Estimation of biomass, carbon stock, CO_2 absorption, and oxygen release in the Metinaro coastal mangrove forest, Díli, Timor-Leste

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Abstract

Mangrove forests are vital for other living beings, help prevent coastal erosion, and mitigate the greenhouse effect while storing more carbon than other types of forests. This research focuses on estimating the biomass, carbon sequestration, CO_2 absortion, and O_2 release of the Metinaro mangrove forest located within the municipality of Díli, East Timor. For the collection of the necessary data, we measured the total height and the diameter at breast height of all the adult trees located in the mangrove forest. The minimum analysis described herein considers the quantitative approach for which specific equations will help estimate the value of biomass and subsequently carbon and CO_2 capture and O_2 release. The Metinaro mangrove forest is estimated to have a total of 15 species of trees with a total biomass of 944.98 tons/ha and sequesters 485.85 tons/ha of carbon, absorbs 1734.91 tons/ha of CO_2, and releases 4279.64 tons/ha of O_2. This data can help the country's future carbon trading and observation of changes in the capacity of the amount of carbon stored by this forest. This helps, conservation and reforestation continues.

Introduction

Timor-Leste forms part of the Wallacea region and crosses the Lydekker line, which consists of Sulawesi, the Moluccas, the Banda Arcs and the Sunda Islands, and covers an area of 338 million hectares, with Timor-Leste contributing 4% of the Wallace forest cover [5][11][20]. East Timor’s forest include the large areas of mangroves along much of the coast. In 2013 it was estimated that there was 1,300 hectares of mangrove cover. Metinaro has the most extensive coastal mangrove forest and contains 19 true mangrove species [3][7][12][16]. This forest is also valuable for carbon sequestration [4][21].

Metinaro has the largest mangrove forest in Timor-Leste in terms of area and diversity of species. This forest also plays a major role in climate change mitigation through the absorption and storage of CO_2 [18][23]. However, with the potential loss of some species and area due to human development and natural occurrences, parts of the forest will still be lost [12]. This also diminishes the CO_2 storage capacity and weakens the climate mitigation role the forest plays. This study aim to estiamte the biomas, carbon stock, CO_2 uptake and O_2 release of the mangrove forest in Metinaro, Díli, Timor-Leste.

Materials and Methods

The Metinaro Mangrove Forest ranges between 20 and 33 degrees Celsius [9][12]. Located along the coastal area north of the capital city of East Timor, Díli (8°30'43.31"S 125°45'49.12"E). The survey was done between 4 and 8 April 2025, in Metinaro Village, Dili Municipality, and specifically in the coastal mangrove forest. The total height and diameter at breast height of the identified mangrove trees were randomly measured within the plot, which measures 20 x 20 m2 for trees larger than 20 cm in diameter. In areas with many mangrove species and individuals, fetching seedlings for planting would be justified.

The equation model for humid mangrove forest is used to retrieve the aboveground biomass in kilograms, CAGB = 0.0509 x pD^2H, whose soil surface biomass regression model includes trunk diameter, D in cm, total height, H in m and density, P in g/cm^3 [10]. The mediation of the height for mediation of Diameter is > 1.3 m [17] and the p value as a form factor for tropical species is 0.55 and 0.7 [2], thus choosing 0.6 for the general representation.

To find the value of belowground biomass for hardwood plants, use the following equation: BGB = 1.576 x AGB x 0.615 [29]. The value of biomass can be converted to carbon in kg by multiplying the biomass value by 0.47, the carbon concentration value [6]. The value of carbon stock can be converted to kg CO_2 absorbed by multiplying it by 3.67, the value of carbon to CO_2 [24]. The O_2 release is calculated as the multiplication of the CO_2 absorption value with the O_2 concentration, which is 2.66 in CO2 [22]

Result and Discussion

The present study covering the Metinaro mangrove forest found 15 mangrove species belonging to 10 different genera. Within these, 2 species categorized under the Ceriops genus were Ceriops tagal (Perr.) C.B.Rob and Ceriops decandra (Griff.) Ding Hou, 2 species under the Avicennia genus were Avicennia alba Blume and Avicennia marina (forssk.) Vierh., and 2 species under the Brugueira genus were Brugueira cylindrica (L.) Blume and Brugueira sexangula (Lour.) Poir. There were also 3 species such as Rhizophora apiculata Blume, Rhizophora mucronata Lam., and Rhizophora stylosa Griff., under the Rhizophora genus, 1 species Osbornia Octodonta F.Muell. within Osbornia, 1 also under Lumnitzera as Lumnitzera racemosa Willd., 1 Pemphis acidula J.R.Forst & G. Forst under Pemphis, 1 Xylocarpus moluccencis (Lam.) M. Roem. within Xylocarpus, 1 Excoecaria agallocha L. under Excoeria, and 1 Sonneratia alba Griff. under Sonneratia.

The results estimate aboveground biomass (AGB), belowground biomass (BGB) and total biomass, carbon stock, CO_2 absorption, and O_2 release represented respectively in the following table:

Tabel 1

Result of the Metinaro mangrove forest biomass, carbon stock, CO_2 Absorption and O_2 release in Tons/ha

No	Species	AGB	BGB	Total biomass	carbon stock	CO_2 absorption	O_2 release
1	*C. tagal* (Perr.) C.B.Rob	7.93	4.03	11.98	5.63	20.67	54.98
2	*A. alba* Blume	42.70	6.40	49.11	23.08	84.71	225.33
3	*S. alba* Griff.	704.52	49.49	754.01	354.38	1300.60	3459.61
4	*R. apiculata* Blume	46.66	9.09	55.76	26.20	96.18	255.84
5	*R. mucronata* Lam.	23.78	3.8	27.66	13.00	47.72	126.95
6	*O. Octodonta* F.Muell	0.59	0.35	0.95	0.44	1.64	4.36
7	*C. decandra* (Griff.) Ding Hou	3.76	1.96	5.73	2.69	9.88	26.29
8	*R. stylosa* Griff.	3.56	27.76	13.05	47.89	127.40	3.56
9	*L. racemosa* Willd.	6.23	1.37	7.61	3.57	13.13	34.92
10	*A. marina* (forssk.) Vierh.	4.77	3.59	6.14	2.88	10.59	28.18
11	*B. sexangula* (Lour.) Poir.	0.36	0.35	0.72	0.33	1.24	3.30
12	*P. acidula* J.R.Forst & G.Forst	0.05	0.07	0.13	0.06	0.23	0.63
13	*X. moluccencis* (lLam). M. Roem.	3.58	1.14	4.72	2.22	8.14	21.67
14	*E. agallocha* L.	1.88	0.50	2.39	1.12	4.12	10.97
15	*B. cylindrica* (L.) Blume	3.78	1.24	5.02	2.36	8.66	23.05
Total		854.15	111.14	944.98	485.85	1734.91	4279.64

It may demonstrate the evolution of climate change because plant biomass is the mass gained during plant development and growth [1][13], the Metinaro mangrove forest contributes an estimated total biomass of 940.01 tons/ha. This would mean that the Metinaro mangrove forest has a proportion of 19.73% of the total GBA of the Indonesian mangrove forest. In addition, it may form a potencial 13.25% of the total GBA of Southeast Asia and only 4.63% of global GBA [15]. The Metinaro mangrove forest also stores carbon for a total of 485.85 tons/ha, absorbs CO_2 for a total of 1734.91 tons/ha and releases O_2 for a total of 4279.64 tons/ha. The species with the greatest contribution is Sonneratia alba Griff. in terms of biomass, carbon stock, CO_2 absorption, and O_2 release [8][30]. While the species with the smallest contribution is Pemphis acidula J.R.Forst & G.Forst [14]. The other species together contribute

73.68% (190.88 tons/ha) to total biomass (17.60% to aboveground biomass and 56.60% to total underground biomass), and 27.19% to total carbon stock. While the species with the smallest contribution is P. acidula J.R.Forst & G.Forst, with an average diameter of 1.5 cm and an average height of 8.7 meters [25][26].

This difference in the total may be due to their diameter and height but also incorporates density, frequency, and dominance, as in S. alba, that is characterized to describe its distributions [9][19][28][30]. Considering these results showed that the Metinaro mangrove forest has the vital role in the climate change mitigation by absorving the CO_2 and being natural carbon sequestration, but the area of the mangrove forest in Metinaro is not well conserved, anthropogenic and natural factors contribute to reduced growth and adaptation of mangroves, contributing to the reduction of biomass, carbon storage, CO_2 absorption, and O_2 release from the mangrove forest itself. In this respect, protection by fencing and reforestation has been regarded as indispensable for the protection of this mangrove forest because it holds ecological importance [3][8][12][27].

Conclusion

The research concluded that the Metinaro mangrove forest has 944.98 tons/ha of total biomass, 485.85 tons/ha of carbon stock, 1734.91 tons/ha of CO_2 absorption, and releases 4279.64 tons/ha of oxygen from 15 identified species, can help the country's future carbon trading, also helping the observation of variable changes of carbon amount in the fores and suggesting future conservation and continuity should reforest this forest.

Declarations

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Author contributions

All author’s contributed equally to this work. Nelson Moniz Costa conceived the study, designed and implemented the survey, and prepared the manuscript, collected and analyzed data.

Dr. Hermenegildo R. Costa and Manuel Soares contributed to the design and the preparation of the manuscript; conducted data analysis, analyzed data, and contributed to the preparation and review of the manuscript.

All authors read and approved the final manuscript before the submission.

Competing interests

The authors declare that they have NO affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript. There is no conflict of interest among authors.

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