

Exploring the biomass and carbon stock of mangrove vegetation in Palk Bay's dugong conservation reserve

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Mangroves are crucial tropical carbon sinks, yet the carbon reserves in Indian mangrove ecosystems, particularly in Palk Bay, remain under-researched. This study evaluates the carbon stock of mangroves in the Dugong Conservation Reserve, Palk Bay, covering 15 zones and 47 transects. Four true mangrove species: *Avicennia marina*, *Rhizophora mucronata*, *Excoecaria agallocha*, and *Lumnitzera racemosa*, were identified with *Avicennia marina* contributing most to the biomass and carbon stock. The mean total biomass obtained was 40.09 ± 26.64 Mg/ha, with above-ground biomass of 25.31 ± 18.86 Mg/ha and below-ground biomass of 14.77 ± 7.93 Mg/ha. Zone 2 exhibited the highest mean biomass per unit area (89.03 Mg/ha) and vegetation carbon stock (38.87 Mg-C/ha), followed by Zone 10. Relatively low biomass and carbon stock values observed in this study can be attributed to the low diversity and abundance of mangrove species in the region. These results underscore the significant carbon storage capacity of the Dugong Conservation Reserve's mangroves and highlight the need for targeted conservation and management efforts to enhance carbon sequestration. This study also emphasises the interconnectedness of mangroves and seagrass ecosystems, which support species like dugongs, reinforcing the reserve's ecological importance.

[**Keywords:** Biomass, Carbon stock, Dugong conservation reserve, Mangrove]

Introduction

Mangroves are a group of salt-tolerant trees and shrubs that grow in the intertidal zones of tropical and subtropical regions around the world¹. They are highly productive ecosystems with significant ecological, economic, and social value. Mangrove forests play a crucial role in mitigating littoral erosion, stabilising coasts, and reducing the damaging impact of hurricanes, waves, tsunamis, and cyclones². These forests also serve as essential habitats for numerous species and support local communities by providing livelihood opportunities³. Mangroves play a critical role in maintaining the water quality of coastal areas, serving as a natural filter that prevents pollutants from entering the ocean⁴. They provide breeding and nursery habitats for a wide range of important fish and invertebrate species and provide numerous ecosystem services, such as aquaculture and tourism⁵.

Mangrove ecosystems have a remarkable ability to store carbon, which is evident from their high soil

carbon stock⁶ and additional support from above-ground biomass, net primary production, low sediment breakdown rate, and high ratio of below-ground to above-ground biomass⁴. This makes them capable of sequestering 3 – 5 times more carbon than upland forests, including temperate and boreal forests that primarily store carbon in soil^{4,6}. Hence, mangroves have a crucial role to play in mitigating climate change. Coastal ecosystems store a significant amount of carbon, commonly referred to as "blue carbon", with considerable proportion sequestered in the below-ground biomass and a smaller fraction stored in the above-ground biomass⁶. Mangroves, which only cover 1 % of the total tropical forest area on earth⁷, are responsible for 3 – 4 % of global carbon sequestration by tropical forests and 10 – 15 % of the ocean's carbon sequestration⁶. The importance of mangrove habitats in mitigating global climate change is now widely recognized¹. In addition to their ecological value, mangroves provide significant economic benefits. They support fisheries by serving

as breeding and nursery grounds, which is crucial for the livelihoods of coastal communities⁴. Mangrove wood is also used for fuel and construction materials, while the forests offer potential for sustainable aquaculture practices, further contributing to local economies⁸.

Mangrove vegetation plays a crucial role in maintaining the health of coastal ecosystems due to its myriad benefits². These ecosystems serve as nurseries and feeding grounds for various species, including dugongs, which rely on seagrass beds found in mangrove areas for food⁵. The presence of mangroves also enhances seaweed biomass, as they provide shelter and nutrient-rich environments for seaweed growth⁹. Therefore, the conservation and restoration of mangrove habitats are essential not only for maintaining carbon stocks and ecosystem health but also for supporting the biodiversity and sustenance of various marine species, including seagrass³, which are vital for the survival of dugongs.

The increasing demand for mangroves for timber and firewood, agricultural land conversion, clearance of mangroves for aquaculture, and coastal pollution pose significant threats to this crucial environment⁴. Given the strategies being implemented to combat climate change, the value of mangroves as a source of carbon sequestration is gaining more recognition. The rising levels of CO₂ in the atmosphere highlight the necessity of finding effective and acceptable approaches to reduce atmospheric CO₂, and carbon sequestration appears to be a more practical strategy. According to the Intergovernmental Panel on Climate Change (IPCC), carbon sequestration through agriculture and forests can significantly reduce atmospheric CO₂ that contribute to global warming¹⁰. To increase carbon storage and credits, mangrove preservation and restoration are crucial¹¹. The state of Tamil Nadu has a mangrove forest cover of 44.94 sq. km, according to the Indian State Forest Report (ISFR) provided by the Forest Survey of India¹². Within this area, very dense mangrove covers 1.11 sq. km, while open and moderately dense mangroves cover 16.88 sq. km and 26.95 sq. km, respectively. Studies assessing the carbon and biomass content of Tamil Nadu's mangroves have yielded several noteworthy findings. For example, Gnanamoorthy *et al.*¹³ reported that the carbon sequestration rate of Pichavaram mangrove forests ranged from 2.33 to 4.44 g C/m²/year. In addition, Narmada *et al.*¹⁴ found that the mangroves in

Muthupett sequestered about 1475.642 Mg/ha of carbon dioxide in 2000, 3646.312 Mg/ha in 2010, and 1677.72 Mg/ha in 2017.

Current study area encompasses the dugong conservation reserve along the Palk Bay coast, spanning the Thanjavur and Pudukkottai districts in Tamil Nadu. According to the FSI¹² mangrove report, the mangrove cover in Thanjavur and Pudukkottai districts was 12.30 sq. km and 1.93 sq. km, respectively. Despite the area's significance, this is the first study that has assessed the biomass and vegetative carbon stock in this region, highlighting the need for detailed site-specific study. By quantifying these parameters, this research aims to fill the knowledge gap and contribute to the existing literature on mangroves. Moreover, given the study area's recognition as an Important Marine Mammal Area (IMMA) by the International Union for Conservation of Nature (IUCN), our findings have global relevance for mangrove conservation efforts.

Materials and Methods

Study area

Palk Bay in Tamil Nadu is among the ecologically significant regions along the mainland coast of India. It is situated between latitudes 9°55' N – 10°45' N and longitudes 78°58' E – 79°55' E with a maximum water depth of 13 m. The area is characterised by a tropical climate, with high temperatures and moderate to heavy rainfall during the monsoon season. This study was conducted as part of a baseline study for the Dugong Conservation Reserve (DCR), which contains 47 mangrove sites from Adirampattinam of Thanjavur district to Ammapattinam of Pudukkottai district along the coast of Palk Bay (Fig. 1). The mangrove species found in these sites include *Avicennia marina*, *Rhizophora mucronata*, *Excoecaria agallocha*, and *Lumnitzera racemosa*, among others. These species thrive in the intertidal zones of the bay, contributing to the rich biodiversity of the region. The 47 sampling stations were divided within 15 zones such as Adirampattinam (Zone 1), Rajamadm Reserve Forest (Zone 2), Agni River Islet (Zone 3), Velivayal (Zone 4), Manora (Zone 5), Ambuliar Estuary (Zone 6), Manthiripattinam (Zone 7), Adaikkathevan (Zone 8), Somanathanpattinam (Zone 9), Kattumavadi (Zone 10), Subramaniapuram (Zone 11), Mumbalai (Zone 12), Kodimunai (Zone 13), Vadakku Ammapattinam (Zone 14), and Avudaiyarpattinam (Zone 15).

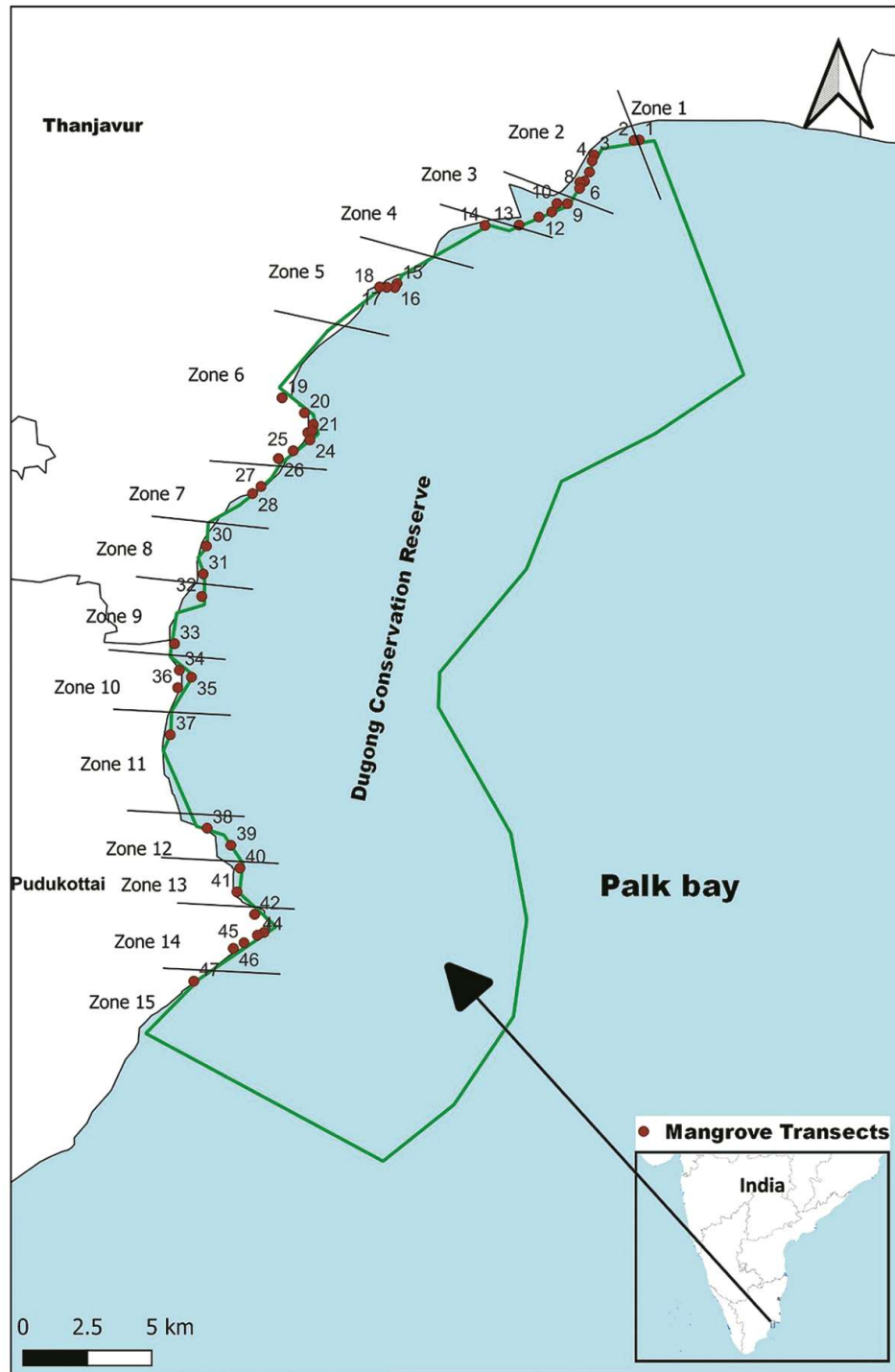


Fig. 1 — Map illustrating the transects in the study area

Field survey and data analysis

Between June and August 2022, field surveys were conducted across the study area, which included 47 sites selected based on receptiveness, importance, and accessibility. For non-destructive determination of biomass, vegetation carbon stock, and species

composition, one linear transect (100 m) was laid perpendicular to the waterfront in each site, with 10×10 m quadrants established along the line transect. These quadrants were examined at 0, 50, and 100 m of the line transect. The assessment included counting all mangrove trees and estimating their girth to breast

height (GBH) and height in meters, but saplings and seedlings were excluded from the study to focus specifically on mature trees. Excluding saplings and seedlings allowed for a more accurate assessment of the carbon stock and biomass of established mangrove forest, which are the primary contributors to carbon sequestration and ecosystem services. Mangroves were identified at the species level at every quadrant, following the methodology described by Kathiresan *et al.*¹⁵.

In this study, the allometric equations for mangroves of Southeast Asia established by Komiyama *et al.*¹⁶ were utilised to estimate the above-ground biomass - AGB (W_{top}) and below-ground biomass - BGB (W_R). These equations use diameter and wood density as predictive variables, and they have a high coefficient of determination (R^2) of 0.979 and 0.954, respectively. The basal area was calculated by dividing the girth by 4π .

The following allometric equations were employed for the calculations.

$$W_{top} = 0.251 rD^{2.46}$$

$$W_R = 0.199 r^{0.899} D^{2.22}$$

Where, W_{top} is the above-ground biomass (kg), W_R is the below-ground biomass (kg), ρ is the species' wood density, and D is the diameter at breast height.

The study also utilised the definitions proposed by Kauffman & Donato¹⁷ to determine the status of standing dead trees, followed by the application of carbon stock correction factors. The three categories of standing dead trees are those without leaves, those without secondary branches, and those without either primary or secondary branches. To calculate the biomass of standing dead trees, Kauffman & Donato¹⁷ recommended subtracting a proportion ranging from 2.5 % (for Class 1 dead trees) to 20 % (for Class 2 dead trees) from the allometric equation developed for live trees. For Class 3 dead trees, the volume of the remaining stem is multiplied by the density of the wood to estimate the biomass.

The wood density of the mangrove species in the Palk Bay area was retrieved from the World Agroforestry Database. The total mean biomass was calculated by adding up the total above and below-ground biomass and dividing it by the total number of plots, expressed as megagrams per hectare (Mg/ha). To determine the carbon content of above and below-ground biomass, biomass was multiplied by 0.48 and 0.39, respectively, according to Kauffman &

Donato¹⁷. The resulting mangrove carbon stock was then converted into CO₂ equivalents by multiplying it with a factor of 3.67, which is derived from the molecular weight ratio between carbon and carbon dioxide¹⁷.

Quantification of species diversity and statistical analysis

The equitability or evenness of woody species in each plot was evaluated using Pielou's index¹⁸, and the overall diversity of woody species was determined using Shannon's index, whereas above-ground biomass was used to link these indices. Statistical and graphical analyses were performed using PAST software¹⁹.

Results

In the study area, four true mangrove floral species from four families were identified, namely *Rhizophora mucronata* (Rhizophoraceae), *Avicennia marina* (Acanthaceae), *Lumnitzera racemosa* (Combretaceae), and *Excoecaria agallocha* (Euphorbiaceae). However, in certain zones, such as zones 1, 4, 7, 11, 14, and 16, the mangroves present were mostly saplings and therefore were not included in the carbon assessment. *Avicennia marina* (Forssk.) was found to be the most dominant species, with a dense population in some transects. The following most dominant species was *Rhizophora mucronata* (Poir.), while only a few *Lumnitzera racemosa* (Willd.) and one tree of *Excoecaria agallocha* (Linnaeus) were found in the study area. The *Lumnitzera racemosa* found were mostly saplings and seedlings, hence, they were not included in the assessment of carbon data. Zones 6 and 2 showed high species diversity.

In sample station 2, all mangroves were standing dead trees. The recorded mean tree density and basal area in mangroves of the study area were 6500 and 33.87, respectively, ranging from 100 to 6,500 trees/ha and from 0.22 to 19.26 m²/ha, respectively. Sample station 2 of zone 2 had the highest tree density (6500 trees), while sample station 15 of zone 5 had the highest mean basal area (Table 1). Shannon index (H') and Pielou's evenness index (J') ranged from 0.04 – 1.30 and 0.50 – 0.96, respectively (Table 2).

Biomass and vegetation carbon stock

The study area's mean total biomass was of 40.09±26.64 Mg/ha, comprising mean above-ground biomass of 25.31±18.86 Mg/ha and mean below-

Table 1 — Biomass and carbon sequestration in mangroves of Dugong Conservation Reserve (In zones 1, 4, 7, 11, & 14, the mangroves present are all saplings and seedlings, hence excluded from analysis)

Zone	Transac ts	Density (trees ha ⁻¹)	Basal area (m ² /ha)	Biomass (Mg/ha)			Carbon stock (Mg C/ha)			CO ₂ equivalent (Mg CO ₂ /ha)
				AG	BG	TB	AG	BG	TVC	TVC
	T2	6500	3387 ± 0	3364 ± 0	9249 ± 0	12613 ± 0	1615 ± 0	3607 ± 0	5222 ± 0	19164 ± 0
	T3	1750 ± 63640	1106 ± 663	6332 ± 4101	3088 ± 1924	9421 ± 6025	2530 ± 2692	1204 ± 750	3732 ± 3443	13697 ± 12634
	T4	103333 ± 76376	1296 ± 624	3727 ± 3146	1799 ± 1485	5526 ± 4631	1789 ± 1510	702 ± 579	2491 ± 2089	9141 ± 7668
Zone 2	T5	133333 ± 73711	1104 ± 949	7802 ± 7912	3380 ± 3148	11183 ± 11058	3745 ± 3798	1318 ± 1228	5063 ± 5025	18583 ± 18440
	T6	600 ± 14142	433 ± 216	2602 ± 1447	1235 ± 651	3836 ± 2099	1249 ± 695	481 ± 254	1730 ± 949	6350 ± 3482
	T7	123333 ± 65064	1113 ± 1075	10373 ± 13402	3844 ± 4350	14216 ± 17748	4979 ± 6433	1499 ± 1696	6478 ± 8128	23774 ± 29829
Zone 3	T9	1050 ± 21213	556 ± 043	3713 ± 011	1812 ± 030	5526 ± 019	1782 ± 005	707 ± 012	2490 ± 007	9136 ± 024
	T10	700 ± 0	240 ± 0	246 ± 0	268 ± 0	515 ± 0	118 ± 0	200 ± 0	319 ± 0	1172 ± 0
	T15	1500 ± 0	1926 ± 0	1623 ± 0	1329 ± 0	2953 ± 0	779 ± 0	1151 ± 0	1931 ± 0	7088 ± 0
Zone 5	T16	700 ± 17320	428 ± 024	248 ± 086	416 ± 212	665 ± 296	119 ± 041	259 ± 115	379 ± 156	1391 ± 575
	T17	750 ± 35355	532 ± 231	221 ± 144	553 ± 043	775 ± 100	106 ± 069	302 ± 039	4086 ± 1085	1499 ± 398
Zone 6	T19	46666 ± 5773	454 ± 249	527 ± 538	606 ± 214	1133 ± 738	252 ± 258	441 ± 287	694 ± 545	2550 ± 2001
	T20	300 ± 0	114 ± 0	103 ± 0	304 ± 0	408 ± 0	049 ± 0	159 ± 0	208 ± 0	766 ± 0
	T23	1325 ± 165605	770 ± 557	1345 ± 334	940 ± 402	2286 ± 650	645 ± 160	891 ± 254	1537 ± 400	5652 ± 1476
	T24	750 ± 49497	674 ± 591	416 ± 341	196 ± 152	611 ± 493	199 ± 164	076 ± 059	276 ± 223	1012 ± 819
Zone 8	T25	100 ± 0	038 ± 0	195 ± 0	101 ± 0	297 ± 0	093 ± 0	039 ± 0	133 ± 0	490 ± 0
	T29	450 ± 35355	8 ± 069	2372 ± 2487	938 ± 925	331 ± 3411	1138 ± 1194	366 ± 361	1504 ± 1554	5521 ± 5704
	T30	53333 ± 37859	524 ± 377	418 ± 215	199 ± 093	618 ± 307	201 ± 103	078 ± 036	279 ± 139	1022 ± 511
	T31	950 ± 7782	777 ± 636	759 ± 206	228 ± 080	987 ± 127	364 ± 099	089 ± 031	453 ± 068	1664 ± 249
Zone 9	T32	400 ± 42426	179 ± 165	237 ± 166	119 ± 077	356 ± 243	114 ± 08	047 ± 03	16 ± 11	588 ± 402
	T33	500 ± 42426	128 ± 137	065 ± 016	037 ± 008	102 ± 024	031 ± 008	015 ± 003	046 ± 011	168 ± 04
Zone 10	T34	56666 ± 3399346	133 ± 047	5260 ± 4244	2115 ± 2159	7375 ± 6377	2525 ± 2037	8249 ± 842	3350 ± 2806	12294 ± 10527
	T35	566666 ± 339935	13 ± 047	5260 ± 4244	2115 ± 2159	7375 ± 6378	2525 ± 2037	82 ± 842	335 ± 2869	1229 ± 10528
	T36	1250 ± 353553	162 ± 059	4344 ± 2248	2107 ± 1009	6452 ± 3258	2085 ± 1079	822 ± 393	2907 ± 1473	10669 ± 5406
Zone 12	T38	46666 ± 25166	061 ± 027	1441 ± 714	7072 ± 355	2148 ± 1072	692 ± 344	275 ± 138	967 ± 48	355 ± 177
Zone 13	T40	100 ± 0	022 ± 0	665 ± 0	308 ± 0	973 ± 0	319 ± 0	120 ± 0	439 ± 0	1613 ± 0
	T41	50332 ± 0	1915 ± 0374	4842 ± 4188	2326 ± 166	7169 ± 5850	232 ± 201	953 ± 57	3277 ± 258	12030 ± 9487
Zone 15	T47	300 ± 100	054 ± 030	2379 ± 2622	1037 ± 1067	3416 ± 3689	1141 ± 1258	4045 ± 416	1546 ± 1674	5675 ± 6147

Table 2 — Diversity indices - species diversity and other statistical analysis

Location	Dominance_D	Simpson_1-D	Shannon_H	Evenness	Margalef d'	Fisher_alpha
Zone 1	0821	0179	0323	0691	0205	0335
Zone 2	0727	0273	0476	0780	0338	0523
Zone 3	0327	0673	1245	0949	0903	1387
Zone 4	0645	0355	0671	0593	0593	0795
Zone 5	0759	0241	0391	0813	0213	0361
Zone 6	0354	0646	1304	0699	1094	1480
Zone 7	0820	0179	0344	0789	0283	0488
Zone 8	0815	0185	0377	0763	0385	0601
Zone 9	0945	0055	0111	0898	0078	0256
Zone 10	0858	0142	0271	0656	0240	0391
Zone 11	0750	0250	0437	0897	0228	0416
Zone 12	0713	0287	0552	0579	0528	0728
Zone 13	0585	0416	0919	0505	0950	1272
Zone 14	0506	0494	0999	0878	0844	1399
Zone 15	1088	0088	0044	0957	0000	0319
Minimum	0327	0055	0044	0505	0000	0256
Maximum	1088	0673	1304	0957	1094	1480

ground biomass of 14.77 ± 7.93 Mg/ha. Sample station 7 had the highest total biomass (142.16 ± 177.48 Mg/ha), while transect 33 has the lowest (1.02 ± 0.24 Mg/ha) biomass. The above-ground biomass ranged from 0.65 ± 0.16 to 103.73 ± 134.02 Mg/ha, with the highest in zone 2. The below-ground biomass ranged from 0.37 ± 0.08 to 92.49 Mg/ha, with the highest in zone 2. Additionally, the total biomass was highest in zone 2. The study area's mean vegetative carbon stock obtained was 18.35 ± 12.44 Mg-C/ha, ranging from 0.46 ± 0.11 to 64.78 ± 81.28 Mg-C/ha (Table 1). Above-ground carbon stock ranged from 0.31 ± 0.08 to 49.79 ± 64.33 Mg-C/ha, while below-ground carbon stock ranged from 0.15 ± 0.03 to 36.07 Mg-C/ha. CO₂ equivalence ranged from 1.68 ± 0.4 to 191.64 ± 0.0 Mg CO₂/ha. Carbon stock was found to be highest in zone 2 and lowest in zone 9.

Discussion

Mangrove trees are the second most significant carbon pool after soil carbon stock, and this pool includes both above-ground shoot biomass and below-ground living roots¹⁷. Several carbon assessment studies have been conducted in Tamil Nadu. For instance, a study conducted by Kathiresan *et al.*¹⁵ in Pichavaram resulted in a mean AGB of 117.7 Mg/ha. In a recent study by Gnanamoorthy *et al.*¹³ on Pichavaram mangrove forests, the carbon sequestration rate varied from 2.33 to 4.44 g C/m²/year. Narmada *et al.*¹⁴ conducted a study on Muthupett mangroves and found that the CO₂ sequestration by the mangrove was about 1475.64 Mg/ha in 2000, 3646.31 Mg/ha in 2010, and 1677.72 Mg/ha in 2017. The AGB and carbon stock were found to be highest in Andaman mangroves (469.20 Mg/ha and 225.22 Mg-C/ha), which is attributed to higher species diversity and fewer anthropogenic disturbances²⁰. However, the mean BGB (17.85 Mg/ha) was found to be very low in Palk Bay compared to global below-ground estimations which can be primarily attributed to low abundance of mangrove species in the region. Additionally, lower species diversity may also contribute to the observed low biomass. The Sundarbans mangroves are considered to be the largest mangrove forest in India. According to the study conducted by Banerjee *et al.*²¹, the average amount of AGB and BGB in Sundarban mangroves ranged from 258.6 to 1,149.96 Mg/ha and 127.48 to 429.18 Mg/ha, respectively. As species abundance increases, biomass and carbon stocks also increase, but the low abundance in present study area

resulted in low AGB and BGB values. Most transects were dominated by a single species, further contributing to low AGB and BGB values. It is worth noting that some biomass studies conducted in Mumbai (1.26 Mg/ha) and central Kerala (13.17 Mg/ha) by Suresh *et al.*²² reported below-ground biomass estimates lower than those of the Palk Bay study sites.

Recent research has emphasised the significance of AGB in mangrove carbon inventories, as it positively correlates with wood production and litter fall, thereby affecting the rate of carbon sequestration²³. The allometric equation for estimating AGB and BGB utilises tree diameter at breast height and wood density. It is well-established that if AGB is high, BGB is also likely to be high. However, various factors, such as increasing salinity and nutrient enrichment, affect AGB and BGB differently in mangroves. For instance, it has been found that increasing salinity improves BGB more than AGB²⁴, whereas nutrient enrichment improves AGB more than BGB^{25,26}.

Despite 30 years of conservation and restoration efforts, the world lost 2.1 % (3,363 km²) of its mangrove acreage between 2000 and 2016, averaging a yearly loss of 0.13 %^(ref. 27). Erosion was the second most significant driver of mangrove loss, responsible for the loss of 927.87 km² during this period, while the conversion of mangroves to aquaculture/agriculture remained the primary driver, resulting in the conversion of 2,193.92 km² of mangrove area²⁸. From 1996-2016, the global mangrove carbon stock decreased by 158.4 million tonnes (Mt) or 1.8 %, compared to 1996, which was 8,627.6 Mt^(ref. 29). The anticipated worldwide greenhouse gas emissions from mangrove loss are estimated to be 2,397 Tg CO₂ eq by the end of the century (2020 – 2100), based on the global mean value of 1.5 Mg-C/ha/year³⁰. Land conversion and erosion are considered as the primary cause of mangrove loss, and hotspots for anticipated GHG emissions from mangrove loss include the Andaman Sea (161 Tg CO₂ eq) and Bay of Bengal (369 Tg CO₂ eq) coasts³⁰. India is often cited as an excellent example of mangrove preservation and restoration, with robust legislation in place for their preservation^{30,31}. However, current programs rely on broad generalisations rather than site-specific data and ecological health status. Therefore, reorganising existing protective measures with proper site-specific information is crucial in the context of mangrove

deterioration despite increasing forest cover. Indian mangroves lost 84.50 km² of their area between 2000 and 2016 due to erosion²⁷, and the introduction of natural stressors is expected to be the primary factor contributing to future mangrove loss²⁷. Thus, maintaining the ecological health of existing mangroves should take precedence to sustain their carbon storage capacity, prevent GHG emissions caused by habitat degradation or conversion, and preserve the pristine environment.

Conclusion

The study highlights the critical role of Palk Bay mangrove patches in carbon sequestration, with a mean biomass of 40.09±26.64 Mg/ha and a mean carbon stock of 18.35±12.44 Mg-C/ha. Zones 2 and 10 showed notably higher biomass and carbon stock, primarily attributed to the dominance of *Avicennia marina* and minimal anthropogenic disturbance. The potential restoration of tidal conditions in severely impacted areas could enhance mangrove regeneration and carbon storage. This underscores the importance of site-specific carbon stock studies in mangroves for effective management. The mangrove ecosystem also has a significant impact on adjacent seagrass ecosystems and associated endangered species, such as dugongs, which rely on seagrass habitats for food and shelter. Additionally, the interconnectedness of mangrove and seagrass ecosystems underscores the need for conservation efforts to benefit both habitats and associated endangered species like dugongs. Implementing sustainable management practices and mangrove restoration initiatives are vital for preserving ecological balance and supporting local communities in the Palk Bay region. These findings are crucial for informing conservation strategies to mitigate climate change through effective management and restoration of mangrove habitats.

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Conflict of Interest

Authors declare no competing or conflict of interest.

Author Contributions

KTS: Investigation, writing-original draft preparation, data curation, and formal analysis; BV:

Funding acquisition, conceptualization, resources, methodology, validation, project administration, and supervision; PK, PA & KA: Investigation; SN: Writing-review and editing & supervision.

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