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Estimation of Carbon Stock in Gambesi Mangrove Ecosystem as an Action Toward Achieving the Sustainable Development Goals

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Mangrove ecosystems are among the most carbon-rich coastal ecosystems, storing substantial amounts of carbon in biomass and sediments. The Gambesi mangrove forest, located on the southern coast of Ternate Island, North Maluku, Indonesia, plays an important ecological role in coastal protection, biodiversity support, and climate change mitigation, yet it faces mounting anthropogenic pressure from land conversion, household waste, and coastal abrasion. This study aims to estimate the carbon stock of the Gambesi mangrove forest and to analyze its contribution to the achievement of the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land). Data were collected from five 10 m × 10 m observation plots using purposive sampling. Tree diameter at breast height (DBH) and species composition were recorded. Above-ground biomass (AGB) was calculated using species-specific allometric equations, and carbon stock was derived using a carbon conversion factor of 0.47. The results indicate that the total carbon stock of the Gambesi mangrove forest estimated at the results show that a total carbon stock of above-ground is 200.47 ton/ha (CO_2-eq is 735.72 ton/ha) and below-ground is 391.18 tons/ha of SOC (CO2-eq 1435.64 tons/ha). This area is dominated by the species *Rhizophora apiculata* and *Sonneratia alba*. These findings confirm the substantial climate mitigation value of the remaining mangrove stands in Gambesi and protection as a concrete local contribution to national and global SDG targets.

Keywords: Biomass, carbon stock, gambesi mangrove, climate change mitigation, Sustainable Development Goals

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1. Introduction

Mangrove forests constitute one of the most carbon-dense ecosystems in the world, storing carbon not only in above-ground biomass but, more importantly, in deep organic-rich soils that can retain carbon for centuries when undisturbed (Song et al., 2023). This combination of biomass and soil carbon places mangroves among the most effective natural climate solutions available, with per-hectare carbon storage often several times higher than that of terrestrial tropical rainforests (Twilley & Rovai, 2019). The carbon stored in coastal and marine ecosystems,

commonly referred to as blue carbon, is distributed across several carbon pools, including living biomass and sedimentary organic carbon (Thomas & Dam, 2025). The regulating service under ecosystem ideas helps reduce climate change directly. To measure it at above-ground biomass, below-ground biomass and soil organic carbon which is called Carbon Pool. Aboveground Biomass (AGB) and Belowground Biomass (BGB), which represent the rapid uptake and structural storage of organic carbon in living tissue, and Soil Organic Carbon (SOC), which locks carbon into waterlogged, anaerobic sediments for centuries. Evaluating these distinct pools provides a comprehensive accounting of how mangrove ecosystems function as highly localized, yet globally significant, carbon sinks (Choudhary, et al, 2024). Beyond their climatic function, mangroves provide critical ecosystem services including coastal protection from abrasion and storm surge, nursery habitat for fish and crustaceans, water quality regulation, and livelihood support for coastal communities (Zhang, et al, 2024).

Indonesia holds one of the largest extents of mangrove forest in the world, yet decades of conversion to settlements, aquaculture, and infrastructure have caused substantial degradation across many regions, including small islands in eastern Indonesia. Ternate Island, North Maluku Province, exemplifies this pressure: its limited land area and dense coastal settlement have driven the conversion and degradation of mangrove stands at several sites, including Mangga Dua, Kastela, Rua, and Gambesi (Rustam, et al, 2022) the Gambesi mangrove forest, situated in Gambesi urban village, South Ternate Subdistrict, Ternate City, is one of the few remaining mangrove areas on the island. Field observations and prior ecological assessments indicate that the mangrove stands in this area range from degraded to moderate condition, with dominant species including *sonneratia alba* and *rhizophora apiculata* (Rustam, et al, 2022). The ecosystem in Gambesi is increasingly threatened by household solid waste accumulation, land reclamation for settlement and agriculture, and coastal abrasion that has begun to encroach on coconut groves and water-spinach (kangkung) farmland belonging to local residents.

Despite its ecological and climatic importance, quantitative data on the carbon stock of the Gambesi mangrove forest remain limited. Previous research by Rustam et al. (2022) has mapped the spatial distribution and structural status of mangrove ecosystems in Ternate Island. It was also documented the ecological and spatial-temporal dynamics of the Gambesi mangrove ecosystem. To date, there has been no ground-validated, quantitative assessment of the total carbon stocks within this specific Gambesi mangrove ecosystems. This study addresses this gap by providing the comprehensive between three pool estimation at aboveground Biomass (AGB): tree biomass and litters, and belowground Biomass (BGB): soil organic carbon at the Gambesi mangrove ecosystem. Accurate carbon stock estimation is essential not only for scientific documentation but also as an evidentiary basis for local climate action planning, blue carbon policy formulation, and potential carbon-financing schemes (Dharmawan et al., 2020). Furthermore, this study offers a novel contribution by integrating these physical carbon metrics with an SDG-linkage analysis. In the global development context, this study is directly relevant to several targets of the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), which calls for urgent action to combat climate change and its impacts; SDG 14 (Life Below Water), which emphasizes the conservation and sustainable use of marine and coastal ecosystems; and SDG 15 (Life on Land), which addresses the protection, restoration, and sustainable management of terrestrial and coastal ecosystems. Mangrove conservation and carbon stock assessment therefore represent a concrete, measurable local action that contributes to these global commitments.

This study aims to: (1) estimate the above-ground and below-ground carbon stock of the Gambesi mangrove forest using field-based allometric methods; (2) analyze the spatial distribution of carbon stock across dominant mangrove species and diameter classes; and (3) discuss the relevance of these findings to the achievement of the SDGs, particularly in relation to climate action and coastal ecosystem sustainability. The findings are expected to provide a scientific baseline for mangrove rehabilitation prioritization, support local government coastal management planning, and contribute to the broader blue carbon database for North Maluku Province.

2. Research Method

1) Study Area and Time

This research was conducted in the Gambesi mangrove forest, Gambesi urban village, South Ternate Subdistrict, Ternate City, North Maluku Province, Indonesia, geographically positioned along the southern coastline of Ternate Island. The study area was selected based on its representativeness of the remaining mangrove stands on Ternate Island and the urgency of documenting its carbon stock given ongoing degradation pressure. Fieldwork was carried out over June-September, 2025.

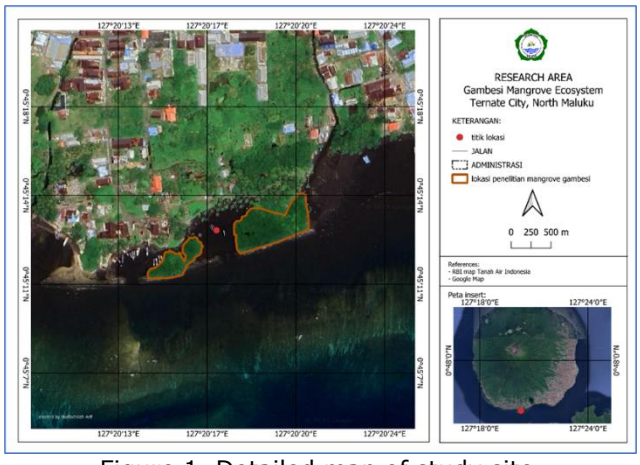


Figure 1. Detailed map of study site

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Table 1. Plot coordinates in research area

plot	latitude	longitude
1	0° 45' 13.98" N	127° 20' 20.05" E
2	0° 45' 13.72" N	127° 20' 19.13" E
3	0° 45' 13.26" N	127° 20' 18.14" E
4	0° 45' 12.51" N	127° 20' 16.20" E
5	0° 45' 11.62" N	127° 20' 14.99" E

2) Research Design and Sampling Method

This study employed a quantitative, field-survey-based descriptive approach. Sampling locations were determined using the purposive sampling method, in which plots were placed perpendicular to the coastline to capture zonation patterns from the seaward to landward mangrove zones. Along each transect, square observation plots measuring 10 m × 10 m. This research was established following standard mangrove vegetation analysis protocols using SNI 7724:2011 about Carbon Measurement and Stocks – Field measurements for forest carbon stock estimation (ground-based forest carbon accounting). A total of 5 plots were established, distributed to represent variation in stand density and species composition within the Gambesi mangrove area.

3) Data Collection

Within each plot, the following parameters were recorded for every individual tree: species identity, diameter at breast height (DBH) measured at 1.3 m above the highest prop root or ground level, and total weight of dead organic matter. For species with irregular stem form (e.g., Rhizophora spp. with prop roots), DBH was measured 30 cm above the highest root following standard mangrove forestry guidelines.

4) Biomass and Carbon Stock Calculation

- **Biomass**

Above-ground biomass (AGB) for each tree was calculated using species-specific or genus-specific allometric equations and using carbon equation of dead organic matter (litter, dead wood and dead trees) that was developed for mangrove vegetation, such as the general equation proposed for mixed mangrove stands:

Table 2. Allometric Formula of some mangrove species

Species	Allometric	References
Sonneratia Alba	AGB = ρ 0.3841 DBH $^{2.101}$	Kauffman and Donato (2012)
Rhizophora apiculata	AGB = 0.43 DBH $^{2.14}$	Ruslianto et al (2019)

Where AGB is above-ground biomass (kg), ρ is the wood density of the species (g cm^{-3}), ρ of *Sonneratia Alba* that used is 0.38 g cm^{-3}; and DBH is diameter at breast height (cm).

AGB is also calculate using this equation of dead organic matter:

$$Bo = \frac{Bks \times Bbt}{Bbs}$$

Where Bo is the weight of the organic material, expressed in kilograms (kg); Bks is the dry weight of the sample, expressed in kilograms (kg); Bbt is the total wet weight, expressed in kilograms (kg); Bbs is the wet weight of the sample, expressed in (kg).

Below-ground biomass (BGB) was calculated by measuring against soil biomass using this equation:

$$B_p = NAP \times B_{ap}$$

B_{bp} is belowground biomass (kg); NAP is the root shoot ratio value; Bap is the above ground biomass value (kg).

Table 3. The root shoot ratio value of forest types in Indonesia

Forest Type	Root Shoot Ratio	Example Location
Tropical rainforest	0.37	Mixed dipterocarp forest in Kalimantan
Deciduous forest	0.20 – 0.24	Teak forest
Tropical dry forest	0.28 – 0.56	Savanna forest in NTT
Tropical shrubland	0.40	Post-fire forest
Tropical mountain forest	0.27 – 0.28	Highland region forest

Data Source: IPCC 2006 Guidelines for National Greenhouse Gas Inventories that attached in SNI 7724:2011

- **Carbon Stock Calculation**

Carbon stock values were further converted to CO_2-equivalent (CO_2-eq) using the molecular weight ratio of CO_2 to C (44/12 = 3.67), in order to express the climate mitigation value of the stand in terms comparable to national greenhouse gas inventories. Carbon stock was subsequently calculated by applying a carbon conversion factor (C organic) of 0.47, following IPCC (2006) guidelines for biomass-to-carbon conversion:

Table 4. Carbon Stock Calculation for AGB and BGB

Above-ground biomass (AGB)	$C_m = B_o$ x % C organic
Below-ground biomass (BGB)	C_t = Kd x ρ x % C organic

Where Cm is the carbon content of dead organic matter (kg); Bo is the total biomass/organic matter (kg); Ct is the soil carbon content (g/cm2); Kd is the depth of the soil sample/peat soil depth (g/cm3); ρ is bulk density (g/cm3); % C organic is the percentage value of carbon content, 0,47.

5) Data Analysis

Carbon stock data were analyzed descriptively per plot, per species, and per diameter class to identify the dominant contributors to total carbon storage. All numerical data were processed using Microsoft Excel to support interpretation of carbon stock variation across the study site. The resulting carbon stock estimates were then qualitatively linked to relevant SDG indicators to frame the discussion of local-to-global development relevance.

3. Result and Discussion

1) Vegetation Structure and Species Composition

Field observations identified two mangrove species (*Rhizopora apiculata* and *Sonneratia alba*) across 46 individual records within the Gambesi study area. The area is dominated by *Sonneratia alba* and *Rhizopora Apiculata* consistent with species reported in earlier assessments of mangrove vegetation on Ternate Island. with an average DBH of 14.76 cm, reflecting a relatively young stand structure.



Figure 2. Species composition of mangrove forest consists of leaf, stem, and root, (a) *Rhizopora apiculata* (b) *Sonneratia alba*

Table 5. Species composition in Gambesi Mangrove Ecosystem

No	Plot	Wide (m2)	Species	DBH (cm)
1			*Sonneratia alba*	17.82
2			*Sonneratia alba*	15.44
3			*Sonneratia alba*	13.57
4			*Sonneratia alba*	16.55
5	1	100	*Sonneratia alba*	16.33
6			*Sonneratia alba*	13.11
7			*Sonneratia alba*	12.6
8			*Sonneratia alba*	12.2
9			*Sonneratia alba*	11.13
10			*Rhizopora Apiculata*	11.46
11			*Rhizopora Apiculata*	11.78
12	2	100	*Rhizopora Apiculata*	11.15
13			*Rhizopora Apiculata*	11.11
14			*Rhizopora Apiculata*	14.78

No	Plot	Wide (m2)	Species	DBH (cm)
15			*Rhizopora Apiculata*	12.83
16			*Rhizopora Apiculata*	13.6
17			*Rhizopora Apiculata*	16.34
18			*Sonneratia alba*	12.45
19			*Sonneratia alba*	13.5
20			*Sonneratia alba*	14.8
21			*Sonneratia alba*	15.67
22			*Sonneratia alba*	14.87
23	3	100	*Sonneratia alba*	18.8
24			*Sonneratia alba*	19.4
25			*Sonneratia alba*	19.82
26			*Sonneratia alba*	19.5
27			*Sonneratia alba*	18.76
28			*Sonneratia alba*	17.44
29	4	100	*Rhizopora Apiculata*	13.25
30			*Rhizopora Apiculata*	13.3
31			*Rhizopora Apiculata*	12.8
32			*Rhizopora Apiculata*	17.82
33			*Rhizopora Apiculata*	12.95
34			*Rhizopora Apiculata*	19.2
35			*Rhizopora Apiculata*	12.7
36			*Rhizopora Apiculata*	17.25
37			*Rhizopora Apiculata*	12.35
38	5	100	*Rhizopora Apiculata*	16.84
39			*Rhizopora Apiculata*	15.86
40			*Rhizopora Apiculata*	14.7
41			*Rhizopora Apiculata*	14.5
42			*Rhizopora Apiculata*	16.47
43			*Rhizopora Apiculata*	12.92
44			*Rhizopora Apiculata*	12.77
45			*Rhizopora Apiculata*	13.05
46			*Rhizopora Apiculata*	13.35
Total wide:		500	Average of DBH:	14.76

2) Carbon Stock Estimation

• Above-ground biomass

Assessment of the mangrove ecosystem in Gambesi revealed that *Rhizopora Apiculata* dominated the area. This indicates that the species stores the highest amount of carbon. As emphasized by Komiyama et al. (2005), carbon dynamics in mangrove environments are heavily influenced by tree biomass and stem diameter (DBH), where larger tree diameters exponentially increase biomass accumulation and carbon capture. As tree diameters expand, biomass accumulation and carbon sequestration increase exponentially. Consequently, stands with larger diameters accumulate and store organic material over significantly longer periods. Besides that, litters and understory plants (such as shrubs and other non-tree plants) also give a small influence to carbon stock in that area. Additionally, coastal tides deposit nutrient-rich sediments, enhancing carbon storage by capturing external organic debris within intricate root structures. This process enriches the underwater soil, supplying vital nutrients that actively fuel the expansion and health of surrounding plant life. By securing this organic material, the ecosystem creates a self-sustaining cycle where trapped carbon feeds the substrate, which in turn fosters denser vegetation capable of capturing even more carbon. Ultimately, this natural tidal mechanism transforms the habitat into a highly efficient carbon sink, reinforcing the coastal environment's overall stability and long-term capacity to mitigate atmospheric carbon (Yaqin et al., 2022).

Total calculated above-ground biomass (AGB) across all plots is 4265.26 kg and carbon stock is 200.47 ton/ha (CO_2-eq is 735.72 ton/ha). This value shows that the carbon stock in the Gambesi mangrove is still at a high density (Nasir et al.,2025). Table 6

summarizes the estimated carbon stock by component. The proportion varies with species composition and standing maturity. Measurement AGB using tree biomass and dead organic matter, which is plant litters. The highest carbon stock is in the plot 4. This plot contains *Rhizopora Apiculata* which stores 58.70 tons/ha Carbon. The species *Rhizophora apiculata* contribute the largest share of total carbon stock. This finding is consistent with the broader literature on mangrove blue carbon, which consistently identifies large-diameter Rhizophora stands as major carbon reservoirs in Indo-Pacific mangrove ecosystems (Donato et al, 2011). The lowest carbon stock is in the plot 1 that contains mostly *Sonneratia alba* which stores 16.99 tons/ha Carbon. The 1 plot is part of mangrove ecosystem that is near from estuary. Badly, the estuary has been contaminated by household waste and oils from the workshop. Systematically, the total mangrove biomass and carbon stock in Gambesi is at risk of decline due to ongoing human activity around the area. Meanwhile, coconut groves, water-spinach (kangkung) farmland, and settlement located near the area.

Table 6. Above-ground biomass and total carbon stock estimation value of Gambesi Mangrove Ecosystem

Plot	Total biomass of mangrove trees (kg)	Total biomass of plant litters (kg)	Carbon stock in biomass (tons)	Carbon content (tons/ha)	CO_2-equivalent (tons/ha)
1	361.03	0.47	0.17	16.99	62.36
2	1030.98	0.77	0.48	48.49	177.97
3	424.26	0.30	0.20	19.95	73.23
4	1248.52	0.48	0.59	58.70	215.44
5	1197.77	0.68	0.56	56.33	206.72
Total	**4262.56**	**2.7**	**2.00**	**200.47**	**735.72**
Total biomass: 4265.26 kg					

• **Below-ground biomass**

Below-ground biomass (BGB) calculations indicated that the plot 4 yielded the highest productivity at 462.13 kg. It is because the calculation of BGB is still influenced by AGB value. On the contrary, the plot 1 recorded the lowest value, with a total biomass is only 133.76 kg. The total biomass is defined in Table 7. The superior carbon retention in *Rhizophora apiculata* is tied to its larger structural dimensions and intricate root architecture, which optimize particle entrapment and carbon storage. This dense root system allows for significantly higher carbon absorption compared to smaller species. *Rhizophora apiculata* also prioritizes resource allocation toward trunk and canopy development (Kaimuddin et al., 2023).

In the plantation forest sector of Gambesi, biomass values on BGB fluctuated between 133.76 and 462.13 kg, which the total biomass on BGB is 1578.15 kg. This study identified a correlation between tidal and Below-Ground Biomass Productivity (BGBP). Tides carry suspended sediments and organic matter from the ocean into the intertidal zone. In the intertidal zone, there is breakwater construction which can trap sediments in the mangrove roots. the sediment can store carbon matter (Erem et al., 2025).

Table 7. Below-Ground Biomass and total carbon stock estimation value of Gambesi Mangrove Ecosystem

Plot	Total biomass AGB (kg)	Total biomass BGB (kg)
1	361.50	133.76
2	1031.75	381.75
3	424.56	157.09
4	1249.00	462.13
5	1198.45	443.43
Total	**4265.26**	**1578.15**

3) Soil Organic Carbon

Plot 1 demonstrates elevated SOC compared to other plots, which is positioned within the river channel (Fig.1). Specifically, Plot 1 contains for a soil organic carbon content of 79.32 tons/ha, translating to a total CO_2-eq of 291.10 tons/ha. In comparison, Plot 2 records an SOC contents of approximately 78.50 tons/ha, Plot 3 contents of 76.57 tons/ha, Plot 4 contents of 78.55 tons/ha, and plot 5 contents of 78.24 tons/ha. This localized enrichment at Plot I is driven by a combination of environmental stability, organic matter supply, and microbial dynamics. Because Plot I Experiences less frequent tidal inundation, it maintains a stable environment that favors the accumulation of surface organic materials. This matter undergoes retarded decomposition within the anaerobic condition's characteristic of dense, clayey mud substrates. As highlighted by Sari and Prayudyaningsih (2017), oxygen-depleted settings stimulate anaerobic microbial pathways, which accelerate organic matter retention and delay the emission of carbon dioxide back into the atmosphere.

Ultimately, the mangrove ecosystem demonstrates a far greater carbon mitigation capacity, storing 391.18 tons/ha of SOC (CO2-eq 278.15 tons/ha). The bulk of mangrove carbon is securely locked in below-ground pools, cementing their role as premier coastal carbon sinks.

Table 8. Soil Organic Carbon (SOC) of Gambesi mangrove ecosystem

Plot	Sample	Depth (cm)	Soil mass (g)	Bulk Density (g/cm3)	Carbon Content (tons/ha)	CO_2-equivalent (tons/ha)
	1	0-5	515	5.25	12.33	45.26
	2	5 10	553	5.64	13.24	48.60
	3	10 15	557	5.68	13.34	48.96
1	4	15 -20	510	5.20	12.21	44.83
	5	20-25	597	6.08	14.30	52.47
	6	25-30	580	5.91	13.89	50.98
			Sub-total		79.32	291.10
	1	0-5	517	5.27	12.38	45.44
	2	5 10	589	6.00	14.11	51.77
	3	10 15	580	5.91	13.89	50.98
2	4	15 -20	505	5.15	12.09	44.39
	5	20-25	572	5.83	13.70	50.27
	6	25-30	515	5.25	12.33	45.26
			Sub-total		78.5	288.11
	1	0-5	569	5.80	13.63	50.01
	2	5 10	567	5.78	13.58	49.84
	3	10 15	515	5.25	12.33	45.26
3	4	15 -20	513	5.23	12.29	45.09
	5	20-25	507	5.17	12.14	44.56
	6	25-30	526	5.36	12.60	46.23
			Sub-total		76.57	280.99
	1	0-5	502	5.12	12.02	44.12
	2	5 10	599	6.10	14.35	52.65
	3	10 15	595	6.06	14.25	52.30
4	4	15 -20	521	5.31	12.48	45.79
	5	20-25	524	5.34	12.55	46.06
	6	25-30	539	5.49	12.91	47.37
			Sub-total		78.55	288.29
	1	0-5	591	6.02	14.15	51.94
	2	5 10	512	5.22	12.26	45.00
	3	10 15	591	6.02	14.15	51.94
5	4	15 -20	528	5.38	12.65	46.41
	5	20-25	520	5.30	12.45	45.70
	6	25-30	525	5.35	12.57	46.14
			Sub-total		78.24	287.15
			Total		391.18	1435.64

4) Contribution to the Sustainable Development Goals (SDGs)

The carbon stock results obtained in this study provide a quantitative basis for linking local mangrove conservation in Gambesi to global sustainable development commitments; SDG 13 (Climate Action): The estimated carbon stock of CO_2-eq 1565.35 tons ha^{-1} demonstrates the measurable climate mitigation value of the Gambesi mangrove forest. Maintaining and rehabilitating this ecosystem directly supports national greenhouse gas reduction commitments under Indonesia's Nationally

Determined Contribution (NDC), particularly the forestry and land-use (FOLU) sector target (Indriyani et al., 2025). SDG 14 (Life Below Water): As a coastal ecosystem at the land–sea interface, the Gambesi mangrove forest supports marine biodiversity by providing nursery and feeding habitat for fish, crustaceans, and other coastal biota, while also buffering nearshore waters from land-based waste and sedimentation. SDG 15 (Life on Land): Conservation and rehabilitation of the remaining mangrove stand contribute to halting biodiversity loss and land degradation in the coastal zone of Ternate Island, in line with the SDG 15 target of protecting and restoring terrestrial and coastal ecosystems (UNDP, 2025).

Table 9. The link between this carbon research and SDGs

No	Research Data	Estimation Impact & Contribution	Relevant SDGs Target	Relevant Indicator
1	Total Aboveground Biomass Carbon Stock	Providing baseline data on carbon sequestration capacity to support Greenhouse Gas (GHG) emission reduction targets.	Target 13.2: Integrate climate change measures into national policies, strategies, and planning.	Indicator 13.2.1: Number of countries with nationally determined contributions, long-term strategies, national adaptation plans and adaptation communications.
2	Belowground / Soil Organic Carbon Stock	Demonstrating ecosystem functions in maintaining soil stability, preventing land degradation, and long-term carbon storage.	Target 15.3: Combate desertification, restore degraded land and soil by desertification, drought and floods, and striving to achieve a land degradation-neutral world.	Indicator 15.3.1: Proportion of land that is degraded over total land area.
3	Stand Density and Species Diversity	Connecting stand structure (e.g., mangrove/natural forest) with ecosystem health in protecting biodiversity.	Target 15.5: Taking urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.	Indicator 15.5.1: Red List Index.
4	Sedimentation Rate and Coastal Carbon (Optional: For Mangrove/Blue Carbon)	Demonstrating the physical role of vegetation in coastal disaster mitigation (erosion, sea-level rise) as well as its function as a carbon sink.	Target 14.2: sustainably managing and protecting marine and coastal ecosystems to avoid significant adverse impacts.	Indicator 14.2.1: Number of countries using ecosystem-based approaches to managing marine areas.

These linkages indicate that mangrove carbon stock assessment is not merely a scientific exercise but a direct, measurable contribution to multiple SDG targets simultaneously, reinforcing the value of integrating blue carbon data into local development and climate policy planning in Ternate City (Ilman et al., 2016).

4. Conclusion

This study estimated the carbon stock of the Gambesi mangrove forest, Ternate City, North Maluku Province, using field-based allometric methods. The results show that a total carbon stock of above-ground is 200.47 ton/ha (CO_2-eq is 735.72 ton/ha) and below-ground is 391.18 tons/ha of SOC (CO2-eq 1435.64 tons/ha). *Rhizopora apiculata* contributing the largest share of total carbon storage. These findings confirm that, despite ongoing degradation pressure, the Gambesi mangrove forest retains meaningful blue carbon value and continues to provide critical coastal protection and biodiversity functions. The study demonstrates that local-scale mangrove carbon assessment provides concrete, measurable evidence supporting the achievement of SDG 13 (Climate Action), SDG 14 (Life Below Water), and SDG 15 (Life on Land). Continued mangrove rehabilitation, community-based waste management, and formal protection status are recommended as priority actions to sustain and enhance the carbon sequestration capacity of the Gambesi mangrove ecosystem.

Future research is recommended to incorporate carbon stock measurement (above-ground and below ground) in all mangrove ecosystems in Ternate

Island and measurement total soil organic carbon in the deeper soil profile. This research only coves only 5 plots in Gambesi mangrove ecosystem. The plot was chosen in landward dan middle zone, while the seaward zone has not yet measured due to the risk to meet some predators. It was recommended to use GIS method to calculate carbon stock of all the zone in mangrove ecosystems. It also suggests to future directions such as long-term/repeated monitoring, uncertainty or error-margin analysis for the carbon estimates, and socio-economic or blue-carbon-credit valuation studies. For the given mangrove typically dominant contribution to carbon stock, in order to produce a more comprehensive blue carbon inventory for this site.

5. Author Contributions

The first author (NA) designed the study, carried out the experiments, performed the statistical analysis, and wrote the manuscript text. Second author (SB) performed the map, prepared the figures, and helped to complete the statistical analysis. Third author (JM) supervised the project and critically revised the manuscript for important intellectual content. Fourth author (MHM) wrote the main manuscript text with the first author. All authors contributed to the interpretation of the results and approved the final version of the manuscript.

6. Competing Interests

The authors have no competing interests to declare.

7. Acknowledgements

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Endnote/Zotero/Mendeley(RIS) BibTex