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Blue carbon conservation: Sediment organic carbon sequestration potential across the intertidal salinity gradient in a micro tidal mangrove ecosystem in Sri Lanka

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Abstract: Mangrove ecosystems are among the most efficient natural carbon sinks, storing substantial quantities of organic carbon within their waterlogged sediments. The prolonged inundation and saline conditions characteristic of mangrove environments limit oxygen availability, thereby suppressing microbial decomposition and promoting the long-term accumulation of organic matter as sediment organic carbon. Understanding the environmental factors controlling carbon storage is essential for the conservation and sustainable management of these blue carbon ecosystems. Therefore, this study investigated the influence of NaCl salinity, soil pH, electrical conductivity (EC), and oxidation–reduction potential (ORP) on the vertical and horizontal distribution of total organic carbon (TOC) in mangrove sediments. Sediment samples were collected along a water-to-land gradient at three depth intervals (0–10 cm, 10–20 cm, and 20–30 cm). TOC and NaCl concentrations were determined using the dichromate oxidation and Mohr titration methods, respectively. Results showed that surface sediments contained significantly higher TOC concentrations than deeper layers ($P < 0.001$), while TOC content gradually declined with increasing sediment depth and distance from the water edge. A significant positive relationship was observed between TOC accumulation and NaCl salinity, EC, and ORP. Elevated NaCl concentrations likely reduced organic matter decomposition by creating physiologically stressful conditions for decomposer microorganisms, thereby enhancing carbon preservation and sequestration within mangrove sediments. Hence our study reveals that salinity as a key environmental regulator of blue carbon storage and suggest that maintaining natural hydrological regimes and salinity gradients is critical for maximizing carbon sequestration potential.

Keywords: Mangrove sediment, NaCl salinity, Oxidation and Reduction Potential, Sediment total organic carbon, Vegetation structure

1. Introduction

Mangroves are among the most productive ecosystems and are renowned for their exceptional capacity to sequester and store carbon both aboveground in biomass and belowground in sediments. A key factor influencing this carbon storage is the water–land gradient, which creates natural zonation patterns in mangrove forests through variations in tidal inundation, salinity, sediment characteristics, and oxygen availability. These environmental gradients affect the distribution, productivity, and ecological functioning of mangrove species, thereby influencing the spatial and vertical accumulation of organic matter and sediment organic carbon. As globally significant blue carbon ecosystems, mangroves contribute directly to climate change mitigation by capturing and storing atmospheric carbon, supporting the achievement of Sustainable Development Goal (SDG) 13: Climate action. Their role in conserving coastal biodiversity and maintaining ecosystem services aligns with SDG 14: Life below water, while the protection and sustainable management of mangrove forests contribute to SDG 15: Life on land through the conservation and restoration of terrestrial and coastal ecosystems. Understanding how environmental gradients regulate carbon sequestration is therefore essential for developing effective conservation and restoration strategies that enhance ecosystem resilience, strengthen blue carbon stocks, and support the achievement of global sustainability targets.

Mangrove structural complexity plays a crucial role in sediment carbon storage within coastal ecosystems. Different mangrove species contribute uniquely to carbon sequestration, with their distinct root systems and canopy structures enhancing sediment trapping and organic matter retention. For instance, the stilt roots of *Rhizophora* spp. and the pneumatophores of *Avicennia* spp. slow water flow, allowing carbon-rich sediments to settle and accumulate. Additionally, the dense canopy cover and high litter production of mature mangrove forests contribute organic material to sediments, while their intricate root networks stabilize soils and prevent erosion.

Intertidal mangrove wetlands undergo periodic submersion and exposure due to tidal cycles, leading to salt accumulation and leaching (Han, 2017). However, salinity levels vary across mangrove ecosystems due to differences in freshwater input, tidal inundation patterns, and topography (Amarasinghe and Perera, 2017). High salinity acts as a major environmental stressor, influencing carbon sequestration rates, nutrient cycling, plant community composition, and blue carbon function (Morrissey *et al*., 2014). Increased salinity reduces microbial metabolic activity by altering osmotic potential, which slows the decomposition of dissolved organic carbon (Setia *et al*., 2013).

Tidal inundation plays a crucial role in carbon dynamics by transporting organic matter into mangrove forests from plant, animal, and microbial remains (Huxham *et al*., 2018). This accumulated carbon is not only derived from local mangrove vegetation—such as leaf litter, propagules, twigs, and subsurface root growth—but also from transported material carried by rivers, tides, and littoral currents. As a result, mangrove sediments serve as some of the largest carbon reservoirs on Earth, storing four to eight times more carbon per unit area than the atmosphere (Donato *et al*., 2011; Gress *et al*., 2017).

Mangrove sediments contain a complex mixture of organic matter accumulated over time from decaying plant material, tidal deposition, and terrestrial runoff (Perera *et al*., 2024; Choudhary *et al*., 2024). These sediments can store carbon for centuries or even millennia, depending on environmental conditions. Their anaerobic, waterlogged nature slows organic matter decomposition, allowing carbon to persist over long periods. The sediment's

characteristics such as composition, aeration, and stability play a key role in determining carbon sequestration potential.

Organic carbon content varies within and across mangrove ecosystems due to environmental factors such as tidal regimes, inundation patterns, rainfall, and freshwater input. Biotic factors, including stand age, plant and microbial density, and species composition, also significantly influence carbon storage (Ceron-Breton *et al*., 2011). The water-land gradient shapes the physical, chemical, and biological processes that govern carbon cycling and storage, making it a critical factor in mangrove carbon sequestration. Interactions between sediment type, tidal influence, salinity, aeration, and vegetation structure create a dynamic environment where carbon capture and storage vary. This study investigates how the water-land gradient affects carbon sequestration in mangrove ecosystems. Understanding these dynamics is essential for effective conservation and management, particularly as mangroves face increasing threats from climate change and human activities.

2. Materials and methods

2.1 Study area

The Kadolkele mangrove ecosystem, located in the western province of Sri Lanka (07°11′49.82′′N, 79°50′32.29′′E), lies on the right bank of the northern Negombo estuary, covering an area of approximately 10 hectares (Dissanayaka and Chandrasekara, 2014). It represents the largest mangrove expanse within the estuary, which opens into the Indian Ocean (Jayakody *et al*., 2008). Kadolkele experiences an average annual rainfall of 2,000–2,500 mm, influenced by both the southwest (May–September) and northeast (December–February) monsoons. The region maintains a warm climate year-round, with temperatures ranging from 25°C to 30°C. Moreover, the Negombo estuary's microtidal nature contributes to its high biodiversity (Jayakody *et al*., 2008; Perera *et al*., 2024).

2.2 Mangrove vegetation density

To sample sediment and vegetation, 10 m wide belt transects were established perpendicular to the shoreline across the water-land gradient at randomly selected locations within the study area. Each transect was subdivided into 10 m × 10 m sampling plots. Within these plots, all mangrove trees were identified and counted to determine vegetation density.

2.3 Mangrove sediment sampling

Sediment samples were collected with a split core sampler for 10 m distance along the each transect. Three different depths of soil samples (0 – 10 cm, 10 cm – 20 cm, 20 cm – 30 cm) were collected in each location along with GPS coordinates. Composite soil samples were prepared for each depth. Roots and plant residues were removed, and larger soil aggregates were manually crushed from the samples and sieved with a 2 mm sieve. Three replicates were measured for each test.

2.4 Organic matter content of mangrove sediment

Determination of sediment organic matter content was performed using the loss on ignition method. The mass of an empty, clean, and dry porcelain dish was recorded. Oven-dried 5.00 g of sediment sample in the porcelain dish was placed in a muffle furnace. The muffle furnace was set to the temperature of 550 °C and the crucible was left in it for 4 hours (Chaikaew and Chavanich, 2017). It was allowed to cool briefly and re-weighted.

$$\text{Organic matter (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \text{ x } 100\%$$

W_1 = weight of the crucible

W_2 = weight of crucible plus oven dried samples

W_3 = weight of the samples plus oven dried samples after ignition

2.5 NaCl content of mangrove sediment

A portion of 1.00g of ground sample was weighted into a porcelain crucible to which 0.25 g of CaO was added. To each crucible, sufficient amount of water was added to make a thin paste. The sample and blank were placed into the furnace and the temperature was gradually increased until temperature reached 550°C. It was allowed 90 min. After cooling the sample, 15.0 mL of hot water was added to the crucibles and the ash was broken into a fine powder. The mixtures were poured through filter paper into 250 mL Erlenmeyer flasks and rinsed the crucibles with water into the filter. The residue in the filters was washed with five 10.0 mL portions of hot water. Distilled water was added until the 100 mL mark of the Erlenmeyer flask. The pH of the extract was adjusted to the range of 4–8, followed by titration with 0.01 N $AgNO_3$ solution. For that potassium chromate is used as an indicator until the yellow color changed into a persistent light orange-red. Distilled water were measured as controls (Raiment and Higginson, 1992; De Silva and Amarasinghe, 2021).

$$\text{\% Cl} = \frac{(S-B) \text{x } Normality\ of\ AgNO3 \text{ x } 3.545}{weight\ of\ sample}$$

%NaCl = %Cl (1.65)

Where; S = Volume of $AgNO_3$ needed for titration of the sample (mL); B = Volume of $AgNO_3$ needed for titration of the blank (mL)

2.6 Organic carbon of mangrove sediment

Determination of sediment organic carbon was performed using the Walkley black method. A portion of 0.1 g of sediment sample was placed in a 500 mL conical flask. A solution of 1/6 N potassium dichromate 10.0 mL was used to oxidize the organic carbon in acidic medium. A standardization blank was run in the same way. The solution was diluted to 200 mL water and filtered by filter papers. Then 85% phosphoric acid 10.0 mL, 0.20 g of Sodium fluoride and 1.5 mL of diphenyl amine indicator were added. The solution was titrated with 0.5 M Ammonium iron (II) sulfate hexahydrate (Ferrous ammonium sulphate) solution delivered from a burette. At the endpoint, the color dull was sharply shifted to a brilliant green color. In this process, internal heat of dilution is used. So, the oxidation process is incomplete. Early studies have

shown that the mean recovery of organic carbon in this method is about 74% (Schumacher, 2002). Therefore, 0.74 is commonly used as the correction factor of incomplete oxidation to increase the accuracy of results by adjusting the organic carbon recovery.
Assumption - 1 mL of 1 N Dichromate solution is equivalent to 3 mg of carbon

$$\text{Organic Carbon} = \frac{(S-B)\ \text{x}\ 0.5\ x\ 0.003\ x\ 1.334}{W}$$

Where; S = Volume of ferrous solution needed for titration of sample (mL); B = Volume of ferrous solution needed for titration of blank (mL); W = Weight of the sample taken (g)

2.7 Chemical parameters of mangrove sediment

A portion of 50.0 mL of distilled water was added into 10.0 g of air-dried of sediment sample in a 100 mL beaker. Solution was stirred at 4 times on 30 minutes interval. pH, conductivity and ORP were read with the temperature by using the multiparameter (Hanna, HI98194).

2.8 Data analysis

A one-way ANOVA ($p < 0.05$) was conducted to compare sediment parameters across the water-land gradient within the mangrove area. Additionally, a Pearson's correlation matrix was used to assess relationships among sediment parameters including NaCl salinity, organic matter, pH, conductivity, and ORP—in relation to organic carbon content across the sediment profile ($p < 0.05$). Furthermore, correlation analysis was performed to examine the relationships between vegetation structure and sediment parameters, such as NaCl content and organic carbon.

3. Results

In the study area of the Kadolkele, four mangrove species belonging to three families have been identified. These species, include: *Rhizophpra mucronata* and *Ceriops tagal*; (Familiy: Rhizophoraceae), *Avicennia marina* (Family: Avicenniaceae) and *Lumnitzera racemosa* (Family: Combretaceae). The results revealed that *R. mucronata* is abundant towards the shoreline (0-10 m). *A. marina* and *L. racemosa* density have increased from shoreline to landward (Figure 1).

The analysis of mangrove sediment layers indicates that the percentage of organic matter, organic carbon, NaCl content, pH, electrical conductivity, and ORP vary across the water-land environmental gradient and sediments depth. As shown in Figure 2, parameters such as organic matter, NaCl salinity, organic carbon, electrical conductivity, and ORP are the highest in surface sediments (0-10 cm) and decrease with increasing depth. Notably, sediments near the shoreline (0 m) display lower NaCl content and electrical conductivity in the surface layer (0-10 cm) compared to the deeper layers (10-20 cm, 20-30 cm) (Figure 3b and Figure 2e).

Moreover, all substrate parameters, except for sediments pH, show an increasing trend from the estuary shoreline towards the land. The pH, however, does not exhibit significant variation with sediment depth and consistently indicates acidic conditions across the study site (Figure 2d). The results also highlight that the highest levels of organic matter, NaCl salinity, organic carbon, electrical conductivity, and ORP were observed at a distance of 20 m from the estuary shoreline, after which a slight decrease was noted (Figure 2a, 2b, 2c, 2e and 2f).

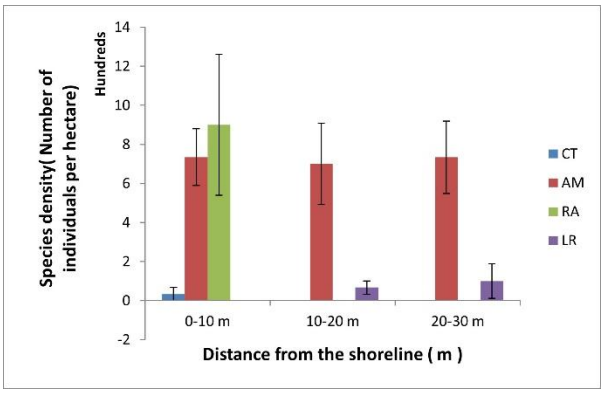


Fig 1. Species density of mangrove stands occupying in area with varying distance from shoreline. Vertical bars indicate the standard errors of the means. CT- *Ceriops tagal*, AM- *Avicennia marina*, RA- *Rhizophora mucronata*, LR- *Lumnitzera racemosa*

The results of the One-Way ANOVA indicated that all sediment parameters varied significantly across the water-land gradient. Specifically, substrate NaCl, organic matter, organic carbon, and conductivity showed significant differences with a p-value < 0.001, while sediment pH was significant at a p-value < 0.01. Furthermore, the ORP in the surface and intermediate sediment layers exhibited significant differences across the water-land gradient. However, ORP in the bottom sediment layer did not show a significant difference across this gradient. Moreover, One-Way ANOVA revealed that, surface sediments (0-10 cm) have a significantly high organic matter content, organic carbon content, NaCl content and ORP content compared to the other two depths ($p < 0.01$). However, there is no significant difference in the organic matter content, organic carbon content, NaCl content between the intermediate layer (10-20 cm) and the lower sediments layer (20-30 cm) ($p < 0.05$). The analysis indicates that pH and conductivity do not exhibit significant differences across any sediment layers ($p < 0.05$). In contrast, ORP shows significant variation among all three depths ($p < 0.001$).

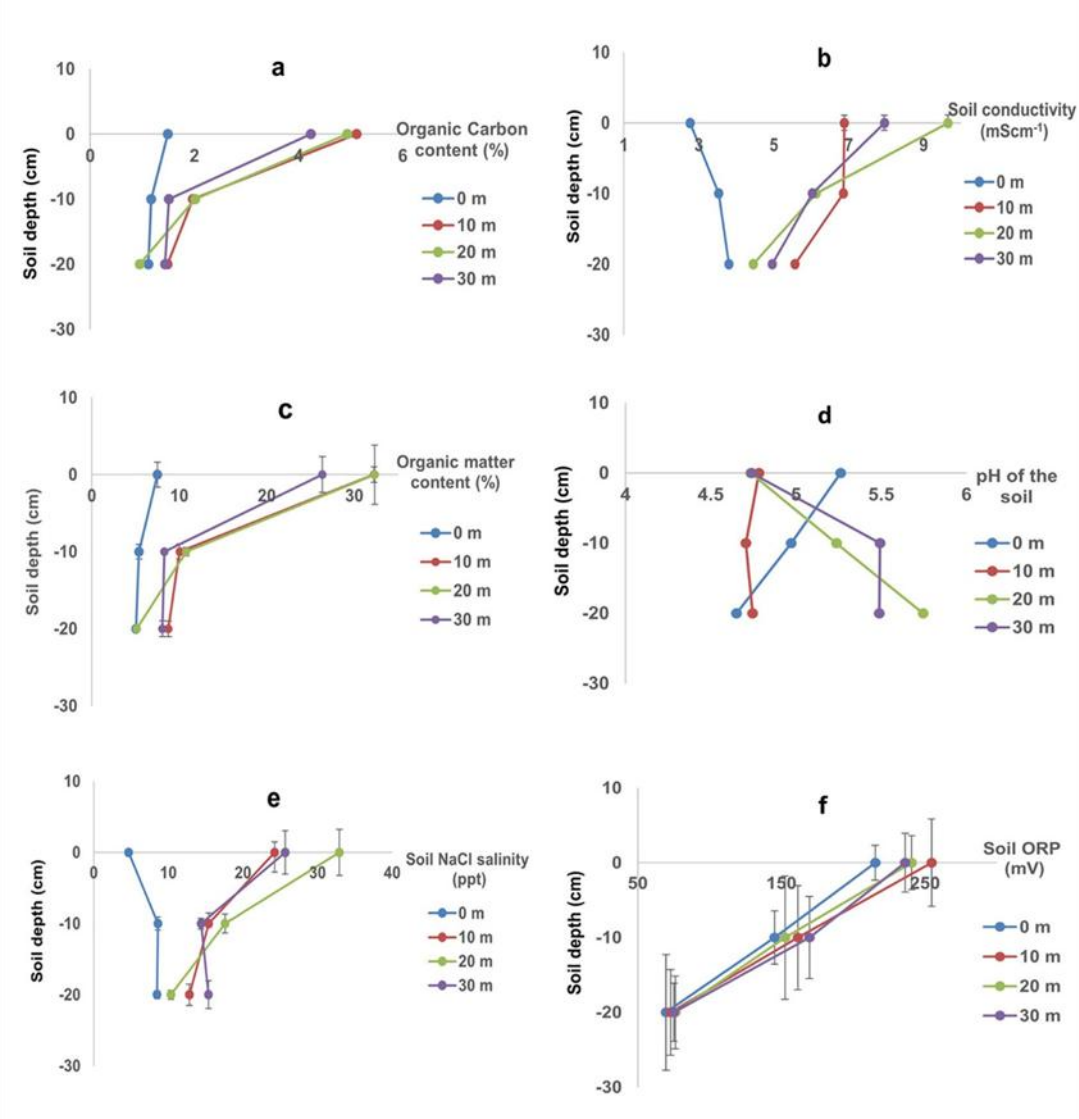


Fig 2. Spatial and vertical distribution of tested sediments parameters in study site. (a) Sediments organic carbon content (%). (b) Sediment electrical conductivity (mS cm^{-1}). (c) Organic matter content (%). (d) Sediment pH. (e) Sediment NaCl salinity (ppt). (f) Sediment ORP (mV).

The percentage of organic carbon and NaCl content increase from the estuary shoreline towards the land in the study site. The highest amount of organic carbon and NaCl salinity are found at a 20 m distance from the estuary shoreline. After that, it is slightly decreased (Figure 3a and Figure 3b).

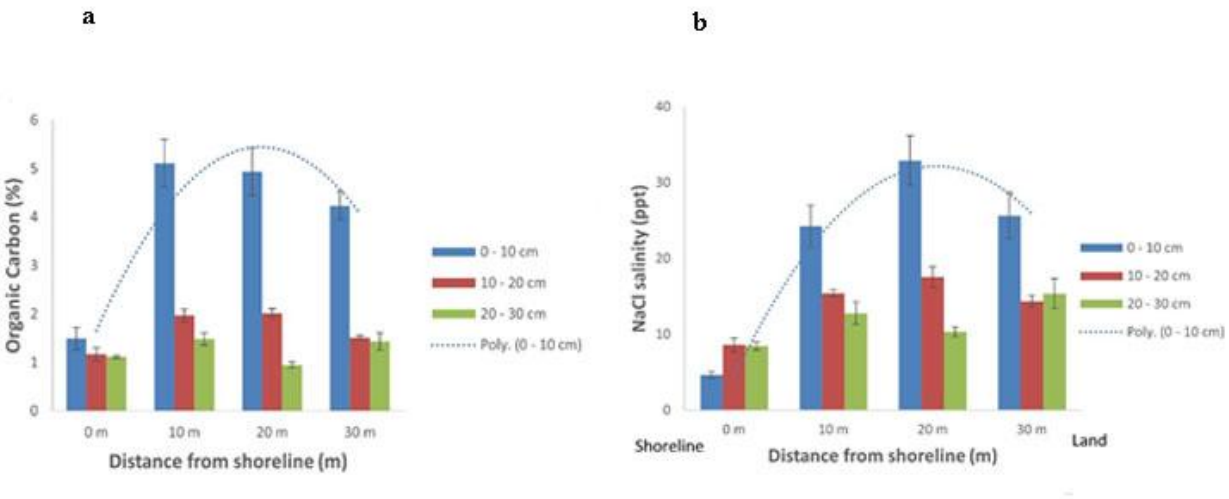


Fig 3. Variation of sediment parameters with varying distance from shoreline to landward in the study site. (a) organic carbon content (%). (b) NaCl salinity (ppt).

Organic carbon is an integral component of the carbon stored in sediment organic matter, and in this study, a similar distribution pattern was observed for both organic matter and organic carbon across the area. The analysis demonstrated a strongly positive correlation between organic matter and organic carbon across all three depths: 0–10 cm (r = 0.99), 10–20 cm (r = 0.95), and 20–30 cm (r = 0.96). Our results revealed that organic carbon had a positive correlation with NaCl salinity and electrical conductivity, while a negative correlation was noted between organic carbon and pH in both surface and intermediate sediment layers. Notably, in the lower sediment layers (20–30 cm), organic carbon showed a negative correlation with ORP (Figure 4).

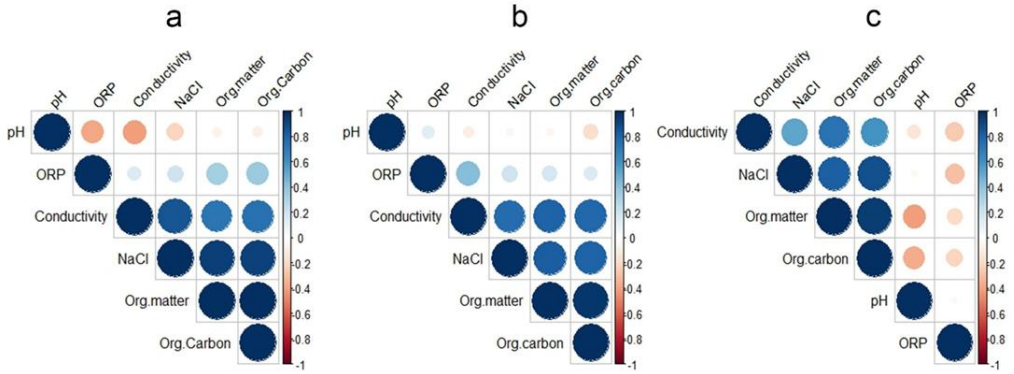


Fig 4. The correlation matrix of organic carbon, organic matter, NaCl, pH, conductivity and ORP of three different depths. (a) Surface sediments (0 -10 cm), (b) Intermediate sediments (10 – 20 cm) and (c) Lower sediments (20-30 cm) of the study sites. Values in the vertical axis are Pearson correlation coefficients between each parameter and the darker the color, greater the correlation between variables

4. Discussion

Mangroves in the Negombo estuary are confined to specific areas within the intertidal zone, likely due to factors such as substrate characteristics, seed and seedling predation, water quality, and human disturbances (De Silva *et al*., 2022). Mangrove species are often distributed in a distinct pattern depending on their tolerance levels of changing environmental conditions, especially sediment salinity and anoxic conditions caused by inundation regimes (Alongi, 2005).

A previous study demonstrated that *A. marina* can tolerate a wide range of salinity levels (De Silva and Amarasinghe, 2021). This species excretes excess salts through specialized salt-excreting glands and trichomes on its leaf surfaces, effectively eliminating approximately 80–85% of salts such as Na^+, K^+, and Cl^- (Göltenboth and Schoppe, 2006). This salt-excretion process may contribute to elevated salinity and electrical conductivity in these areas. Furthermore, Avicennia marina promotes the accumulation of organic matter within sediments, leading to higher organic carbon content, particularly in areas where A. marina is abundant (Figure 1 and Figure 3). *Rhizophora mucronat*a is predominantly found along the estuarine waterfront of the Negombo Estuary, where frequent tidal flushing removes dissolved and particulate organic matter from the sediment surface. This process limits organic matter accumulation and results in comparatively low sediment organic carbon content within the *R. mucronata* zone. As such our findings highlight the variability in carbon sequestration potential among mangrove forests dominated by different species or mixed-species stands

At the Kadolkele study site, the black-colored sediment horizon rich in organic matter extends no deeper than 30 cm. Consequently, sediment samples for this study were collected from three specific depths: 0–10 cm, 10–20 cm, and 20–30 cm. Our findings align with those of Ceron-Bretón *et al*. (2011), indicating that organic matter and organic carbon content in mangrove sediments decrease with depth. This decline is likely due to the reduction in clay content with increasing depth, resulting in a lower cation exchange capacity compared to the clay-rich surface layers. As noted by Perera and Amarasinghe (2019), this reduced cation exchange capacity limits the retention of organic carbon in deeper soil layers.

The carbon sequestration rate in mangrove ecosystems is strongly influenced by environmental conditions, particularly tidal exchange and sedimentation of suspended matter (Kristensen *et al*., 2008). Near the shoreline, regular tidal flushing and river runoff remove dissolved and particulate organic matter, transporting it from the sediment into shallow waters. This process reduces the shoreline sediments' capacity to retain organic matter, resulting in low organic carbon content near the 0 m mark. However, mangrove zones located 10–20 m from the shoreline experience less frequent tidal inundation. Intricate root systems in these areas play a crucial role in trapping litter, both from mangrove vegetation and organic material carried by surface runoff. The relatively low relief of these zones further facilitates organic matter accumulation. Consequently, our study found a progressive increase in organic matter content from the shoreline toward landward areas, accompanied by higher organic carbon levels. Prolonged inundation in these zones creates anaerobic conditions within the sediment, slowing decomposition and allowing partially decomposed organic material to accumulate. This process enhances organic carbon storage, particularly in areas with heavy rainfall or poor drainage (Ceron-Bretón *et al*., 2011; Chaikaew and Chavanich, 2017). Interestingly, beyond 30 m from the shoreline, organic matter and organic carbon content begin to decline. This decrease is likely due to prolonged atmospheric exposure, which accelerates oxidation and releases stored organic carbon as CO_2. Furthermore, reduced tidal inundation in this region limits the input of organic matter from external sources, further contributing to lower organic content.

Mangrove sediments are typically oxygen-deficient due to waterlogging, which restricts oxygen diffusion into sediment pore spaces (Pezeshki and De Laune, 2012). This condition results in relatively low redox conditions, which decrease with depth. Plant roots rapidly consume available oxygen, creating oxygen-deficient conditions that influence microbial activity and sediment reductants (Greenway *et al*., 2006).

In this study, Kadolkele mangrove sediment's oxidation-reduction potential (ORP) values are somewhat higher than those reported in previous studies (Das *et al*., 2012; Cooray *et al*., 2021). This

variation may be due to the presence of numerous crab burrows in the landward zone. These interconnected burrows facilitate oxygen penetration into deeper sediment layers, increasing the surface area of the sediment-air-water interface (Dissanayake and Chandrasekara, 2014). As a result, deeper sediment layers do not exhibit the highly negative ORP values typical of mangrove sediments. Yang *et al*. (2006) reported that high sediment moisture content, clay content and organic matter content of sediment retains high water content. So, it also may cause oxygen-deficient conditions.The current study showed the lowest ORP in the zone near the shoreline. It may be due to the saturation of sediment pore spaces by seawater, and it reduces the spaces to the diffusion of air. This study site is a frequent waterlogged condition was observed in the landward zone (30 m). Hence, this zone retains the tidewater as well as the rainwater for a longer time. Therefore high moisture conditions in sediment of this zone can be the reason for ORP low in this 30 m zone. However, gradgually from surface sediments to deeper sediment layers, ORP values decrease, creating anaerobic conditions that slow decomposition and promote long-term carbon retention. This leads to a negative correlation between ORP and organic carbon (r = -0.19) in deeper sediments. Despite the slow decomposition rate associated with high salinity, the continuous input of organic matter from leaf litter facilitates the accumulation of organic carbon in the sediment. This process plays a vital role in sustaining carbon storage, even under challenging environmental conditions.

The results of this study indicate that sediment organic carbon content is relatively low compared to organic matter content. In the oxygen-deficient conditions typical of mangrove forests, microbial decomposition of sediment organic matter occurs at a significantly slower rate. These anaerobic conditions promote decomposition through slow enzymatic pathways, leading to minimal organic carbon release (Alongi, 2013).

Low oxygen content in sediments leads to reduced ORP, impacting several sediment chemical processes, including denitrification, iron and sulfate reduction, and pH changes (Pezeshki and De Laune, 2012). According to the current study, sediment pH ranges from 3.9 to 6.5, indicating conditions that vary from highly acidic to neutral. Previous studies have reported similar findings, with pH values ranging from 3.92 to 6.82 (De Silva and Amarasinghe, 2007). The accumulation of organic acids from microbial metabolism further lowers sediment pH (Matsui *et al*., 2015), contributing to a negative correlation between organic carbon and sediment pH (r = -0.08, r = -0.17, and r = -0.37, respectively, with depth) (Figure 4). In addition to that, after 10 m from the shoreline, a high density of aerial root system (pneumatophores) can be observed due to oxygen deficiencies under waterlogged conditions. So, it also proves these sites are in oxygen deficient conditions. Also, high clay content in this area can retain more water and subsequent anaerobic conditions in sediment. As a result of this, high anaerobic conditions and low pH can be seen in the study site.

Sediment electrical conductivity reflects the total dissolved ion content in the sediment solution, including Na^+, Ca^{2+}, Cl^-, SO_4^{2-}, K^+, and Mg^{2+}, which accumulate primarily through tidal flooding (Niste *et al*., 2015). Increased ionic strength can affect solute concentrations by reducing the sorption of organic compounds onto sediment particles, thereby enhancing their mobility (Mavi and Marschner, 2012). This process may explain the observed vertical and spatial increase in sediment organic matter content, which correlates with sediment electrical conductivity. The results indicate a strong positive correlation between electrical conductivity and sediment NaCl content across spatial and vertical distributions, with correlation coefficients of r = 0.86, r = 0.77, and r = 0.53 at different sediment depths (Figure 4).

Salinity also exhibits a significant positive correlation with sediment organic matter content, with correlation coefficients of r = 0.93, r = 0.82, and r = 0.82 at different sediment depths (Figure 4). These findings align with those of Hapsari *et al*. (2020), who reported a strong positive relationship between sediment organic carbon concentration and salinity in Java, Indonesia. High sediment salinity can contribute to the accumulation of organic matter in mangrove sediments, primarily through the flocculation of organic material or its aggregation with clay colloids. This process, known as salinity-induced immobilization of organic matter (Kida and Fujitake, 2020), plays a crucial role in organic matter retention within mangrove ecosystems.

These insights highlight the importance of understanding species-specific and environmental influences on mangrove sediment processes, particularly for conservation and restoration efforts in estuarine ecosystems. As such the current study demonstrates the importance of mangrove sediments as long-term carbon sinks, particularly under saline, waterlogged, and low-oxygen conditions that favor organic carbon accumulation. The significantly higher total organic carbon content in surface sediments, and its decline with increasing depth and along the water land gradient, highlight the need to conserve intact sediment profiles to sustain carbon sequestration capacity. Conservation efforts should therefore prioritize the protection of natural hydrological regimes and sediment structure, as disturbances can alter redox conditions and reduce soil carbon storage. From a planning perspective, mangrove areas characterized by high salinity, electrical conductivity, and favorable oxidation reduction potential should be identified as priority zones for conservation and restoration. Management strategies should focus on maintaining natural salinity gradients and minimizing sediment disturbance, rather than solely emphasizing vegetation planting. Incorporating mangrove sediment carbon stocks into coastal management and climate mitigation frameworks will strengthen the role of mangroves as effective blue carbon ecosystems.

5. Conclusion

The findings of this study indicate that mangrove sediment characteristics, including organic carbon content, ORP, and salinity, are influenced by species composition, sediment depth, and tidal dynamics. Different mangrove species contribute to varying levels of sediment organic matter and carbon sequestration. The spatial distribution of organic carbon and ORP suggests that carbon sequestration potential varies across different mangrove zones. Understanding these dynamics is crucial for mangrove conservation and carbon management efforts.

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Conflict of interest

Authors declare no conflict of interest

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