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Estimation of carbon stock in seagrass communities in Central Tapanuli

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Abstract This study aims to determine the carbon stock in seagrass communities in Central Tapanuli, North Sumatera, Indonesia. The research was conducted from July to August 2020 in the coastal areas of Hajoran and Jago Jago. The parameters measured in this study were density, coverage, biomass, carbon content, and carbon stock in seagrass. Biomass analysis and carbon measurement are divided into the top (above-ground biomass) and the bottom substrate (below-ground biomass). Carbon measurements are conducted using the loss on ignition (LOI) approach. The results showed that the seagrass ecosystem on the coast of Central Tapanuli Regency, which was covered by monospecies *Enhalus acoroides*, was in a less healthy condition with a cover percentage of 30.3-33.3% and a density of 59-67 shoots/m². Above-ground and below-ground seagrass biomass reached 140.19-188.72 g/m² and 368.13-423.69 g/m² respectively, while carbon stock reached 70.57-94.86 g Corg/m² and 18731-19603 g Corg/m² and total standing stock range 257.87-290.90 g Corg/m². The data obtained from this research can be used as a database to see the potential of seagrass beds as storage of CO₂ and as an effort to mitigate and adapt to climate change.

Keywords: biomass, carbon stock, Central Tapanuli, monospecies, seagrass

1 Introduction

The increase in carbon dioxide concentration has now exceeded the normal threshold in the atmosphere, reaching 400 ppm, which is expected to continue to rise every year [1]. There are many impacts caused by global warming on coastal and marine areas, such as acidification of seawater, coral bleaching, rising temperatures and sea levels. Climate change was causing spatial-temporal variability of the physicochemical parameter of coastal and oceans, driving to more frequent extreme climate events (e.g., altered upwelling and ocean circulation) [2]. Carbon sequestration potential is a key aspect of climate regulation, and seagrass meadows have shown high carbon sequestration potential as they accumulate from both in situ production and sedimentation of particulate carbon from the water column [3].

As an important coastal ecosystem, seagrass has many roles, including as a habitat for coastal and marine biota, feeding ground, nursery dan spawning ground, primary producers, trapping and stabilizing sediment, protecting coastal areas from abrasion and flooding, increasing fishery production, purifying water and captures and stores carbon dioxide [4-7]. Seagrass carries out a photosynthetic process as well



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as terrestrial plants where carbon dioxide is absorbed and stored as biomass [8]. This process can help reduce carbon dioxide levels in nature when the area of terrestrial forest decreases each year due to natural or intentional factors. For coastal and marine vegetation, the process of carbon sequestration and storage is known as blue carbon [9]. In 2009, UNEP, FAO, and UNESCO coined the term Blue Carbon, while in Indonesia the term was first introduced on 24 February 2010 at the World Minister of Environment Forum in Nusa Dua, Bali [10]. The estimated carbon that can be stored in the seagrass network ranges from 0-13 mg CO₂/ha while the sediment below ranges from 880-6000 mg CO₂/ha [11]. Seagrass meadows have been determined as necessary sinks in the global carbon cycle, as a result of they are extremely productive systems that bury organic carbon. According to [12], at least 29% of the global seagrass area has been lost globally, implying that close to 1/3 of the associated carbon sink capacity of seagrass meadows has been lost. The loss of carbon sink capacity is probably greater since seagrass meadows lose biomass and gross primary production well before they are extirpated, so that extant seagrass meadows are also expected to have lost sink capacity relative to undisturbed seagrass meadows. Efforts to stop seagrass loss and to recover lost seagrass areas will, therefore, contribute to rebuilding some of the lost seagrass carbon sink capacity and help to mitigate climate change [13].

Based on a study of [14], there is still a discrepancy in the spatial distribution of carbon data in seagrass beds where from 946 sampling locations with 3460 observations, mostly in North America, Western Europe, and Australia, and there is still little data obtained from the tropical region of Indo-Pacific. Research on blue carbon in seagrass has been carried out in several regions in Indonesia [15-17], although the number is still less than research on blue carbon in mangroves. Therefore, it is necessary to conduct a study in the North Sumatra region, especially in Central Tapanuli which has a stretch of seagrass beds in its waters. This study aims to analyze the potential of carbon storage in seagrass to reduce carbon dioxide emissions. By knowing this function, it is hoped that destructive action on seagrass beds can be prevented, and sustainable rehabilitation or conservation efforts can be prevented on seagrass can be realized.

2. Material and Methods

2.1. Study area

The map of the research location is presented in Figure 1. This research was conducted from July to August 2020 on the coast of Central Tapanuli, North Sumatra.

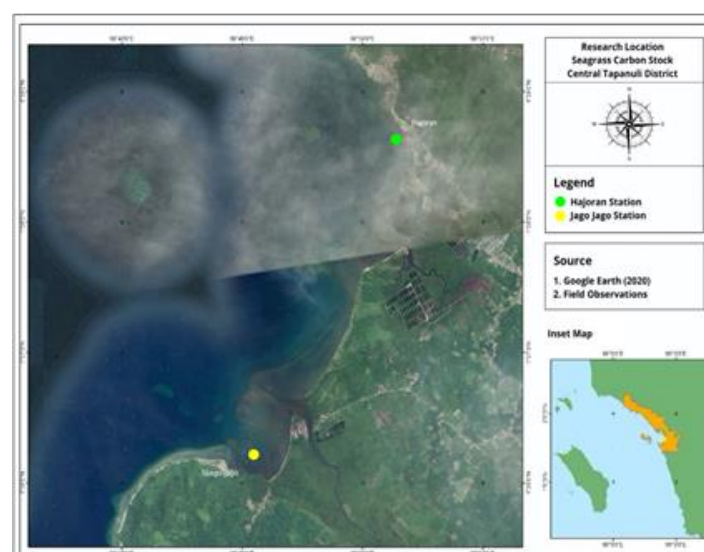


Figure 1. Study sites map.

The located in two villages (Hajoran: 1°38'43.23"N; 98°50'18.20"E and Jago-Jago: 1°36'6.52"N; 98°49'5.03"E), each of which consisted of three stations (Figure 1). The carbon measurement was carried out at the Phytochemical Laboratory of the Faculty of Pharmacy, University of North Sumatra. Direct observations in the field were carried out on environmental parameters, while for seagrass data assessed were density, cover, biomass, and carbon content.

2.2. Analysis of seagrass cover and density

The assessment and data collection of seagrass density and percentage cover were carried out using line transect drawn straight from the coastline up to 100 m towards the sea using a 0.5 x 0.5 m² plot that was placed every 10 meters [18]. This method was executed at low tide, where the water depth a half meter on average, to make it easier to identify seagrass and collect samples. Seagrass coverage is the percentage of an area covered by a seagrass canopy. The assessment of the condition and cover of seagrass is based on visual observation and refers to [19] concerning the Standard Criteria for Damage and Guidelines for Determining the Status of Seagrass (Table 1).

Table 1. Criteria of seagrass cover.

	Condition	Coverage
Good	Healthy	≥ 60%
Moderate	Less healthy	30 % - 59.9 %
Bad	Poor	≤29.9 %

Density is the number of seagrass shoots in an area 25 x 25 cm plot grids was used to assess seagrass density. The calculation for density used the equation [20]:

$$D = \text{number of shoot of a species over a given plot area} \times 16 \quad (1)$$

where D is density (shoots.m²), 16 is the conversion factor to per square meter if the quadrant plot is 25x 25 cm.

2.3. Biomass

Biomass sampling was carried out on seagrass shoots which were then separated into two parts consisting of above-ground biomass (AGB) and below-ground biomass (BGB). Seagrass is dried using an oven at 60 degrees Celsius for 72 hours until it reaches a constant weight. The equation used to analyze the biomass content [20]:

$$AGB = AGB_x \times DS_x \quad (2)$$

$$BGB = BGB_x \times DS_x \quad (3)$$

where AGB is total above-ground biomass and BGB is total below-ground in unit g m², AGB_x is above-ground biomass species x in unit g/shoots and BGB_x is below-ground biomass of species x and DS_x is shoot density per species.

2.4. Seagrass carbon

Organic carbon analysis was carried out using the loss on ignition (LOI) approach. Calculation of organic carbon stock in seagrass is determined by multiplying the percentage of the organic carbon content of each species with the dry biomass [20] as follows:

$$\%LOI = \frac{(\text{weight before burning} - \text{weight after burning})}{\text{weight before burning}} \times 100\% \quad (4)$$

$$AG_x - OCS (g \text{ Cor } g \text{ m}^2) = OCC \times AGB_x \quad (5)$$

$$BGB_x - OCS (g \text{ Cor } g \text{ m}^2) = OCC \times BGB_x \quad (6)$$

where LOI is loss on ignition, OCC is organic carbon content, and OCS is organic carbon stock.

3. Result and Discussion

3.1. Environmental condition

Seagrass on the coast of Central Tapanuli grows on a stretch adjacent to mangroves and coral reefs so that their habitat is in a substrate that varies from the sandy substrate with coral fragments to sandy mud. In areas with sandy substrate with coral fragments, the water clarity level is relatively higher or clearer than in areas with sandy mud substrate. The measurement of aquatic parameters shows that the quality of the waters of Central Tapanuli is relatively good for seagrass habitat (Table 2).

Table 2. Physico-chemical parameters of water.

Location	Salinity (ppm)	DO (mg/l)	pH	Temperature (°C)	Current (m/s)	TSS (mg/l)	N	P
Hajoran	36	3.26	7.4	31.26	0.23	25.00	3.37	0.003
Jago-Jago	35.67	5.3	7.53	30.73	0.2	23.67	2.94	0.07

Based on the results of the study, the average salinity was between 35.67 - 36 ppm in the two study locations. Each type of seagrass has a different ability to tolerate salinity which can affect the number of shoots to its biomass [21]. For dissolved oxygen in the range of 3.26-5.3 mg/l, the low dissolved oxygen in the Hajoran area is most likely due to the sampling located near the jetty and community settlements where domestic waste goes directly to the sea. Regarding [22] concerning seawater quality standards, dissolved oxygen levels of more than 5 mg/l are in a good category. Water pH measurements carried out in this study ranged from 7.4 to 7.53, according to seawater's pH, which is generally not neutral but alkaline. The current value ranges from 0.20 – 0.23 m/s, that value of water movement is quite small because the current measurement is carried out at the low tide. Meanwhile, the TSS measurement varies between 23.6 - 25 mg/l, this value slightly exceeds the TSS threshold for seagrass habitat as stipulated in the Minister of Environment Decree No 51/2004, which is less than 20 mg/l. According to Yunita [23], the existence and reproductive activity of seagrass are highly dependent on the environment so that the better the aquatic environment, the seagrass has a high chance of reproducing which affects its density. In addition, [24] stated that one of the physical factors affecting seagrass distribution is the availability of suitable substrates to grow.

3.2. Identification, cover, and density seagrass

The seagrass on the coast of Central Tapanuli are dominated by *Enhalus acoroides*, a species commonly found in tropical waters *E. acoroides* were known to have a widespread distribution in Indonesian waters [24, 25]. This species is easy to identify because of its larger size than other types of seagrass. Its large morphology allows it to grow to dominate a seagrass community and have a longer life span. This species is able to live in a variety of substrates ranging from the muddy substrate to coral fragments so that this species can be found in the two research locations with different substrate waters. Several studies found that several environmental factors significantly affected the growth of *Enhalus acoroides* that are turbidity, temperature, salinity, and nutrition [26].

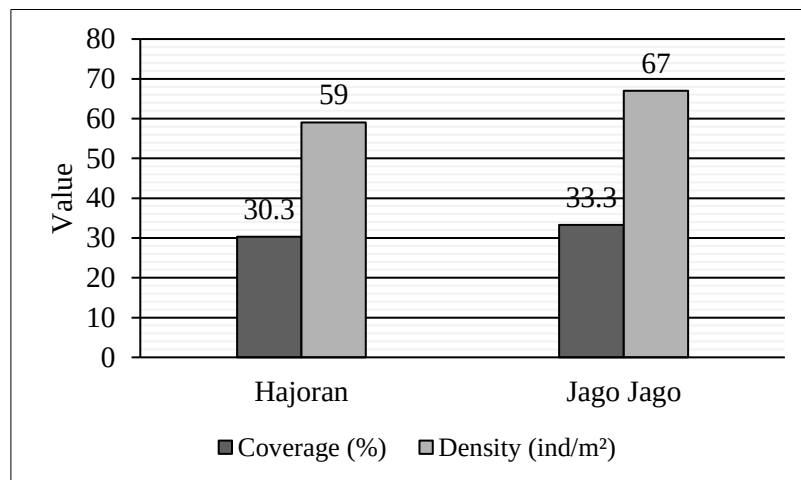


Figure 2. Percentage of cover and density of *Enhalus acoroides*.

Assessment results on seagrass cover in the monospecies *Enhalus acoroides* ranged from 30.3-33.3%. Referring to [19] regarding the status of seagrass beds, this percentage of cover indicates that seagrasses located on the coast of Central Tapanuli are in poor and less healthy conditions. In general, the percentage of seagrass cover is directly proportional to its density so that the higher the percent cover, the higher the density and vice versa. At the research location, it was found that the density ranged from 59 to 67 shoots/m² (Figure 2). The low percentage of cover and density of *Enhalus acoroides* is possible because the water areas where seagrass grows in Hajoran are close to residential areas. Meanwhile, in Jago-Jago, seagrass grows side by side with mangroves so that, there is a possibility of competition for a place to live and nutrition. This is supported by research by [27] which found that there is interaction and competition for a place to grow between seagrass and mangroves that live side by side.

3.3. Seagrass biomass

Seagrass biomass is divided into two parts, namely above-ground biomass consisting of leaf blades and midrib and below-ground biomass consisting of roots and rhizome. The results of measurements of the biomass of *Enhalus acoroides* at the study location showed that the value of the below-ground biomass was much greater than that above-ground biomass with the average biomass above-ground the substrate ranging from 140.19 – 188.72 g/m² and the below-ground biomass ranging from 368.13 – 423.69 g/m² (Figure 3) Duarte *et al.* [28] and Tasabaramo *et al.* [29] revealed that in general the ratio of biomass at the bottom of the seagrass was greater than that of the upper part, this was due to the results of photosynthesis, and the nutrients absorbed by the roots were mostly stored in rhizomes to support the seagrass ability to withstand ocean currents and waves.

The level of density is generally directly proportional to the total biomass of seagrass where the higher the density, the higher the total biomass and vice versa. This can be evidenced by a higher density level in Jago-Jago followed by higher biomass than the density and biomass of seagrass at Hajoran. In addition, as a large seagrass, *Enhalus acoroides* can produce a higher biomass value than other types which are generally smaller and shaped like grass. This is supported by several previous studies which show that large species such as *Enhalus acoroides* tend to have a higher biomass value than other species so that they are often the largest contributor to total biomass in a seagrass bed community [30].

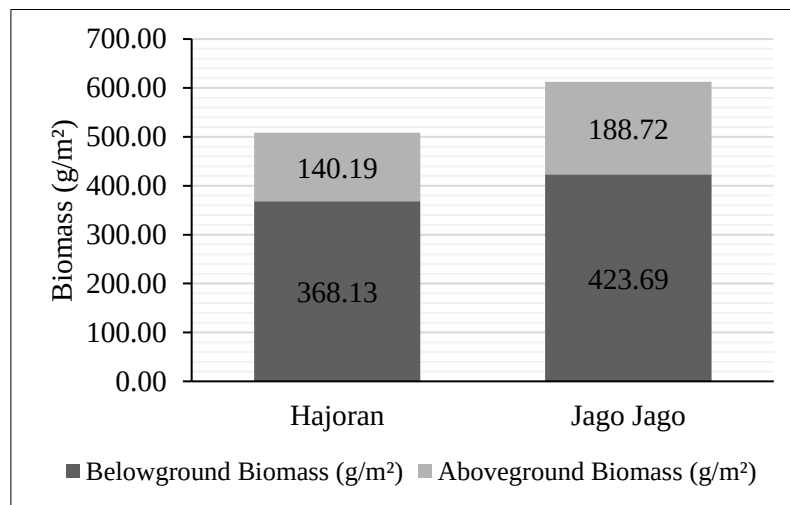


Figure 3. *Enhalus acoroides* density biomass

3.4. Seagrass carbon

The measurement of organic carbon in seagrass was carried out using the LOI method. The results of the average measurement of carbon stock ranged from 70.57 – 94.86 g Corg/m² at the top and 187.31 – 196.03 g Corg/m² at the bottom (Figure 4). The advantage of this condition is that when the fronds and seagrass leaves are broken due to natural or anthropogenic factors, whereas seagrass is still able to store a large amount of carbon at the bottom while waiting for the leaves to grow again. The total standing stock of carbon obtained from this study was 257.87 – 290.90 g Corg/m² (Figure 5). The top of the seagrass, such as the leaves, is a short-term carbon store because it is widely used in the food chain (consumed by herbivores) and is susceptible to exposure to aerobic conditions and chemicals [14].

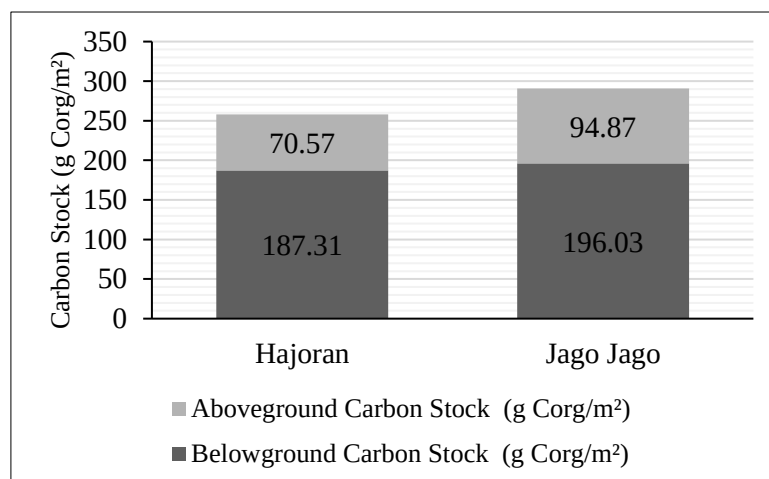


Figure 4. Above-ground and below-ground carbon stock.

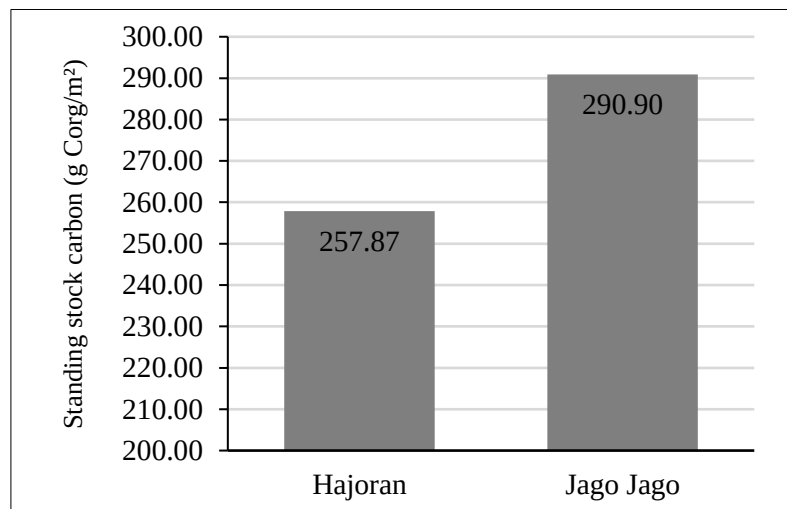


Figure 5. Standing stock carbon.

Each species has a different ability to absorb and store carbon As well as its ability to produce biomass, the carbon stock contained in its tissues are stored larger at the bottom, namely the rhizome and roots. *Enhalus acoroides* that grow in tropical water have a high ability to absorb and store carbon because of the larger size of the stem, rhizome, and roots than other species so that it can produce large biomass and high carbon uptake [31]. Large species are also able to survive longer because of the slow turnover of roots and rhizomes compared to small species such as *Halophila ovalis* which affects their ability to accumulate total carbon storage [30, 32, 17].

Seasonal factors also affect the ability of seagrass as carbon storage. High waves in the rainy season are causing litter to increase and reduce its ability to store seagrass while in the dry season the sun's intensity is higher so that seagrass is more exposed to the sun during low tide which causes the ability to absorb and store carbon to be better [33]. The probability that the carbon value obtained is higher in this study because the measurement and sampling were carried out in the eastern or dry season period, but further research is needed to confirm this because there is no research result on seagrass carbon in Central Tapanuli which was carried out in the western season which can be used as a comparison.

The amount of carbon stored in seagrass is influenced by various factors so that there are differences in carbon stocks in seagrass in each region (Table 3). Seagrass is proven to be able to absorb and store carbon dioxide in its biomass, this shows that seagrass has an important role in climate change mitigation, so that it needs to preserve the seagrass ecosystem to be sustainable. However, when the seagrass beds are damaged, it eliminates their ecological function and releases the carbon stored back into the atmosphere [34-36].

Table 3. Comparison of carbon stock in the different area of Indonesia.

Location	Carbon Stock (g Corgm ⁻²)	Source
Berakit (Bintan, Riau Islands)	233.67	[30]
Pulau Kaposong (South Sulawesi)	16.40	[15]
Karang Tirta (West Sumatera)	12.99	[37]
Pulau Befondi (Papua)	18.04	[38]

The table shows that each region in Indonesia has different potential carbon stock., when compared to the location of this study with other research in Table 3 illustrates that Hajoran and Jago-jago (Central Tapanuli) have the higher potential carbon stock than others which ranges 251.87-290.90 g Corg/m². Regarding [39] stated the total above-ground carbon, below-ground carbon, standing stock, and carbon

sequestration of seagrass meadows in Indonesia were ca 80–314 ktC, 196–696 ktC, 276–1005 ktC and 1.6–7.4 MtC/year, respectively. Considering their potential for carbon stock and carbon sequestration, Indonesia's seagrass meadows play important roles in greenhouse gas reduction and climate change mitigation.

4. Conclusion

This study found the seagrass community on the coast of Hajoran and Jago-jago which is covered by the monospecific *Enhalus acoroides* is in a less healthy condition with a cover percentage of 30.3–33.3% and a density of 59 - 67 shoots/m². The percentage of biomass reached 140.19–188.72 g/m² at the top and 368.13–423.69 g/m² below-ground, while carbon stock reached 70.57–94.86 g Corg/m² at the top and 187.31–196.03 g Corg/m² at the bottom of substrate and the total standing stock range 257.87–290.90 g Corg/m². The data obtained from this research can be used as a database to see the potential of seagrass beds as storage of CO₂ and as an effort to mitigate and adapt to climate change. In addition, seagrass beds role can be taken into consideration in conservation efforts for the sustainability of the seagrass ecosystem in Central Tapanuli.

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