Estimating Blue Carbon Stock: Mangrove and Seagrass Biomass Assessment in Tunda Island, Serang, Banten, Indonesia

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Abstract. Tunda Island is one of the islands at the northern tip of Banten Province, with natural and well-maintained seagrass and mangrove ecosystems. Even though its location is close to an urban area, the use of aquatic resources such as fishing and cultivation is small compared to other islands. However, developing issues such as sand mining plans will undoubtedly impact the surrounding coastal ecosystems, such as mangroves and seagrass in Tunda Island. Related to their role in reducing the impact of climate change, these two ecosystems need to be protected because coastal ecosystems are ten times more effective at sequestering carbon dioxide per area than boreal, temperate, or tropical forests. Therefore, this study aimed to determine the potential of seagrass and mangrove biomass for blue carbon storage on Tunda Island as baseline data for managing small islands that are still natural. Calculation of the area of mangrove and seagrass ecosystems on Tunda Island was obtained by classifying high-resolution imagery from Unmanned Aerial Vehicle (UAV) Drones. The potential for blue carbon storage was calculated using the allometric equation on seagrass (percent cover and density) and mangroves (DBH and wood density). The results showed that Tunda Island had six species of seagrass, which were dominated by *Thalassia hemprichii*, and six species of mangrove, which *Rhizopora apiculata* dominated. Based on the results of the UAV Drone image classification, the mangrove and seagrass ecosystem area was 14 and 398 ha. After that, it can be calculated that the potential value of blue carbon stores in Tunda Island is 160,38 tons C, with the most significant carbon stock being 60% in the mangrove ecosystem biomass and 40% in seagrass biomass. These results mean that blue carbon stock in Tunda Island has a small value compared with Indonesia's average mangrove and seagrass carbon data.

1. Introduction

Tunda Island was located in Serang Regency, Banten Province; geographically, the west, east, and north sides of Tunda Island directly border the Java Sea. According to [1], the coastal ecosystem on Tunda Island is still classified as natural and well-maintained.

Mangroves and seagrass can still be found, and there has been no large-scale exploitation by the people around the island. Therefore, the blue carbon ecosystem in Tunda Island certainly has great potential for its role in carbon storage as a small island in Indonesia.

Blue carbon ecosystems, notably mangroves and seagrass, serve multifaceted roles encompassing ecological, biological, and economic functions. Additionally, they emerge as pivotal players in ameliorating the impacts of contemporary climate change phenomena, including rising sea levels, heightened climate variability, and associated socio-economic perturbations [2]. Their significance in this regard underscores their paramount importance within the broader discourse of environmental conservation and climate resilience. The rapid increase in blue carbon research in the last few decades provides a solution for carbon absorption: coastal ecosystems are ten times more effective at sequestering carbon dioxide per area than boreal, temperate, or tropical forests [2]. This statement is supported by [3] that the mangrove has massive potential stock carbon with a value of 5.2 Gt. The estimated carbon stock of seagrass beds in Indonesian waters reaches ca. 276–1,005 ktC from the calculation of the potential seagrass area, which only covers 25% [4].

Sea sand mining activities, which are currently a current issue, are making Tunda Island very vulnerable to environmental change. Mining activities have impacts in the form of damage and degradation of environmental conditions [5]. Sand mining activities in the sea also cause the problem of degradation of the marine environment, especially the coastal ecosystem on Tunda Island [6]. The results of previous research explain that destroying mangrove and seagrass ecosystems causes degradation, resulting in carbon dioxide (CO_2) emissions that contribute to carbon sequestration capacity loss, climate change, and invaluable ecosystem services loss and correlate with the ability to mitigate climate change issues. For this reason, studies related to the carbon stock of seagrass and mangroves on Tunda Island are essential as a first step in obtaining the latest data on the potential of small islands in mitigating climate change impacts.

2. Method

2.1. Study Site

The study area is located on Tunda Island, Serang, Banten, Indonesia (Fig. 1). Data collection on blue carbon from biomass was conducted on 10 - 15 July 2023. The blue carbon ecosystems that were already measured were mangrove seagrass, and we used Unmanned Aerial Vehicle (UAV) Drones to measure the area of each ecosystem.

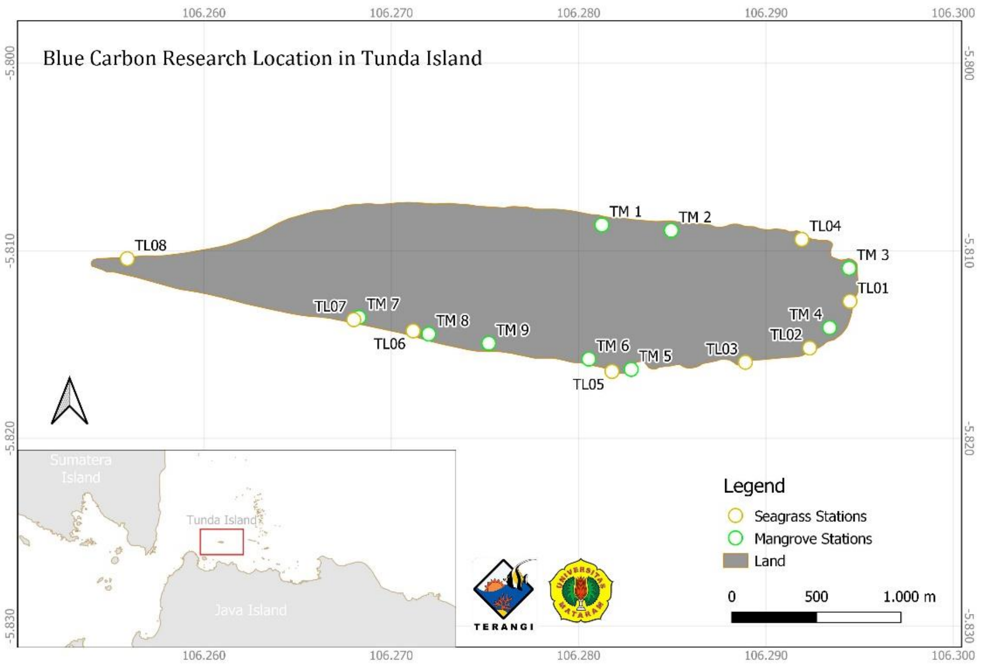

Fig. 1. Map of Research Location in Tunda Island

2.2 Mangrove and seagrass data collection

Mangrove data collection was carried out in 9 plots indicated by the green icon on the map that spread around the island (Fig. 1). The mangrove data was calculated using a quadrant plot sized 10x10 m, which includes tree and sapling levels [7]. The data collected from the field observation included the species, diameter (dbh), canopy coverage, and density of the mangrove ecosystem. All the data were collected following the MHI Protocols and then recorded in the Monmang 2 software [7].

Seagrass data collected at eight stations indicated by yellow dots on the map using a perpendicular from the beach to the shore (Fig. 1). Seagrass data collection points were carried out at every 10% of the total transect length with the total points in one transect were 11 observation points. The data were taken, such as type of species, seagrass cover, and density. The calculation of seagrass cover data refers to [8], and seagrass density is obtained by counting the number of stands of each type at each observation point.

2.3. Drone data collection and analysis

Benthic habitats have been mapped using Drone technology in several locations in Indonesia, such as Wakatobi [9], Lancang Island, and Sebaru Besar Island [10]. In this study, drone Images were taken using DJI Mavic Pro platinum built-in with a Red-Green-Blue (RGB) sensor/camera. DJI GO application was used for the aerial photo acquisition process. The drone flies up to 100 m while taking pictures of coastal areas in Tunda Island with 70% minimum overlapping images. All aerial photo acquisitions were completed on Mei – Juli 2023. The flying tracks in the study area gave over 1,000 aerial photos of the coastal ecosystem on Tunda Island. After that, all photos were combined (Orthomosaic) using Agisoft Metashape software to produce Geo tiff Images for the classification process.

Seagrass and mangrove habitat have been determined using visual interpretation with QGIS software. We used high resolution from Google Satellite to close the holes in case the Orthomosaic process failed to generate orthophoto images in the study area.

2.4. Stock Carbon Estimation

Estimating mangrove and seagrass carbon stocks uses an allometric approach that calculates biomass indicators such as canopy cover and density for the seagrass ecosystem and diameter and wood density for the mangrove ecosystem. Common allometrics, as shown in equation 1, were used to calculate biomass [11] and convert it to the carbon value, which multiplies the biomass value by 0,47 [12]. Seagrass carbon stock was calculated using the model equation shown in equation 2, which considers carbon value from seagrass cover and density [4].

$$W = 0.251\ \rho\ D^{2.46} \quad (1)$$

W: dry weight
p: wood density
D: diameter

$$\text{Above Ground Carbon} = 22.424701 - 0.001945(\mathit{Density}) + 0.143814(\mathit{Coverage}) \quad (2)$$

3. Result and Discussion

3.1. Mangrove Community Structure

The percentage of mangrove cover value on Tunda Island was 58-77%, with the highest area value found in TM 1 and the lowest in TM 2 (Fig 2). The average mangrove cover value is 69%, a moderate condition. The mangrove density value on Tunda Island is 4 - 12 stands/plot area and is dominated by tree level. The sapling was only found at two research stations, TM 1 and TM 2. The highest density value was found at TM 8 and the lowest at TM 5. The location at TM 5 provides the lowest density value because it is close to the port area and residents, so it gets more intervention than other stations. Another study showed that Tunda Island was vulnerable to external influences, both natural and due to human activities, such as household waste and land conversion [13].

Based on Figure 3, the diameter of stands mangrove data shows that mangrove stands on Tunda Island have values ranging from 5 – 27 cm/plot area with an average of 13 cm/plot area. This value is more significant when compared to mangroves in other locations, such as Sabu Raijua at 7 cm/plot area [4], and smaller when compared to mangroves that are classified as natural, such as in Rote Ndao at 16 cm/plot area [15]. Mangrove *R. apiculata* had the highest IVI value and dominance on Tunda Island. Another research shows that *R. apiculata* should be found and dominated by muddy substrates and estuarian mangrove habitats [16]. In this study, Tunda Island, which has oceanic mangrove characteristics, gives contradictory results. Oceanic mangrove habitat near Tunda Island, such as Pari, Harapan, and Kelapa Islands, gives a result that mangrove habitat was dominated by *R. stylosa or R mucronata* [17-18]. However, this happens because the mangrove forests on Tunda Island mostly grow in the protected areas behind the coastline, making the muddy substrate suitable for *R apiculate*.

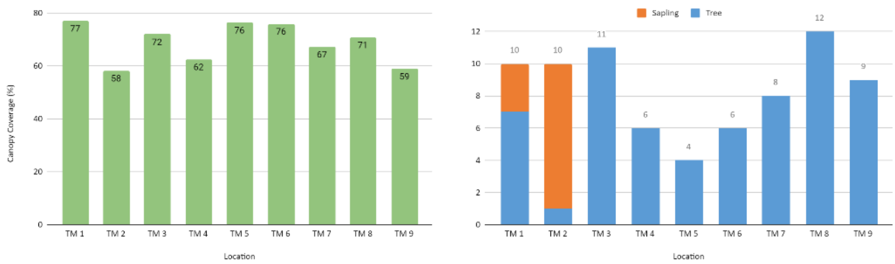

Fig. 2. Mangrove Canopy (left) and Density (Right) from the field observation

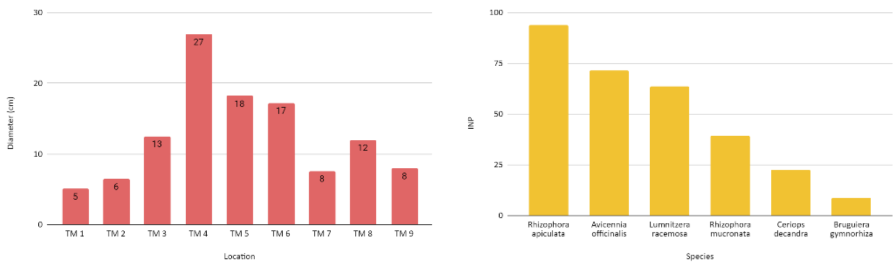

Fig 3. Diameter at Breast Height (Left) and Important Value Index (Right)

3.2. Seagrass Community Structure

This study found that there are five seagrass species, and *Thalassia hemprichii* was one of the most dominant species on Tunda Island. [19] in their study said *T hemprichii* was grown cosmopolite and spread evenly in all areas in Indonesia. These statements are supported by the high adaptation ability of this species for tolerance to salinity, temperature changes, and substrate types compared to other types [20]. A previous study gave the result that *T hemprichii* is one of the species that are dominant in Tunda Island [21]. Another location also gives the same result that the coastal ecosystem in Pari Island, Kepulauan Seribu, formed by species *T hemprichii* for their seagrass bed area [22].

The data on canopy cover has found around 8-24% with an average value of 12±8%, making seagrass in this area into a low category. The canopy cover of TL 02 (Fig 5) has the lowest value, but the density was higher compared to other stations. This happened in TL 02 due to the influence of a more diverse species composition and more dominant seagrass species with small leaves, such as *Halophila ovalis* and *Cymodoceae rotundata.* This happens because the density value in seagrass is greatly influenced by differences in leaf width [23]. On the other hand, their species composition was dominated by the pioneer type (small leaves growth), which gives a high-density value on TL 02 (137 ind/m^2).

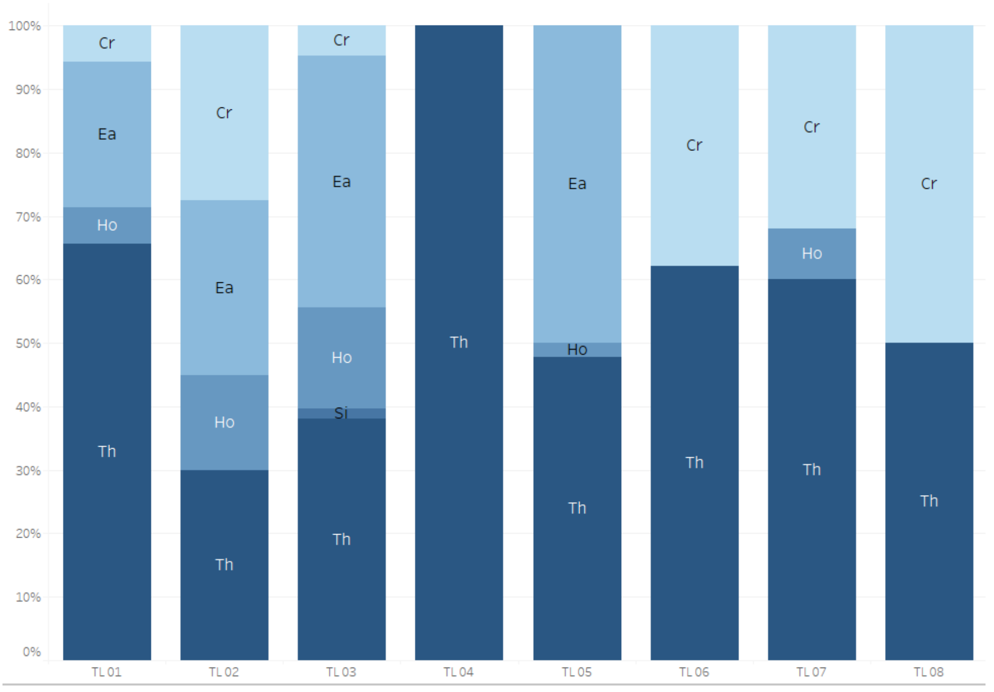

Fig. 4. Seagrass Species Composition

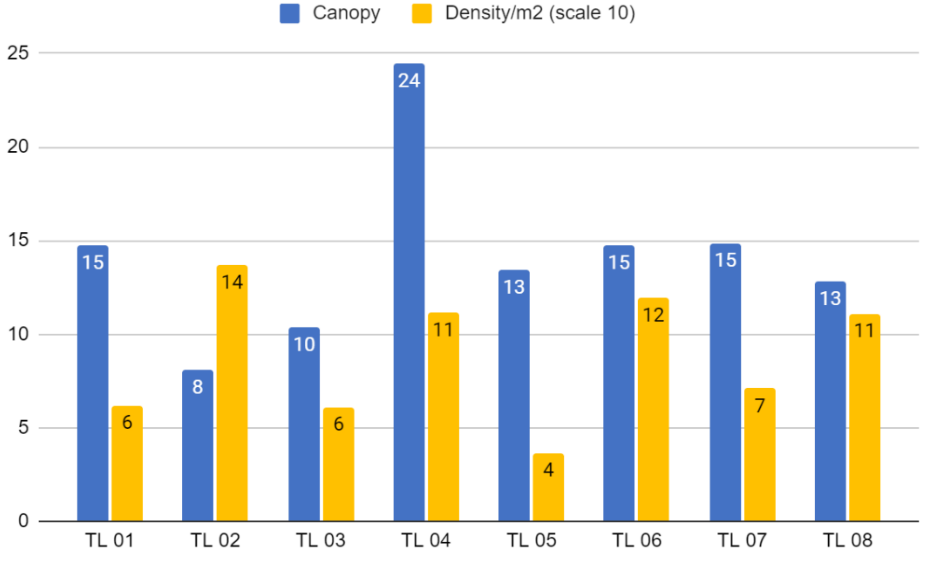

Fig. 5. Canopy and Density Seagrass

3.3. Mangrove and Seagrass area classification

Orthophoto image was produced from the north to the south area in Tunda Island. Due to the technical issued such as sun glint and limitation of computation process makes the orthomosaic process unable to generate all the coastal area in Tunda Island. Therefore, high-resolution images from Google satellite acquired in 2023 were used to cover that problem. Mangrove and seagrass area that produced by drone images were very clear visible for classification process by manual interpretation (Figure 6). After the classification process, the study found that the mangrove area was 14 ha and the seagrass area was 32 ha (Figure 7). A previous study that generated mangrove and seagrass areas from WorldView-2 gave results mangrove had lower of 10 ha and seagrass had bigger of 50 ha [21, 24].

Based on this study result, the utilization of drone technology to measure seagrass and mangroves from small areas is quite effective as an alternative for providing images in high spatial resolution. The drone technology produced higher accuracy for shallow water benthic habitat compared to other high spatial resolution [25]. Improvement of this technology for the classification process was needed for further research to get the best result for the map. Several literatures give some suggestions to avoid sunglint such as flying time before 08.00 am local time and viewing camera drone angle around 30 – 45^0 [25-26].

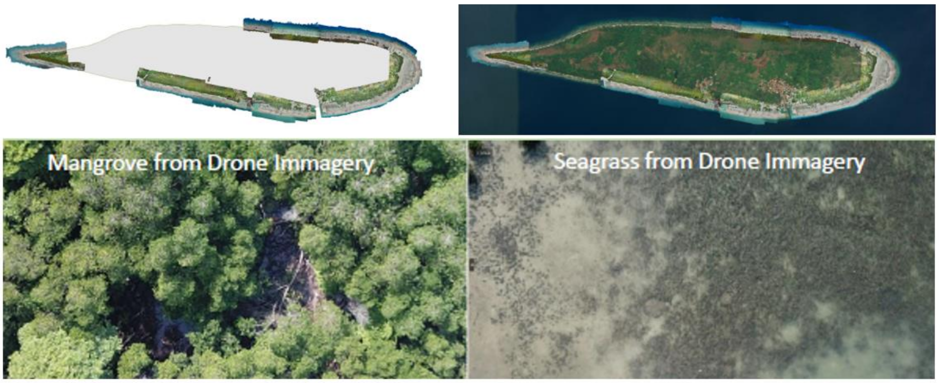

Fig. 6. Digital photos/geotiff images from orthomosaic process (above left), geotiff images add google satellites (above right), mangrove appearance from drone images (down left), and seagrass appearance from drone images (down right)

Fig. 7. Result of classification process in seagrass (yellow) and mangrove (green)

3.4. Stock Carbon Estimation

The calculations using an allometric algorithm show that the value of carbon stock in the mangrove ecosystem was 132,8 ton/ha with a total mangrove area of 14,34 ha. Compared to other small islands in Indonesia, referring to [27], the carbon stock of mangrove on Tunda Island was relatively high. [28] stated that in addition to many individuals, the diameter value also affects the value of carbon stocks, where the increase in old trees will increase the amount of carbon stock absorbed and stored by plants. The *R apiculata* species has the highest carbon storage, around 200 g C/m^2. It can be influenced by the density and diameter of the tree itself, where the more significant the diameter of a tree, the greater the biomass value [29].

The results of the calculation of stock carbon seagrass from the observation location obtained a value of 80 - 85 gr C/m^2, the most significant value obtained from the type of *T. hemprichii* at 85 gr C/m^2. Based on Table 1, the total carbon value obtained on Tunda Island is 27.57 tons with a total area of 32.75 ha. The total carbon value on Tunda Island is high compared to the research conducted on Semak Daun Island [30]. The high value of carbon stock can be influenced by seagrass area, density, species, and anthropogenic activities around the location. According to [31], seagrass carbon content can be influenced by differences in biomass of each seagrass type, so the higher the biomass, the higher the carbon content value. Carbon stock in mangroves and seagrass refers to the amount of carbon stored within the plant biomass of these coastal ecosystems. These ecosystems capture and sequester carbon dioxide (CO^2), a significant greenhouse gas responsible for global warming and climate change [32]. This signifies that every measurement of carbon stock in mangroves and seagrass is significant in mitigating greenhouse gas emissions.

The estimated carbon stock values for each species, be it mangrove or seagrass, exhibit distinct variations. *R. apiculta* and *T. hemprichii* have the highest values compared to other species (Figure 8). [33-34] said that the variation in carbon values among different species is a result of discrepancies in biomass quantities. Plants, through the process of photosynthesis, capture carbon dioxide (CO^2) from the atmosphere, converting it into organic carbon, specifically carbohydrates. This organic carbon is then stored in various parts of the plant, including stems, leaves, or roots.

Based on the average value of potential carbon storage for mangroves and seagrass on Tunda Island (Table 1). It can be seen that the average value of carbon storage for mangroves is 9.26 tons C/ha, and for seagrass, 0.84 tons C/ha is still relatively low when compared with the average value of carbon storage from seagrass and mangrove biomass in Indonesia. In the policy brief on the potential for carbon reserves and uptake of mangrove and seagrass ecosystems in Indonesia, it is stated that the average value of carbon reserves for mangroves is 320.06 tons C/ha and seagrass is 0.94 tons C/ha [4].

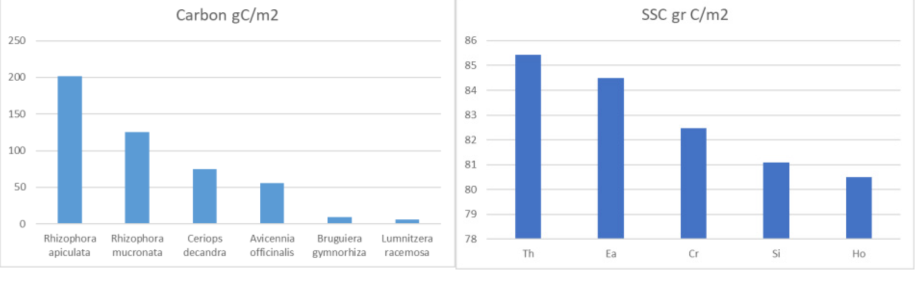

Fig. 8. Mangrove (Left) and Seagrass (Seagrass) carbon stock estimation for each species

Table 1. Calculation of Blue Carbon Value in Tunda Island

No	Ecosystem	Ton C/ha	Area ha	Ton C
1	Mangrove	9,26	14,34	132,80
2	Seagrass	0,84	32,75	27,57
Total				160,38

4. Conclusion

The condition of the mangroves on Tunda Island is in the moderate category, while the seagrass is in the damaged category. The *R. apiculata* type dominates mangroves while the *T. hempricii* type dominates seagrass. The total carbon stock from seagrass and mangrove biomass on Tunda Island was 160,38 tons, with the most significant proportion belonging to mangroves at 82% and seagrass at 18%. Even though the coastal ecosystem in Tunda Island was classified as a natural condition, the average potential storage value of blue carbon on Tunda Island was relatively low compared to the Indonesian average value.

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