dominance of sediment carbon was found in S. alba. This pattern confirms the important role of root morphology and mangrove zoning in controlling sediment deposition and organic matter accumulation.

These findings are in line with the studies of Donato et al. (2011) and Alongi (2014) who stated that mangroves with root supports and complex root systems have a high capacity to trap carbon-rich fine sediments. The dominance of sedimentary carbon in Rhizophora in Poton Bako also reflects the relatively mature and stable condition of the mangrove community, as reported by Kauffman et al. (2020) on Southeast Asian mangroves. In contrast, the low carbon content of *Xylocarpus moluccensis* supports the finding of Murdiyarso et al. (2015) that mangrove back-zone species are generally associated with lower rates of sedimentation and carbon storage.

Sonneratia alba shows a high sediment carbon content throughout the site, corroborating the results of research by Alongi et al. (2000) and Hutchison et al. (2014) which place Sonneratia as a key carbon-storing species in the front zone of mangroves with high tidal influence. Variations in sediment carbon values in the genus Avicennia indicate the sensitivity of this species to local conditions, especially sediment texture and hydrodynamic dynamics, as reported by Bouillon et al. (2008).

The carbon pattern of mangrove sediments in South Lombok is consistent with the global trend of blue carbon, where Rhizophoraceae and Sonneratiaceae species play a dominant role in sedimentary carbon storage. Poton Bako emerged as the location with the highest blue carbon potential, while Kedome showed a strong dependence on specific species. These results confirm that mangrove conservation and rehabilitation strategies based on climate change mitigation need to consider site-specifics, natural zoning, and species with high carbon storage capacity, in order to maintain ecosystem stability while preventing carbon release into the atmosphere

Carbon Content of Each Mangrove Species

Reducing the content of each susbstrat in mangrove habitats was carried out on 8 species of mangroves found in the mangrove ecosystem area on the South coast, Lombok. The results of measuring sediment carbon content in each mangrove species are presented in Figure 3.

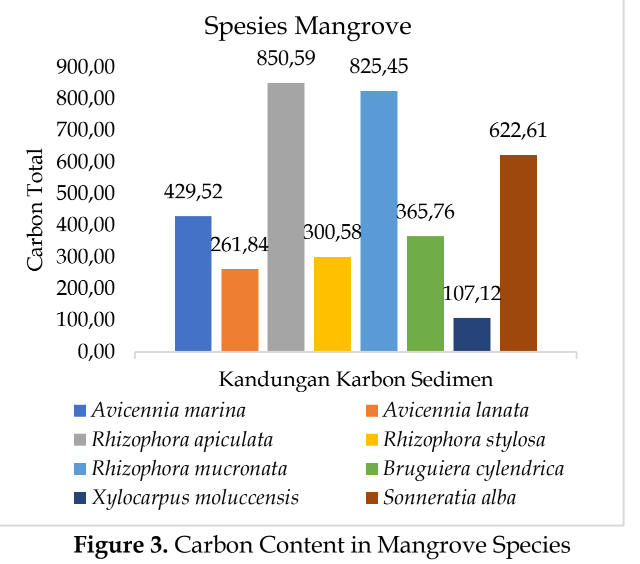

Figure 3. Carbon Content in Mangrove Species

Figure 3 shows that the high sediment carbon content of *Rhizophora apiculata* and *R. mucronata* indicates that species of *the Rhizophoraceae* family have a dominant contribution to sediment carbon storage. This is closely related to the complex and dense character of stilt roots, which effectively trap fine sediments and increase the deposition of organic matter. This condition encourages long-term carbon accumulation in the mangrove substrate. *Sonneratia alba* ranks third highest and consistently plays an important role as a carbon store. This species generally grows in the front zone of mangroves that are affected by tides, so its pneumathophoric root system contributes to capturing organic particles from the water column. The relatively high carbon value of *S. alba* indicates its strategic role in the coastal blue carbon scheme.

At the intermediate level, *Avicennia marina, Bruguiera cylindrica*, and *Rhizophora stylosa* show moderate carbon storage capacity. This variation is influenced by a combination of root morphological factors, zoning position, and local sediment conditions. *Avicennia lanata*, although tolerant to extreme environmental conditions, has a lower carbon content, indicating that ecological tolerance is not always directly proportional to the sediment's carbon storage ability. The lowest values in *Xylocarpus moluccensis* reflect the character of the mangrove back-zone species that are affected by smaller tides and low levels of sedimentation, so that sediment carbon accumulation takes place more slowly.

The pattern of sedimentary carbon dominance in Rhizophora species in this study is in line with the findings of Donato et al. (2011) and Alongi (2014) who reported that mangroves with complex root systems account for the largest carbon stores in tropical coastal ecosystems. The high carbon content of Sonneratia alba is also consistent with the results of Alongi et al. (2000) and Hutchison et al. (2014) which place Sonneratia as a key species in the front zone of mangroves in sedimentary carbon storage. In contrast, the low sedimentary carbon in *Xylocarpus moluccensis* supports the report of Murdiyarso et al. (2015) that back-zone mangrove species generally contribute less to sedimentary carbon stocks. The variation in values in the genus Avicennia is also in line with the findings of Bouillon et al. (2008) which emphasize the strong influence of sediment texture and local hydrodynamics on carbon storage capacity.

In Avicennia-dominated areas, sediment grain size and organic matter content are critical. For example, sediments under Avicennia are often suboxic due to root systems and bioturbation, which can influence organic matter degradation and carbon storage (Sakho et al., 2015). Avicennia species exhibit unique adaptations, such as pneumatophores and high lignin content in their wood, which contribute to their role as significant blue carbon species. These adaptations enhance sediment stability and carbon sequestration (Mondal et al., 2026).

The variation in carbon storage values within the genus Avicennia aligns with findings that sediment texture and local hydrodynamics are critical determinants. These factors, combined with species-specific traits and environmental conditions, shape the carbon storage capacity of Avicennia-dominated mangrove ecosystems (Amiri, 2021; Asante et al., 2024). Overall, the results of this study corroborate the global pattern of blue carbon, where species with complex root systems and located in active tidal zones play a dominant role in sedimentary carbon storage, making it important to prioritize in mangrove conservation and rehabilitation strategies based on climate change mitigation (de Silva et al., 2025).

Sediment texture of the South Lombok Mangrove Ecosystem

Variations in sediment texture in three mangrove ecosystem locations in South Lombok, namely Tanjung Luar, Kedome, and Poton Bako, were analyzed based on the percentage of sand, dust (silt), and clay in each plot. Sediment texture is an important abiotic factor that directly affects the distribution of mangrove vegetation, substrate stability, and the process of accumulation of organic matter and sediment carbon. In general, sediments throughout the study sites were dominated by sand fractions, with the percentage of sand ranging from 43.66% to 94%. The dust fraction was in the range of 4.52%–47.77%, while the clay fraction was relatively low and stable throughout the site, which was 4.45%–7.97%. This pattern shows that the South Lombok mangrove ecosystem develops on sand to dusty sand substrates, with a low clay content. The percentage of sediment texture of the South Lombok Mangrove Ecosystem is shown in Table 6.

Table 6. Sediment Texture Percentage of South Lombok Mangrove Ecosystem

Location	Plot	Pasir (%)	Dust (%)	Tekstur Clay (%)
Tanjung Luar	I	47.20	42.30	6.25
	II	77.88	14.54	4.45
	III	43.66	47.77	4.45
Kedome	IV	88.64	5.42	5.25
	V	50.47	12.81	7.97
	VI	85.55	5.57	5.47
Poton Bako	VII	78.67	16.13	5.20
	VIII	75.80	10.60	6.45
	IX	94	4.52	4.51

Table 6 shows the results of sediment texture analysis showing that the entire study site is dominated by sand fractions, with variations in the proportion of dust and clay between plots and locations. In Tanjung Luar, the sedimentary texture is relatively heterogeneous; Plots I and III have a balanced sand-dust composition, while Plot II is dominated by coarse sand. The dome shows a consistent dominance of sand on most of the plot, although Plot V shows an increase in the fraction of dust and clay that forms a finer sedimentary microhabitat. Meanwhile, Poton Bako is characterized by a very high predominance of sand, with low and relatively homogeneous fine fractions, although some plots still show limited ability to trap fine materials.

The dominance of sand fractions in the three locations indicates that the mangrove ecosystem of South Lombok develops in a coastal environment with medium to high hydrodynamic energy, which is influenced by tidal currents and waves. This pattern is in line with the findings of Alongi (2020) and Bianchi et al. (2021) who reported that open-beach mangroves generally thrive on sandy substrates with rapid sedimentation rates and limited supply of fine sediments Sugiana et al. (2024).

The presence of dust and clay fractions, which although small but vary between plots, plays an important role in the retention of water, organic matter, and sedimentary carbon. A recent study by Sanderman et al. (2022) showed that sedimentary carbon content increased significantly in mangroves with a higher proportion of clay dust, even though the vegetation was relatively similar. This supports the findings of this study, especially on plots with a more balanced sand-dust texture in Tanjung Luar and Kedome.

In terms of vegetation ecology, the predominance of sandy sediments favors species with complex root systems, such as *Rhizophora* and *Sonneratia*, which are able to stabilize substrates and trap sediments in dynamic environments. These findings are consistent with the reports of Friess et al. (2019) and Taillardat et al. (2018) which confirm that root morphology is a key factor in mangrove adaptation to high-energy sediment conditions. Implicitly, these results confirm that the potential of blue carbon is determined not only by the composition of the species, but also by the physical characteristics of the sediment. Recent global comparative studies (Macreadie et al., 2021) also emphasize that mangrove areas with higher fine fractions have greater carbon conservation value. Therefore, microhabitat zones with relatively high dust and clay content in South Lombok have the potential to be a priority for conservation and rehabilitation based on climate change mitigation, despite being in a generally sandy coastal landscape.

Mangroves are indispensable for coastal substrate stability, acting through root reinforcement, wave energy dissipation, sediment accretion, and soil texture optimization. Their resilience to environmental stressors further enhances their role as a nature-based solution for shoreline protection. Conservation and restoration of mangrove ecosystems are essential to sustain these critical functions in the face of climate change and human pressures (Karimi et al., 2022; Gomes et al., 2025).

Nutrient Content (NPK) with Total Sediment Carbon Content in Each Mangrove Zone

The nutrient content of mangrove sediments in South Lombok shows clear variation between species, with the highest values of nitrogen (N), phosphorus (P), and potassium (K) consistently found in zones dominated by the Rhizophoraceae family, in particular *Rhizophora mucronata* and *R. apiculata*. Instead *Xylocarpus moluccensis* shows the lowest NPK content, reflecting differences in growing zones and the rate of organic matter accumulation.

Table 7. Nutrient Content (NPK) with Total Sediment Carbon Content in Each Mangrove Zone

Species	Total Nutrient Content		
	N (%)	P (ppm)	K (Meq %)
Avicennia marina	2.25	24.30	15.45
Avicennia lanata	3.15	30.45	15.72
Rhizophora apiculata	4.27	55.29	20.26
Rhizophora stylosa	2.27	72.31	6.76
Rhizophora mucronata	4.28	99.35	22.63
Bruguiera cylendrica	3.25	62.40	8.75
Xylocarpus moluccensis	1.25	20.95	3.55
Sonneratia alba	2.25	31.65	4.58

Table 7 explains that the high content of N (±4.27–4.28%), P (up to ±99 ppm), and K (up to ±22.63 Meq%) in sediments under *the Rhizophora* stand confirms the role of this species in improving sediment fertility through litter accumulation, slow decomposition, and nutrient trapping efficiency by complex root systems.

The pattern of nutrient dominance in *Rhizophora* zone is in line with the findings of Alongi (2020) and Ouyang & Lee (2021) who reported that mangrove forests with a root structure have a high capacity to trap dissolved nutrients from tidal waters. Recent studies by Baker et al. (2022) also show that nitrogen and phosphorus-rich mangrove sediments are generally directly related to high litter inputs and anaerobic sediment conditions that slow down nutrient mineralization (Dharmayasa et al. (2025).

The high phosphorus content in the *Rhizophora zone* in this study is consistent with the results of Bianchi et al. (2021), who stated that P in mangrove ecosystems tends to accumulate in sediments with fine fractions and high organic matter due to the phosphate adsorption process. Similarly, the high potassium in the *Rhizophora* zone supports the findings of Lovelock et al. (2023) that show an important role of K in mangrove tolerance to salinity and osmotic stress, especially in species growing in active tidal zones. In contrast, the low NPK in *Xylocarpus moluccensis* is in line with the reports of Friess et al. (2019) and Macreadie et al. (2021), which explain that the back mangrove zone generally has lower nutrient dynamics due to the limited influence of tides and a smaller rate of organic sedimentation.

The close relationship between the high content of NPK and sediment carbon in the *Rhizophora* zone reinforces the concept that sediment fertility is the main controller of mangrove blue carbon capacity. These findings confirm the results of a recent global meta-analysis (Alongi et al., 2023) which concluded that mangrove areas with active nutrient cycles contribute the most to long-term carbon storage. Thus, the species *Rhizophora mucronata* and *R. apiculata* play a strategic role not only in maintaining ecosystem productivity, but also as a key component in mangrove management based on climate change mitigation, especially in the coastal areas of South Lombok.

Conclusion

Mangrove ecosystem aloong the south coast of Lombok, particularly at Poton Bako, Tanjung Luar, and Kedome exhibit moderate species diversity (H' = 0.45–1.50) with clear differences in community stability. Poton Bako showed the highest diversity and evenness (H' = 1.50; E = 0.87), indicating a more stable mangrove structure than Tanjung Luar and Kedome.

Sediment carbon storage varied by station and species and reached its highest values beneath Rhizophora apiculata, *Rhizophora mucronata*, and *Sonneratia alba*. Although sediments were predominantly sandy (>50%), the presence of silt–clay fractions (≈5–47%) and relatively high nutrients in Rhizophora zones (N up to 4.28%; P up to 99.35 ppm; K up to 22.63 meq%) enhanced carbon retention. Environmental conditions (pH 5.7–6.2; salinity 34.5–35.5‰; temperature 27–29°C) were within optimal ranges, further supporting carbon accumulation.

These findings demonstrate that sandy mangrove substrates can still function as effective blue carbon sinks when supported by favorable nutrient conditions and stable species composition. This study clarifies the ecological controls of sediment carbon at a previously unreported site and underscores the blue carbon significance of South Lombok mangroves. Strengthening protection through ecosystem-based coastal management and conservation is therefore essential to sustain their climate-mitigation function.

Coastal management in this region should prioritize the protection of Rhizophora-dominated zones and areas with finer sediment fractions due to their higher carbon retention capacity. Waste management and nutrient input control are essential in fisheries and ecotourism areas to prevent ecological degradation that may disrupt sediment carbon processes. Integrating blue carbon considerations into local coastal planning and mangrove conservation programs will strengthen ecosystem-based management strategies.

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Author Contributions

Conceptualization, P.H. and M.S.I.; methodology, P.H.; investigation, P.H.; formal analysis, P.H.; data curation, M.S.I.; writing-original draft preparation, P.H.; writing-review and editing, P.H. and M.S.I.; supervision, M.S.I.; project administration, P.H. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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