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Assessment of the Blue Carbon Stocks Including Mangroves, Seagrasses, Salt Marshes and Algae in Selected Locations in Northern Province, Sri Lanka

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Abstract
Blue carbon is carbon stored in coastal and marine ecosystems. Coastal ecosystems such as mangroves, tidal marshes, seagrass meadows and algae sequester and store more carbon per unit area than terrestrial forests and are now recognized for their role in mitigating climate change. However, most of these coastal ecosystems are not under protection; hence, their potential as carbon sinks could be threatened. This study aimed to assess the carbon storage capacities of mangroves, seagrasses, salt marshes and algae in selected locations in Northern Province, Sri Lanka. The study was conducted in Vidathalathivu in Mannar, Kiranchi in Kilinochchi and Pooneryn. With regard to For mangrove sampling, belt transects were taken from the shore toward the land. Nested circular plots with a 7m radius were established. Large trees were sampled for diameter and height. Small trees (<3 cm DBH) were sampled in a 2m radius. Litter, pneumatophores and seedlings were sampled in plots of 30 cm x 30cm area. Soil samples were taken at depths; 0-30cm, 30-60cm, 60-100 cm for the measurement of bulk density and carbon content. In the salt marshes and sea grasses, 1 x 1m plots were sampled. 22m x 7m plots were used for planted algae in the sea. In all the ecosystems studied, soil contributed to the highest organic carbon. Mangroves recorded the highest carbon content (695.03 Mg/ha), followed by seagrasses (266.55 Mg/ha), salt marshes (203.95 Mg/ha), and algae (0.38 Mg/ha). The carbon sequestration rate of mangroves was 6.52 Mg/ha/yr. These blue carbon stocks could offset approximately 1.2% of Sri Lanka's annual carbon emissions if properly protected. However, these ecosystems face significant threats from coastal development, aquaculture expansion, and climate change impacts like sea-level rise. The study highlights the significance of conserving and restoring blue carbon ecosystems in mitigating climate change, and provides baseline data for potential carbon offset initiatives that could be valued at US$126-378 per hectare annually, based on current carbon market prices.

Keywords: *Blue carbon, Seagrasses, salt marshes, carbon sequestration, climate change,*

Introduction

Following the Paris Agreement's goal of keeping global warming below 2°C by 2050, it is increasingly vital to recognize, evaluate, and include in future carbon inventories systems that naturally store atmospheric CO_2.

In this context, blue carbon ecosystems provide coastal communities with opportunities to mitigate climate change while also delivering a variety of other ecological benefits. However, these ecosystems are increasingly threatened by anthropogenic activities and climate change impacts. The alteration of environmental conditions by humans, such as changes in soil salinity, water salinity, pH, temperature, and the availability of nutrients, may either directly lead to the extinction of blue carbon plants or cause their existing populations to deteriorate over time. Worldwide, mangroves are being lost at a rate of 0.7-3% annually, seagrasses at 7% annually, and salt marshes at 1-2% annually (Valiela et al., 2001; Duarte et al., 2005; Waycott et al., 2009; Spalding et al., 2010). In Sri Lanka, mangroves and other blue carbon ecosystems have faced significant pressures from shrimp farming, salt pans, poorly planned construction, and unsustainable economic activities.

Studies on blue carbon environments show that mangroves can store carbon around 280 Mg C/ha, tidal marshes around 250 Mg C/ha, and seagrass meadows around 140 Mg C/ha. That is equivalent to capturing 1,030 Mg CO_2,/ha) in mangroves, 920 Mg CO_2/ha in tidal marshes, and 520 Mg CO_2/ha in seagrass meadows (Howard et al., 2014). Donato et al. (2011) reported that Indo-Pacific mangroves store an average of 1,023 Mg C/ha, showing their exceptional capacity for carbon storage. Perera and Amarasinghe (2018) reported total organic carbon in the mangrove ecosystems in Batticaloa Lagoon in Sri Lanka to be 506 t C/ha. The contribution of aboveground components was 131 t C/ha while that of the belowground vegetative components (roots) was 27 t C/ha. The soil contributed to 348 t C/ha, which was the highest.

The organic carbon sequestration in seagrass beds was between 41 and 66 g C/m^2/yr (Kennedy et al., 2010). The carbon storage of seagrass beds was reported to be around 140-194 Mg C/ha globally (Fourqurean et al., 2012). With regard to salt marshes, the carbon storage was around 162 Mg C/ha (Kelleway et al., 2016). However, studies conducted on carbon storage/sequestration of seagrass beds and salt marshes in Sri Lanka are extremely rare, thus the commencement of this study.

This study aimed to assess the carbon storage capacities of mangroves, seagrasses, salt marshes and algae in selected locations in Northern Province of Sri Lanka. Specific objectives include: (i) To partition the biomass and organic carbon content between the plant components and the soil in the blue carbon ecosystems studied. (ii) To compare the differences between mangroves, sea grasses, salt marshes and algae in the distribution of biomass and organic carbon contents.(iii) To assess the carbon sequestration rates of these ecosystems and their potential contribution to climate change mitigation efforts and (iv) To identify current threats to these blue carbon ecosystems and recommend conservation strategies.

Materials and Methods

Study Site

The study was conducted in the Northern Province of Sri Lanka, specifically in Vidathalathivu in Mannar, Kiranchi in Kilinochchi and Pooneryn. The Northern Province is located in northern Sri Lanka, surrounded by the Gulf of Mannar and Palk Bay to the west, the Bay of Bengal to the north and east, and the Eastern, North Central, and North Western provinces to the south.

The climate of the province is characterized as tropical monsoonal, with a distinct dry season (February to September) and a wet season (October to January). The average annual temperatures range between 28°C and 30°C, with January being the coolest month and May the warmest. The relative humidity ranges from 70% during the day to 90% at night. The annual precipitation in the north-west and south-east of the Inland is less than 1,250 mm, with rainfall primarily occurring during the north-east monsoon (November to February).

These study sites were selected based on the presence of relatively undisturbed blue carbon ecosystems and also to represent different hydrogeomorphic settings. The mangrove stands in Vidathalathivu are part of a larger contiguous patch (approximately 390 ha) dominated by *Avicennia marina*, while Pooneryn and Paliyaru have smaller, more fragmented stands. The seagrass beds in Vidatalativu and Kiranchi represent meadows with different dominant species and exposure to wave action. The salt marshes at Maligaithidal and Sippi Aru differ in tidal regimes and freshwater influence.

Table 01 describes the details of the sampling sites selected for the study while Figure 1 shows them on Sri Lanka map.

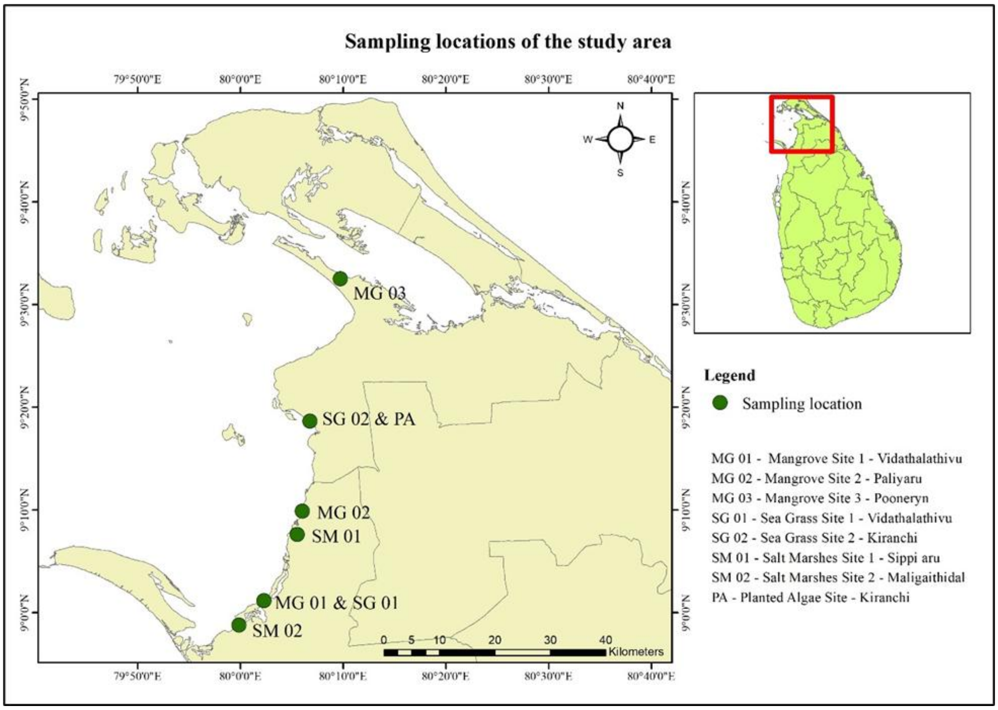

Figure 01: *Map of Selected sampling sites for mangrove, salt marshes, and seagrass ecosystems in Northern Province, Sri Lanka.*

Table 01: Details of the sampling sites selected for mangrove, seagrass, salt marsh and algae ecosystems, including GPS locations.

Ecosystem type	Location name	GPS location	No. of plots	Plot size/m^2	Total area sampled/ m^2
Mangrove site 1	Vidathalathivu	9.01947°N, 80.03842°E	5	154	770
Mangrove site 2	Pooneryn	80.159149 9.540139	5	154	770
Mangrove site 3	Paliyaru	9° 9'50.87"N, 80° 6'9.48"E	5	154	770

Sea Grass	Vidatalativu	9.01947°N, 80.03842°E	5	1	5
Sea Grass	Kiranchi	9°18'37.35"N, 80° 6'49.62"E	7	1	7
Salt marshes site 1	Maligaithidal	10°52'38.90"N, 79°17'27.70"E	5	1	5
Salt marshes site 2	Sippi aru	9° 7'34.13"N, 80° 5'33.37"E	6	1	6
Planted algae	Kiranchi	9°18'37.35"N, 80° 6'49.62"E	2	154	308

Sampling Methods

Mangroves

Belt transects were taken from the shore towards the land. Nested circular plots having 7m radius were established, large trees (DBH > 3 cm) were sampled for diameter at breast height (DBH) and height. Small trees (<3 cm DBH) were sampled in 2 m radius plots concentric with the larger plot. Litter, pneumatophores and seedlings were sampled in plots of 30 cm x 30 cm area within the 2 m radius plot. Five replicate plots were established at each site to ensure representative sampling of the ecosystem.

Soil samples were taken at depths; 0-30 cm, 30-60 cm, 60-100 cm using a soil auger with a diameter of 5 cm for the measurement of bulk density and carbon content. It should be noted that mangrove soils can extend beyond 1m depth, sometimes reaching several meters (Donato et al., 2011), so our measurements likely represent conservative estimates of the total soil carbon pool.

Hemispherical photographs were taken using a hemi-photo setup, which included fish eye lenses on cameras, remotely sensed data, and a spherical densiometer to estimate carbon sequestration. These photographs were taken at the center of each plot at a height of 1.3 m above the ground, levelled, and oriented to magnetic north. The images were analyzed using HemiView Canopy Analysis Software (Delta-T Devices, UK) to calculate canopy openness, leaf area index (LAI), and photosynthetically active radiation (PAR) interception. These parameters were then used to estimate net primary production and carbon sequestration following the approach described by Monteith (1972) and adapted by Patil et al. (2013) for tropical mangroves.

Seagrasses

Belt transects were established parallel to the seascape and 1m x 1m plots were established along the transect constructed in the study sites of Vidatalativu and Kiranchi. A total of 5 plots were sampled in Vidatalativu and 7 plots in Kiranchi. In each plot, species composition was identified, and the frequency of seagrass in the plot was counted. Further, the percentage coverage of the seagrasses in the plot was observed.

Within a 30 cm x 30 cm quadrat in each plot, all seagrass shoots were carefully uprooted to ensure collection of both above and belowground biomass. Samples were placed in clean, labeled polythene bags containing GPS location, time, date, and species name for subsequent experiments and carbon analysis.

Soil samples were taken at each plot to a depth of 1 m (0-30 cm; 30-60 cm and 60-100 cm). The soil samples were placed in clean polythene bags and brought to the laboratory for carbon assessment.

Salt Marshes

Belt transects were established parallel to the seascape and 1 m x 1 m plots were established along the transects constructed in the study sites of Maligaithidal and Sippi Aru. A total of 5 plots were sampled in Maligaithidal and 6 plots in Sippi Aru. In each plot, species composition was identified and the frequency of salt marsh species in the plot was counted. Further, the percentage coverage in the plot was observed.

Within a 30 cm x 30 cm quadrat in each plot, all salt marsh vegetation was carefully uprooted to ensure collection of both above and belowground biomass. The samples were brought to the laboratory for carbon analysis.

Soil samples were taken at the core of each plot in three depth intervals, as same as the mangroves and seagrasses.

Algae

Algae sampling was carried out using 22 m x 7 m square plots which comprised 73 lines. Each line consisted of an average of 39 clumps, resulting in a total average of 2847 algae clumps for each plot. Two plots were used for sampling purpose. In each plot, species were identified and the frequency in the plot was counted.

It is important to note that the algae studied were from aquaculture farms and were not rooted in soil but were attached to ropes suspended in the water column.

Therefore, soil carbon was not assessed for algae. However, future studies should consider the potential contribution of algae to carbon burial in adjacent sediments, as suggested by Krause-Jensen and Duarte (2016).

Assessment Methods to Calculate Total Organic Carbon Content

Assessment of Vegetative Organic Carbon

For mangroves, the following allometric equations were used to calculate the above-ground and below-ground biomass:

For *Avicennia marina:*
Above Ground Biomass (AGB) = $0.1848 (DBH)^{2.3524}$ - (Dharmawan and Siregar, 2008)
Below Ground Biomass (BGB) = $0.199p^{0.899} (DBH)^{2.22}$ – (Dharmawan and Siregar,2008)
Wood Density p= 0.66 (World Agroforestry Centre, 2011)

For *Rhizophora* spp:
Above Ground Biomass (AGB) = $0.1709 (D)^{2.516}$ - (World Agroforestry Centre, 2011)
Below Ground Biomass (BGB) = $0.199 p^{0.899} (D)^{2.22}$
Wood Density p = 1.05

For *C. tagal:*
Above Ground Biomass (AGB) = $0.32D^{2.56}$ - (Comley and McGuiness, 2005)
Below Ground Biomass (BGB) = $0.158D^{1.95}$

While these equations were not developed specifically for Sri Lankan mangroves, they were selected based on similar species and climatic conditions in the Indo-Pacific region. We acknowledge that using non-site-specific allometric equations introduces some uncertainty in our biomass estimates, which could be addressed in future studies by developing local allometric equations.

The carbon content was calculated using a carbon conversion factor of 0.5 for above-ground and below-ground biomass, 0.45 for litter and seedlings, and 0.39 for pneumatophores, following Kaufman and Donato (2012).

For seagrasses and salt marshes, the samples were oven-dried at 105°C until a constant weight was achieved. The carbon content was calculated as 35% of the dried weight as per Fourqurean et al. (2012a).

For Algae, the carbon content was determined using the Walkley-Black method following the procedure described by E. Grobler (1979). In this method, the organic carbon in the sample is oxidized by potassium dichromate in the presence of concentrated sulfuric acid, and the unreacted dichromate is titrated with ferrous ammonium sulfate.

Assessment of Soil Organic Carbon

Soil samples were oven-dried at 105°C until a constant weight was achieved. Soil bulk density was calculated by dividing dry weight of the sample by the volume of the sample. The carbon content was assessed using the Loss on Ignition (LOI) method, where samples were heated at 450°C for 16 hours in a muffle furnace.

The organic carbon content was calculated as follows:
%C (combustion) = 0.03 + 0.36 x %weight loss by LOI (Konare et al., 2010)

Soil Carbon (Mg/ha) = Bulk density x Soil Depth interval x %C

Total soil carbon pools were determined by summing the carbon content of each sampled soil depth interval (0-30 cm, 30-60 cm, and 60-100 cm). It is important to note that our sampling was limited to 1m depth, which is likely an underestimate of the total soil carbon pool, particularly in mangrove ecosystems where carbon-rich soils can extend several meters deep (Donato et al., 2011).

Assessment of Total Organic Carbon

Total organic carbon in mangroves was calculated by summing the carbon in above-ground, below-ground, seedlings, litter, pneumatophores, and soil components. For seagrasses and salt marshes, total organic carbon was calculated as the sum of vegetative carbon and soil carbon. For algae, only vegetative carbon was considered as the plantation was not connected to the soil.

Converting Organic Carbon into Carbon Dioxide Equivalents

The total carbon stock was converted to CO_2, equivalents by multiplying by 3.67 using the following equation:

1 t C = 3.67 t CO_2 (US EPA, 2019)

Economic Valuation of Carbon Stocks

To provide an economic context for the carbon sequestration potential of these ecosystems, we calculated the economic value of the carbon stocks using current carbon market prices. The voluntary carbon market price for blue carbon credits ranges from US$5-15 per tonne CO_2, equivalent (Wylie et al., 2016). We used this range to estimate the economic value of the carbon sequestration rates observed in our study.

Statistical Analysis

Basic descriptive statistics, including means, standard errors, and ranges, were calculated for carbon stocks in different ecosystem components. One-way ANOVA was performed using MINITAB statistical software to test for significant differences in carbon storage between different ecosystems and sites. When significant differences were detected ($p < 0.05$), Tukey's post-hoc test was used to identify which means differed significantly. Correlation analysis was also conducted to examine relationships between ecological factors (species composition, stand density) and carbon storage.

Results and Discussion

Mangrove Ecosystems

Vegetation Structure of Mangroves

Six mangrove species were identified in the study sites: *Avicennia marina, Ceriops tagal, Excoecaria agallocha, Luminetzera racemose, Rhizophora murconata and Pemphis acidula.* The stand density was highest in Vidatalativu (3214 ± 1607 trees/ha) compared to Pooneryn (2240 ± 137.7 trees/ha) and Paliyaru (2273 ± 298 trees/ha). According to the Shannon index, Pooneryn mangrove site recorded the highest species diversity (Shannon index = 2.30) despite not having the highest tree density.

Avicennia marina recorded the highest Importance Value Index (IVI) in all sites, being well represented due to its high population compared to other species. This species showed high tolerance to salinity, which may explain its dominance in the study area. Roberts et al. (2011) explained that A. marina has a series of cambia that together create internal phloem tissues with water-holding capacity that may also heal embolisms by forming new vascular cells, contributing to its high salinity tolerance.

Species distribution in mangroves is influenced by water salinity, soil salinity, tidal height, and soil aeration. *Avicennia marina* is commonly found near the shoreline due to its high tolerance for these environmental factors.

Biomass and Total Organic Carbon Content in Mangroves

The biomass and organic carbon content of mangroves is presented in Table 2.

Table 02: *Biomass and Total Organic Carbon (TOC) content (above and below ground) values recorded for mangroves in the study sites.*

Sampling area	**Biomass ($Mgha^{-1}$)**			**Total organic carbon (TOC) content (Mg C ha-1)**		
	Above ground	**Below ground**	**Total**	**Above ground**	**Below ground**	**Total**
Vidathalathivu	177.77 ± 58.07	132.39± 49.75	310.16± 107.82	88.88 ±29.04	66.2 ± 24.88	155.08 ± 53.58
Pooneryn	196.67± 59.57	137.63± 46.5	334 ± 106.07	98.33 ± 29.78	68.81±23.25	167.15± 49.79
Paliyaru	230.68± 97.22	123.48± 32.29	354.16± 129.51	115.34±48.61	61.74 ± 16.15	177.08 ± 56.63
Mean for entire study area						166.43 ± 11.02

No significant differences were found in biomass or carbon content between the three mangrove sites (ANOVA, $p > 0.05$). The total vegetative organic carbon captured by the ecosystem considering all components (stand, pneumatophores, litter, and seedlings) was highest in Pooneryn (198.90 Mg/ha) followed by Vidathalathivu (189.85 Mg/ha) and Paliyaru (179.25 Mg/ha). The mean vegetative organic carbon for the entire study area was 189.33 Mg/ha.

These results are higher than those reported by Perera and Amarasinghe (2018) for mangroves in Batticaloa lagoon, Sri Lanka (158.57 Mg/ha). One possible explanation for this difference is the relatively undisturbed nature of the Northern Province mangroves compared to those in Batticaloa, which have experienced greater anthropogenic pressures.

Comparing with international studies, our findings are in line with those reported by Kauffman and Cole (2010) for mangroves in Micronesian locations (169-517 Mg/ha) and Fatoyinbo et al. (2018) for mangroves in Africa's Zambesi River (192-252 Mg/ha). However, they are lower than the global average reported by Donato et al. (2011) for Indo-Pacific mangroves (1,023 Mg/ha), which may reflect differences in environmental conditions, stand age, or methodology.

Soil Organic Carbon Content in Mangroves

The soil organic carbon content in mangroves is presented in Table 03.

Table 3: Soil Bulk Density and total organic carbon in mangrove sites at three depth intervals.

Depth/ cm	SBD for samples from Vidatalativu	Vidathalathive site TOC Mg ha-1	SBD for samples from Pooneryn	Pooneryn TOC $Mgha^{-1}$	SBD for samples from Paliyaru	Paliyaru TOC $Mgha^{-1}$
0-30	1.675	239.20± 67.7	1.003	214.46±12.6	1.624	210.90±70.3
30-60	1.188	133.09±40.1	0.885	119.02±2.7	1.161	173.43±18.8
60-100	1.051	164.92±2.4	0.636	151.4±47.1	0.942	112.5±10.1
Total Soil OC of the site		537.20±110.2		484.88±22.4		495±99.2

A trend was identified in soil organic carbon distribution with depth, with higher content in the surface soil (0-30 cm) compared to deeper layers in all sites. This is consistent with findings from other studies on tropical forests, including mangroves (Banerjee et al., 2013; Perera and Amarasinghe, 2015). However, in Vidatalativu and Pooneryn, there was a higher carbon content in the 60-100 cm layer compared to the 30-60 cm layer, possibly due to the clay soil texture with high cation exchange capacity in the deeper layer.

The high bulk density in Vidathalathivu (mean 1.30 g/cmÂ^{3}) compared to other sites may be due to its clay-type soil, which contributes to its higher soil organic carbon content. The mean soil organic carbon content for the entire study area was 505.69 Mg/ha, which is higher than that reported by Perera and Amarasinghe (2018) for mangroves in Sri Lanka (316-580 Mg/ha, mean 405 Mg/ha).

It is important to note that our sampling was limited to 1 m depth, which likely underestimates the total carbon soil pool. Kauffman et al. (2020) found that mangrove soil carbon stocks can extend to depths of 3m or more, potentially doubling the total carbon stock compared to 1 m sampling.

Carbon Sequestration in Mangroves

Carbon sequestration rate was calculated based on net biomass accumulation through net primary production, as estimated from hemispherical photography analysis. The highest rate was recorded in Paliyaru (7.25 Mg/ha/yr), while Pooneryn and Vidatalativu recorded 6.75 Mg/ha/yr and 6.10 Mg/ha/yr, respectively. The mean carbon sequestration rate for the entire study area was 6.52 Mg/ha/yr.

These values are comparable to those reported by Ong et al. (1984, 1993) for monocultures of *Rhizophora apiculata* in Malaysia (1.6, 9.0, 6.5, and 6.0 t C/ha/yr for stands of 5, 10, 15, and 25 years of age, respectively) and fall within the global range of 1.8-14 Mg/ha/yr reported by Mcleod et al. (2011).

The relatively high carbon sequestration rates observed in our study sites indicate the healthy state of these mangrove ecosystems and their significant potential for climate change mitigation if properly protected and managed.

Seagrass Ecosystems

Vegetation Structure of Seagrasses

Three seagrass species were identified in the study sites: *Thalassima hemprichii, Cymodocea serrulate,* and *Ruppia maritima.* The dominant species in Vidatalativu was *Thalassima hemprichii* with a relative density of 64,286 plants/ha, while in Kiranchi, *Cymodocea serrulate* was dominant with a relative density of 48,667 plants/ha.

According to the Shannon diversity index, Kiranchi exhibited higher ecological diversity (1.27) compared to Vidatalativu (0.70), indicating a more even distribution of species in Kiranchi, despite having fewer total plants.

Biomass and Total Organic Carbon Content in Seagrasses

The biomass of seagrasses in Vidatalativu (3.88 Â± 1.53 Mg/ha) was higher than in Kiranchi (3.08 ± 1.15 Mg/ha), though this difference was not statistically significant (ANOVA, $p = 0.293$). Correspondingly, the total organic carbon content was higher in Vidatalativu (1.36 ± 0.54 Mg/ha) compared to Kiranchi (1.08 ± 0.40 Mg/ha). The mean vegetative organic carbon for the entire study area was 1.15 Mg/ha.

Although these values are lower than those reported by Fourqurean et al. (2012b) for Mediterranean meadows dominated by *Posidonia oceanica* (7.29 Mg/ha), they are comparable to those for Florida Bay seagrasses dominated by *T. testudinum* (1.44 Mg/ha). The difference can be attributed to variations in species composition, as Mediterranean seagrasses like *P. oceanica* are known to have larger biomass and higher carbon content compared to tropical species (Lavery et al., 2013).

Soil Organic Carbon Content in Seagrasses

The soil organic carbon content in seagrasses showed a decreasing trend with increasing depth, with the highest values in the 0-30 cm layer (Table 4). The total soil organic carbon was similar in both sites: 266.90 ± 47.5 Mg/ha in Vidatalativu and 263.91 ± 47.7 Mg/ha in Kiranchi, with no significant difference between sites (ANOVA, $p = 0.889$). The mean soil organic carbon for the entire study area was 265.40 Mg/ha.

This consistent decrease in organic carbon with depth differs from the pattern observed in mangroves and suggests different carbon accumulation processes. In seagrass meadows, the carbon accumulation is predominantly driven by the trapping of suspended particles from the water column and the direct deposition of seagrass detritus, both of which are more active in surface sediments (Kennedy et al., 2010).

Total Organic Carbon Content in Seagrasses

The total organic carbon content (vegetative + soil) was 268.2 ± 48.0 Mg/ha in Vidatalativu and 264.9 ± 47.5 Mg/ha in Kiranchi, with a mean of 266.55 Mg/ha for the entire study area. Soil carbon contributed 99.56% of the total organic carbon.

These values are higher than those reported by Carly et al. (2021) for seagrass meadows in India (184.24 ± 23.84 Mg/ha), Myanmar (136.67 ± 64.77 Mg/ha), Thailand (134.20 ± 73.89 Mg/ha), and Vietnam (133.16 ± 36.97 Mg/ha).

Salt Marsh Ecosystems

Vegetation Structure of Salt Marshes

Two salt marsh species were identified in the study sites: *Suaeda* sp. and *Salicornia* sp. The dominant species in both Maligaithidal and Sippi Aru was *Salicornia* sp., with densities of 440,000 plants/ha and 545,000 plants/ha, respectively.

Biomass and Total Organic Carbon Content in Salt Marshes

The biomass of salt marshes was higher in Sippi Aru (4.74 Mg/ha) compared to Maligaithidal (2.98 Mg/ha). Correspondingly, the total organic carbon content was higher in Sippi Aru (1.66 ± 0.53 Mg/ha) compared to Maligaithidal (1.04 ± 0.34 Mg/ha). The mean vegetative organic carbon for the entire study area was 1.15 Mg/ha.

Soil Organic Carbon Content in Salt Marshes

The soil organic carbon content in salt marshes showed a decreasing trend with increasing depth, with the highest values in the 0-30 cm layer. The total soil organic carbon was higher in Maligaithidal (206.32 ± 32.76 Mg/ha) compared to Sippi Aru (195.14 ± 26.3 Mg/ha). The mean soil organic carbon for the entire study area was 201.65 Mg/ha.

Total Organic Carbon Content in Salt Marshes

The total organic carbon content (vegetative + soil) was 207.36 ± 32.79 Mg/ha in Maligaithidal and 196.8 ± 26.8 Mg/ha in Sippi Aru, with a mean of 202.8 Mg/ha for the entire study area. Soil carbon contributed 99.4% of the total organic carbon.

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