Carbon stock of the seagrass *Enhalus acoroides* and *Thalassia hemprichii* in Tanjung Tiram coastal waters, Poka, Ambon Island

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Abstract. Seagrass is a marine plant that can reduce carbon dioxide by storing carbon and can bind carbon in thousands of years. The ability of seagrass beds as a carbon sink can be determined by calculating carbon stocks. The purpose of this study was to analyze the carbon stock of seagrass *Enhalus acoroides* and *Thalassia hemprichii*. This research took place at Tanjung Tiram Coastal Waters, Poka Village, Ambon Island on June 2019. The study was conducted at two different stations, namely station one on mixed sand and gravel substrates and station two on mixed sand and mud substrates. Carbon content was analyzed by using the Walkley and Black method. The results of the study showed that carbon stock of *E. acoroides* ranged from 78.89 gC.m$^{-2}$ to 107.42 gC.m$^{-2}$ and was higher than *T. hemprichii*, which ranges from 50.04 gC.m$^{-2}$ to 64.75 gC.m$^{-2}$. The carbon stock was higher in the below-ground component, especially in rhizome which was 46.94 gC.m$^{-2}$ - 61 gC.m$^{-2}$ (*E. acoroides*) and 25.74 gC.m$^{-2}$ - 33.59 gC.m$^{-2}$ (*T. hemprichii*). Seagrass beds in the mixed sand and mud substrates have a higher carbon stock and can store more carbon.

1. Introduction

The climate change was characterized by an increase in global temperatures, rising sea levels, changes in rainfall (precipitation) as well as increasing extreme events such as floods, droughts, heatwaves, and storms have seized the attention of various groups such as scientists, environmental practitioners, decision-makers and other communities. The main cause of these events is the increase in greenhouse gas emissions such as CO$_2$, CH$_4$, and N$_2$O as a result of increased anthropogenic activity. The concentration of CO$_2$ in the atmosphere in 1780 was 280 ppm [1]. The current concentration of CO$_2$ increased sharply with the global average measurements between 1984 and 2011 amounted to 390 ± 0.1 ppm. The average CO$_2$ concentration in Indonesia between 2004 and 2013 amounted to 379.9 ± 4.9 ppm with the highest measurements reached 390.3 ppm in June 2013[2]. High concentrations of CO$_2$ in the atmosphere will automatically increase CO$_2$ concentrations in ocean waters. According to Borges [3, 4] that coastal waters play an important role in the total global carbon budget because they receive carbon and nutrient flow from the land and the presence of large-sized coastal vegetation. In addition, coastal waters represent about 8% of ocean waters, and globally coastal waters produce 25% of marine primary productivity that requires carbon dioxide in the process of photosynthesis [5].

Seagrass is one of the coastal vegetation, requires CO$_2$ to carry out photosynthesis, and to convert it into carbohydrates stored in biomass, both biomass in part above ground (such as leaves sheath and
leaves blade) and the part below ground (such as rhizomes and roots). Carbon storage in biomass, especially at the below-ground, makes the role of seagrasses more important because it will be stored for a long time [6]. In the process of photosynthesis, seagrass utilizes inorganic carbon in the water column so that seagrass can reduce CO$_2$ [7]. Through the process of photosynthesis, seagrass shows the ability to sink CO$_2$ from the atmosphere into the sea by a mechanism of partial pressure difference from the atmosphere to the sea, which is then stored either in the form of seagrass biomass itself or stored in the bottom of waters or sediments. Thus seagrasses can reduce CO$_2$ gas as one of the effects of global warming due to increased greenhouse gas emissions.

One of the areas in Ambon Island that has a fairly wide seagrass field with a sloping beach topography is Tanjung Tiram Waters, Poka Village. These waters are overgrown by five species of seagrass, namely *Cymodocea rotundata*, *Halodule pinifolia*, *Enhalus acoroides*, *Thalassia hemprichii* and *Halophila ovalis* where *T. hemprichii*, and *E. acoroides* have a greater percentage of cover [8]. Related to the function of seagrass as carbon sinks, the seagrass beds in Tanjung Tiram have the potential to absorb and to store carbon while at the same time reducing carbon dioxide in the waters and the atmosphere. This study aims to determine the potential of carbon stocks at the above-ground (leaves) and the below-ground (roots and rhizomes) in seagrass species *T. hemprichii* and *E. acoroides*.

2. Method

2.1. Sampling method

This research took place at Tanjung Tiram Coastal Waters, Poka Village, Ambon Island on June 2019 (Figure 1). Seagrass sampling was carried out at two research stations, namely station 1, with the type of mixed sand and rubble substrate and station 2, with the type of mixed sand and mud substrate. Seagrass sampling was conducted in an observation plot measuring 1 x 1 m with six repetitions at each station. Samples of seagrass *T. hemprichii* and *E. acoroides* were taken in full, including leaves, rhizome, and roots. The sample was then cleaned off the attaching organism and put into a plastic sample, then taken to the laboratory. Seagrass density was calculated as the number of the shoot of each seagrass species per sampling area.

![Figure 1. Seagrass sampling locations in Tanjung Tiram, Ambon Island](image-url)
2.2. Sample analysis method

Seagrass biomass was counted in the part above-ground, including the leaf sheath and leaf blade (not separated), and the part below-ground includes the roots and rhizomes. The sample was then dried at 60°C for 24 hours until it reached a constant weight and weighed to obtain a dry weight. Furthermore, seagrass biomass was calculated by multiplying the density of each species by biomass per shoot.

Analysis of carbon content was carried out at the Laboratory of the Department of Soil and Land Resources, Faculty of Agriculture, Bogor Agricultural University based on the Walkley & Black method [9] as follows: 1 g of dry sample was put into a 50 ml measuring flask, then 10 ml 0.167 M K₂Cr₂O₇ and 10 ml concentrated H₂SO₄ were added and then shaken. The orange-red color in the solution must be maintained. If the color changes to green or blue, then K₂Cr₂O₇ and H₂SO₄ were added until orange-red color is maintained and the amount of this addition is recorded so the same amount must be added to the blank. The solution was then allowed to cool for about 30 minutes. After that, 5 ml of 85% H₃PO₄ and 1 ml of diphenylamine were added, and the solution was diluted with distilled water until the volume of the solution reaches 50 ml. As many as 5 ml of the solution was transferred to a 50 ml Erlenmeyer flask, and 15 ml of distilled water was added, then titration was done by adding 1 N or 0.5 N FeSO₄ solution until the color turned greenish. The procedure is carried out for samples and blanks. The following formula was used for calculating carbon:

\[
\% C = \frac{(B - A) \times M \text{ FeSO}_4 \times 12 \times 100}{g \text{ sample} \times 4000}
\]

where: \(B\) = ml blank titration
\(A\) = ml sample titration
12/4000 = miliequivalent weight of C in grams

Carbon storage was obtained from total biomass multiplied by carbon content so that biomass can be determined in units of gC.m⁻² [10].

3. Results and discussion

3.1. Carbon stock

The results of carbon stock analysis show that E. acoroides vegetation has a total carbon stock ranging from 78.89 gC.m⁻² - 107.42 gC.m⁻², and this value was higher than the total carbon stock of T. hemprichii ranging from 50.04 gC.m⁻² - 64.75 gC.m⁻² (Table 1). The carbon stock was higher in the below-ground component, especially in the rhizome, which was 46.94 gC.m⁻² - 61 gC.m⁻² (E. acoroides) and 25.74 gC.m⁻² - 33.59 gC.m⁻² (T. hemprichii). This is related to the morphological structure of species E. acoroides, which have larger leaves, rhizomes, and roots compared to T. hemprichii, so that the potential to store carbon in biomass is greater. According to Laffoley and Grimsditch [11] morphologically large seagrass species tend to store greater biomass at the below ground, and the capacity to accumulate carbon becomes higher. The results of this study were in line with research conducted by Duarte and Chiscano [12]; Kiswara [13]; Rahmawati and Kiswara [14]; Irawan [15] who found the allocation of carbon stocks in the below-ground component was greater than the above-ground.

The potential of blue carbon in the below-ground part was likely to be stored longer and will continue to grow if the seagrass ecosystem was preserved, while the above-ground part was more utilized in the food chain and decomposes and had little potential to be stored in the substrate. Besides, the rate of the carbon sink in seagrass ecosystems, both originating from seagrass litter or another high organic biota can be maintained for thousands of years [16]. This was consistent with research conducted by Gacia et al. [17] in the seagrass beds of Posidonia oceanica in Mediterranean waters that carbon deposits produced by the monospecies seagrass ecosystem amounted to 198 gC.m⁻² year⁻¹ with 72% sourced from seston and 28% sourced from litter. The amount of sediment released by the
remineralization process that occurs from the sediment back into the water column was estimated at 15.6 gC.m\(^{-2}\).year\(^{-1}\), and 182 gC.m\(^{-2}\).year\(^{-1}\) remaining remains stored in sediments that are potentially buried thousands of years as a carbon sink [17].

Table 1. The value of carbon stock in parts of seagrass

| Station | Species     | Carbon stock (gC.m\(^{-2}\)) |
|---------|-------------|------------------------------|
|         |             | Leaves | Rhizomes | Roots | Total |
| 1       | T. hemprichii | 20.09  | 25.74    | 4.21  | 50.04 |
|         | E. acoroides  | 16.60  | 46.94    | 15.35 | 78.89 |
| 2       | T. hemprichii | 24.13  | 33.59    | 7.03  | 64.75 |
|         | E. acoroides  | 23.36  | 61.00    | 23.06 | 107.42 |

According to Baron et al., [18], to calculate the biomass in units of grams of carbon per meter square (gC.m\(^{-2}\)) or known as carbon stock was to calculate the carbon weights of biomass per m\(^2\) parts of seagrass plants from gram dry weight (g.DW.m\(^{-2}\)) converted to mol C with percentage carbon content (% C) dry weight of biomass. It means that the value of carbon stocks was determined by the value of biomass and carbon content. Thus, the value of carbon stocks at a high was supported by the value of carbon content (Figure 2) as well as the high value of biomass (Table 2). The carbon content of T. hemprichii ranged from 30.09 % DW (root) - 48.65 % DW (rhizome) and of E. acoroides 41.13 % DW (leaf) - 53.10 % DW (rhizome). These values are higher than those obtained by Rahmawati and Kiswara [14] for E. acoroides, ranging from 32.26% DW (above-ground) - 33.26% DW (below-ground). According to Duarte et al., [19], the average carbon content in seagrasses was approximately 33.6% DW, and the range for E. acoroides was 37 - 42% DW. The results of this study are higher and are thought to be related to the environmental, nutritional conditions that support the nutritional conditions and organic matter of the seagrass.

![Figure 2. Carbon content in seagrass organs](image)

3.2. Biomass and density

The total biomass of T. hemprichii ranged from 115 gDW.m\(^{-2}\) - 160.60 gDW.m\(^{-2}\) with a ratio of above-ground and below-ground was 1:1.5 and E. acoroides ranged from 163.80 gDW.m\(^{-2}\) - 230.80 gDW.m\(^{-2}\) with a ratio of above-ground and below-ground was 1 : 3 (Table 2). According to Azkab [20], seagrass biomass is the weight of all material that lives in a certain unit of area, both on the above-ground and below-ground expressed in grams of dry weight per m\(^2\). Seagrass biomass as a potential for blue carbon was stored more at the below-ground [21]. Biomass formed in the below-ground part was
generally more dense compared to biomass in the above-ground part. Besides, the high biomass in the below-ground part was related to the rhizome and root morphological size. According to Fourquean et al. [22], organic carbon was stored in seagrass biomass by an average of 2.52 ± 0.48 mg C.ha⁻¹, and two-thirds are stored in rhizomes and roots.

**Table 2. The value of biomass in parts of seagrass**

| Station | Species         | biomass (gDW.m⁻²) | Leaves | Rhizomes | Roots | Total  |
|---------|-----------------|-------------------|--------|----------|-------|--------|
|         |                 |                   |        |          |       |        |
| 1       | *T. hemprichii*  | 48.30             | 52.90  | 13.80    | 115.00|        |
|         | *E. acoroides*   | 39.00             | 88.40  | 36.40    | 163.80|        |
| 2       | *T. hemprichii*  | 64.24             | 73.00  | 23.36    | 160.60|        |
|         | *E. acoroides*   | 56.80             | 120.75 | 53.25    | 230.80|        |

Biomass is related to seagrass density, and high density will cause high biomass as well. The density of seagrass *T. hemprichii* ranged from 230 shoot.m⁻² - 292 shoot.m⁻² and *E. acoroides* ranged from 52 shoot.m⁻² - 71 shoot.m⁻² (Figure 3). Although the density of *T. hemprichii* was higher than *E. acoroides*, it had a smaller biomass value. According to Fortes [23] that the amount of seagrass biomass, in addition to being a function of density, was also a function of plant size. Thus, although *E. acoroides* has a low-density value, because it has a body size that is much larger than *T. hemprichii*, it will have greater biomass.

![Figure 3. The density of seagrass](image)

The value of density, biomass, and carbon stock in the seagrass of Tanjung Tiram coastal waters, Poka was higher in station two, which was mixed sand and mud substrate. Yunitha [24] stated that the magnitude of the substrate grains influences the absorption of organic carbon because the larger substrate grains reduce the ability of the substrate to absorb organic carbon. Besides that, Christon [25] states that the amount of seagrass biomass on the smaller substrate was caused by a positive effect on the nutrient absorption system, while a larger (coarse) substrate will decrease nutrients and organic matter.

Seagrass *T. hemprichii* and *E. acoroides* in Tanjung Tiram Coastal Waters, Poka Village, proved capable of storing carbon recorded in parts of their organs. The amount of CO₂ that can be stored in 2 species of seagrass in these waters with an area of seagrass of 6.075 ha was 18.291 Mg CO₂. Thus the seagrass can reduce CO₂, as well as play a role in mitigating climate change.
4. Conclusion
The coastal waters of Tanjung Tiram, Poka Village, Ambon Island have a total carbon stock in 2 seagrass species (T. hemprichii and E. acoroides) of 301.10 gC.m\(^{-2}\). The carbon stock value is mostly found at the below-ground, which is 72% and more specifically in the rhizome part, which is 55.55%.

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References
[1] [IPCC] Intergovernmental Panel of Climate Change 2007 Synthesis Report An assessment of Intergovernmental Panel of Climate Change. A reference
[2] [BMKG] Badan Meteorologi Klimatologi Geofisika. 2013 Data CO\(_2\) atmosfer [internet]. Tersedia pada: http://gawkototabang.com/hal.php?hal=co2 Another reference
[3] Borges AV 2005 Do We Have Enough Pieces of the Jigsaw to Integrate CO\(_2\) Fluxes in the Coastal Ocean?. Estuaries. 28(1) 3–27. More references
[4] Borges AV 2011 Present day carbon dioxide fluxes in the coastal ocean and possible feedback under global change. In: Duarte P, Santana Casiano JM, editor. Ocean and the Atmospheric Carbon Content. Berlin (DE): Springer Publishing. pp 47-77.
[5] Ribas-Ribas M, Hernández-Ayón JM, Camacho-Ilbar VF, Cabello-Pasini A, Mejía-Trejo A, Durazo R, Galindo-Bect S, Souza AJ, Forja JM, Siqueiros-Velencia A 2011 Effect of upwelling, tides and biological processes on the organic carbon system of a coastal lagoon in Baja California. J Est Coast and Shelf Sci 30 1–10. doi: 10.1016/j.ecss.2011.09.017
[6] Kiswara W, Ulumuddin YI 2009 Peran vegetasi pantai dalam siklus karbon global: mangrove dan lamun sebagai rosot karbon. Workshop Ocean and climate change. Laut sebagai pengendali perubahan iklim: peran laut Indonesia dalam mereduksi percepatan proses pemanasan global. Bogor 4 Agustus 2009.
[7] Beer S, Björk M, Hellblom F, Axelsson L 2002 Inorganic carbon utilization in marine angiosperms (seagrass). Funct Plant Biol. 29 349-354.
[8] Tupan, Cl. 2016. Status Padang Lamun Perairan Tanjung Tiram, Poka, Teluk Ambon Dalam. Prosiding Seminar Nasional Kelautan dan Perikanan ke III. Fakultas Kelautan dan Perikanan, Universitas Nusa Cendana. Kupang. Pp 94 – 100.
[9] Schumacher BA 2002 Methods for The Determination of Total Organic Carbon (TOC) in Soils and Sediments. USA: United States Environment Protection Agency. Environmental Science Division National.
[10] Blue Carbon Initiative 2014 Coastal Blue Carbon Methods for Assessing Carbon Stocks and Emissions Factors in Mangrove, Tidal Salt Marshes, and Seagrass Meadows.
[11] Laffoley D and Grimsditch GD 2009 The Management of Natural Coastal Carbon Sinks. IUCN, Gland Switzerland.
[12] Duarte CM and Chiscano CL 1999 Seagrass biomass and production: a reassessment. Aqua Bot 65 159-174
[13] Kiswara W 2010 Studi pendahuluan: Potensi padang lamun sebagai karbon rosot dan penyerap karbon di Pulau Pari, Teluk Jakarta. Oseanologi dan limnologi di Indonesia 36 (3): 361 – 376.
[14] Rahmawati S dan Kiswara W 2012 Carbon stock and the capability as carbon sink in monospecies vegetation of Enhalus acoroides in Pari Island, Jakarta. Oseanologi dan limnologi di Indonesia 38 (1) 143 – 150.
[15] Irawan A 2017 The carbon stock and potential uptake of seagrass beds in the northern and eastern part of Bintan Island. Oseanologi dan limnologi di Indonesia 2 (3) 35 – 48.
[16] Kiswara W 2009 Potensi padang lamun sebagai penyerap karbon: *Studi kasus di Pulau Pari, Teluk Jakarta*. Disampaikan dalam PIT ISOI VI 16-17 November 2009. Bogor (ID)

[17] Garcia E, Duarte CM, Middelburg JJ 2002 Carbon and nutrient deposition in a Mediterranean seagrass (*Posidonia oceanica*) meadow. *Limnol. Oceanogr.* 47(1) 23-32

[18] Barron C, Marba N, Terrados J, Kennedy H, Duarte CM 2004 Community metabolism and carbon budget along a gradient of seagrass (*Cymodocea nodosa*) colonization. *Limnology Oceanografi* 49(5) 1642–1651

[19] Duarte CM 1990 Seagrass nutrient content. *Marine Ecology Progress Series.* 67 201–207.

[20] Azkab, MH 2000 Produktivitas di Lamun. *Oseana* 25 (1) 1-11. Balitbang Biologi Laut, Pustlibang Biologi Laut-LIPI, Jakarta.

[21] Rustam A, Bengen DG, Arifin Z, Gaol JL, dan Arhatin RE 2014a Growth Rate and Productivity Dynamics of Enhalus acoroides Leaves at the Seagrass Ecosystem in Pari Islands Based on In Situ and Alos Satellite Data. *International Journal of Remote Sensing and Earth Sciences (IJReSES)* 10(1) 37-46

[22] Fourqurean JW, Duarte CM, Kennedy H, Marba N, Holmer M, Mateo MA, Apostalki ET, Kendrick GA, Krause-Jensen D, Mc Glathery KJ, Serrano O 2012 Seagrass ecosystem as a globally significant carbon stock. Nat Geosci 1-5.

[23] Fortes MD 1990 Seagrasses: A Resource Unknown in the ASEAN Region. *ICLARM Education Ser* 5. International Center for Living Aquatic Resources Management, Manila, Philippines. p 361

[24] Yunitha A 2015 *Kandungan C-Organik pada Lamun Berdasarkan Habitat dan Jenis Lamun di Pesisir Desa Bahoi Kabupaten Minahasa Utara Sulawesi Utara*. Tesis, Institut Pertanian Bogor, Bogor.

[25] Christon 2012 Pengaruh Tinggi Pasang Surut Terhadap Pertumbuhan dan Biomassa Daun Lamun *Enhalus acoroides* di Pulau Pari Kepulauan Seribu Jakarta. *Jurnal Universitas Padjajaran* 3(3) 287-294.