Eco. Env. & Cons. 26 (2) : 2020; pp. (798-803)

ISSN 0971–765X

The potential of seagrass as a carbon stock and carbon sequestration in suli coastal waters, Ambon Island, Indonesia

Charlotha Irenny Tupan[1]* and Mintje Wawo[1]

[1]Faculty of Fisheries and Marine Science, Pattimura University, Ambon, Indonesia

(Received 14 October, 2019; accepted 13 January, 2020)

ABSTRACT

As an autotrophic organism, seagrass has the ability to carry out photosynthesis by utilizing CO_2 to produce new organic material and store it in biomass. The purpose of this study was to analyze carbon stocks and carbon sequestration of seagrasses *Enhalus acoroides* and *Thalassia hemprichii*. This research was conducted on May 2019 and located in the Suli Coastal Waters, Ambon Island. The study was conducted at two different stations, namely station one on the sandy substrate and station two on the muddy substrate. Analysis of carbon stocks began with the calculation of density and biomass, while carbon sequestration was analyzed based on growth and production rates. Seagrass samples were collected in 3 observation plots measuring 1 x 1 m placed randomly in the seagrass bed of *Thalassia hemprichii* and *Enhalus acoroides* at each station. The analysis of carbon content was based on the Walkley and Black method. The results of this study indicated that the total potential carbon stocks in the *T. hemprichii* ranged from 74.75gC.m^{-2}- 119.98 gC.m^{-2} and in the *E. acoroides* ranged from 92.69gC.m^{-2}-159.86 gC.m^{-2}. Seagrass's ability to absorb CO_2 to produce biomass was 1.15gC.m^{-2}.d^{-1}- 1.51 gC.m^{-2}.d^{-1} for *T. hemprichii* and 1.42 - 1.62 gC.m^{-2}.d^{-1}for *E. acoroides*. The muddy substrate with overgrown by *E. acoroides* had the potential of carbon stock, and carbon sequestration was higher than the sandy substrate with *T. hemprichii*.

Key words: *Biomass, Carbon, Productivity, Seagrass*

Introduction

Global warming is one of the issues that is developing in many countries. Global warming is characterized by rising temperatures on the surface of the earth due to the increased concentration of greenhouse gases in the atmosphere, such as carbon dioxide (CO_2). Coastal ecosystems have the ability to absorb and to store carbon over long periods relatively, including mangrove forests and seagrass beds. Seagrass beds are complex and productive ecosystems in marine and coastal ecosystems. One of the main roles of seagrass is to store carbon with its unique characteristics (Kennedy and Bjork, 2009). Based on carbon budget analysis, metabolic measurements, and estimation of carbon storage capacity, seagrass communities exhibit autotrophic properties so that they act as carbon storage (Duarte *et al.*, 2010). Seagrasses can reduce carbon dioxide by storing carbon 35 times faster than that of tropical rain forests and can bind carbon in thousands of years (Nellemann *et al.*, 2009; Macreadie *et al.*, 2014). In addition, seagrass ecosystems can capture around 70% of the total organic carbon in the sea (Nellemann *et al.*, 2009).

As an autotrophic organism, seagrass has the ability to carry out photosynthesis to produce new organic material. CO_2 will be bound and converted into biomass in the form of body organs or food reserves,through photosynthesis (Harris and Feriz, 2011). This biomass will then enter the food web through a herbivory process followed by predation of the next trophic level and through the process of litter decomposition (Hutomo and Azkab, 1987). Thus, seagrass plants play an important role in the absorption of CO_2 gas and become an important producer for other organisms in the food web. The ability of seagrass to carry out photosynthesis utilizing carbon dioxide (CO_2) and storing it in biomass is known as blue carbon. This plant uses CO_2 gas dissolved in water. In carrying out photosynthesis, seagrass utilizes inorganic carbon dissolved in the water column so that seagrass can reduce CO_2 (Beer *et al.*, 2002).

The increasing impact of CO_2 gas pollution has resulted in increasing human awareness of the importance of plants in absorbing CO_2 (Bala, 2014). Recently, most of the attention has been paid to terrestrial plants rather than marine plants (Duarte *et al.*, 2013). This is due to the lack of information about the importance of marine plants in absorbing CO_2 and turning it into carbon stocks, especially for seagrass vegetation. Therefore, the research that examines potential stock and carbon uptake by marine plants, especially for seagrasses, needs to be carried out to enrich the information on the functions and services of these plants to reduce pollution by absorbing CO_2gas. The purpose of this study was to analyze carbon stocks and carbon sequestration of seagrasses *E. acoroides* and *T.hemprichii*.

Materials and Methods

The study area

This research was carried out in the Suli Coastal waters, Ambon Island, Indonesia,on May 2019. Sampling was carried out at two stations representing the sandy substrate (station 1) and muddy substrate (station 2) (Figure 1).

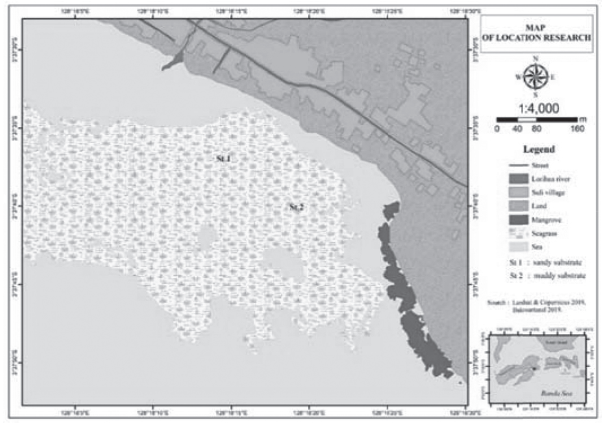

Fig. 1. Map of Research Location

Carbon stock analysis

Calculation of carbon stocks was began by calculating the value of the seagrass density and biomass. Seagrass density was calculated in a 1x1m observation plot. Three observation plots were placed in the seagrass bed of *E. acoroides* and *T. hemprichii* at each station. The measurement of biomass was done by harvesting methods. Harvested seagrass samples were separated into roots, rhizomes, and leaves and dried at 60^0 C for 24 hours until they reach a constant weight. Carbon content analysis was based on the Walkley and Black method (Schumacher, 2002).

Carbon sequestration analysis

Carbon sequestration in seagrass beds was analyzed by measuring the production rate of seagrass as a result of carbon conversion in photosynthesis. The calculation of the seagrass production rate began with growth measurements of seagrass at each station. Growth rates of seagrass were measured on the leaves by using the tagging method (Short and Duarte, 2001). The growth of leaf was observed in the dominant seagrass species, namely *T. hemprichii* and *E. acoroides,* as many as 30 shoots for ten days. Seagrass leaves are marked with a thread at the height of 2 cm from the base of the leaf. To support it, bamboo sticks were used where the tip of the sticks was placed on the thread mark. After ten days, right on the leaf above, the supporting stick was cut, and the sample was put into a plastic sample. Next, the section between the cut leaves and the marker thread (growing leaves) was measured for growth length. The leaves were then put into plastic samples and labeled. In the laboratory, leaves were dried at 60 °C for 24 hours until they reach a constant weight, and the biomass was analyzed. Carbon content analysis was based on the Walkley and Black method (Schumacher, 2002).

Method of data analysis

Growth, production, biomass, and density data were calculated according to Short and Duarte (2001).

Density

Density was calculated by the formula:

$$D = ni / A$$

Where:

D = Density (shoot.m^{-2})

ni = Shoot number of seagrass species (shoot)

A = Area of observation (m^2)

Biomass

Biomass was calculated by the formula:

$$B = W \times D$$

Where :

B = Biomass of seagrass species (gDW.m^{-2})

W = Dry weight of a shoot (gDW)

D = Density (shoot.m^{-2})

Growth

Leaf growth of *E. acoroides* and *T. hemprichii* were calculated by the formula:

$$G = (Lt-L0)/\Delta t$$

Where:

G= Growth (cm.day^{-1})

ΔT = Observation length of time (days)

L0 = Leaf length starting observation (cm)

Lt = Length of leaf end on day t (cm)

Production

The production of *E. acoroides* and *T. hemprichii* leaves is calculated by the formula:

$$Pt = P \times D$$

Where :

Pt =Leaf production per area (gDW.m^{-2}.day^{-1})

P =Leaf production of each shoot (gDW.$shoot^{-1}$.day^{-1})

D = Density (shoot.m^{-2})

Carbon stock

Carbon stock was calculated from total biomass multiplied by carbon content so that biomass can be determined in units of gC.m^{-2} (Barron *et al.*, 2004).

Carbon Stock (gC.m^{-2}) = Biomass (gDW.m^{-2}) × C organic (%) / 100

Results

Carbon stock

Based on the analysis of seagrass density values,as shown in Figure 2. Higher densities were represented by *T. hemprichii* both at station 1 (316 shoot.m^{-2}) and at station 2 (482 shoot.m^{-2}). However, the highest total biomass value was shown by *E. acoroides* at station 2 of 342.02gDW.m^{-2} (Table 1). *E.acoroides* has a much larger morphological form than that of *T. hemprichii*, resulting in more biomass being stored in the species. The value of seagrass biomass of a species will support the amount of carbon content. The carbon content of each seagrass species can be seen in Figures 2 and 3. The largest carbon content was in the rhizome for both two seagrass species. This causes the carbon stock stored was also high in the rhizome and, more specifically, for *E. acoroides* at 92.80gC.m^{-2} (Table 2), followed by the leaves, and the lowest was in the roots (Table 2). The highest total carbon stock owned by *E. acoroides* was 159.86 gC.m^{-2} followed by *T. hemprichii* was 119.98gC. m^{-2} at station 2.

Table 1. Biomass of seagrasses

Station	Species	Biomass (gDW.m^{-2})			
		Leaves	Rhizomes	Roots	Total
1	*T. hemprichii*	72.68	79.00	25.28	176.96
	E. acoroides	48.80	106.75	45.75	201.30
2	*T. hemprichii*	110.86	120.50	38.56	269.92
	E. acoroides	87.22	176.40	78.40	342.02

Table 2. Carbon stock of seagrasses

Station	Species	Carbon stock (gC.m^{-2})			
		Leaves	Rhizomes	Roots	Total
1	*T. hemprichii*	29.92	37.11	7.72	74.75
	E. acoroides	19.28	54.97	18.44	92.69
2	*T. hemprichii*	47.00	60.26	12.72	119.98
	E. acoroides	35.03	92.80	32.03	159.86

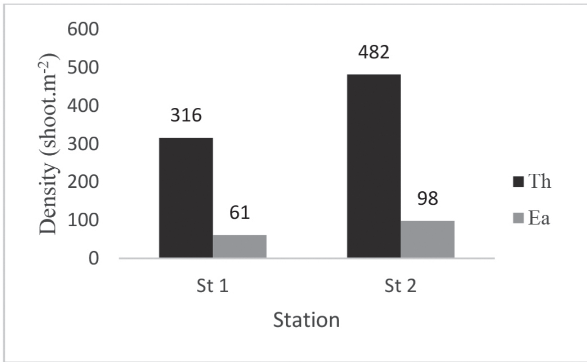

Fig. 2. Density of seagrasses

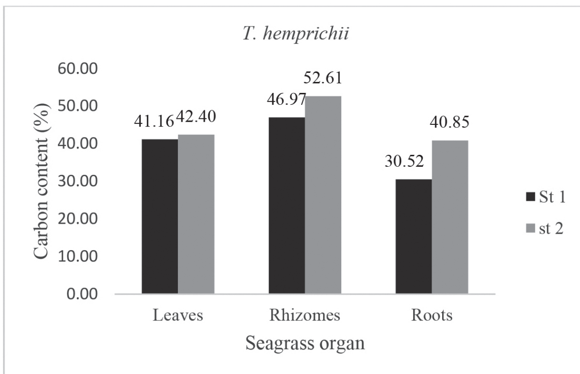

Fig. 3. The carbon content of each *T. hemprichii* organ

Carbon sequestration

Carbon sequestration in photosynthesis is related to the growth or increase of plant biomass. By measuring productivity, it also measures the average growth of seagrass leaves. The average growth of seagrass leaves at each station can be seen in Figure 4. The growth of seagrass *E. acoroides* was higher than that of *T. hemprichii,* which ranged from 1.10 to 1.27 cm. day^{-1}. Whereas *T. hemprichii* ranged from 0.55 to 0.57 cm.day^{-1}. The growth rate of *E. acoroides* is almost three times higher than *T. hemprichii*. Based on growth data, productivity values are calculated and converted into carbon values, as shown in Table 3. The productivity calculations indicated that *E. acoroides* in an area of 1 m^2 in 1 day can absorb CO_2 and convert it into the biomass of 1.62 g on muddy substrates and 1.42 g on sandy substrate. Whereas *T. hemprichii* with similar conditions can absorb CO_2 and convert it into the biomass of 1.15 g on the muddy substrate and 1.51 g on the sandy substrate.

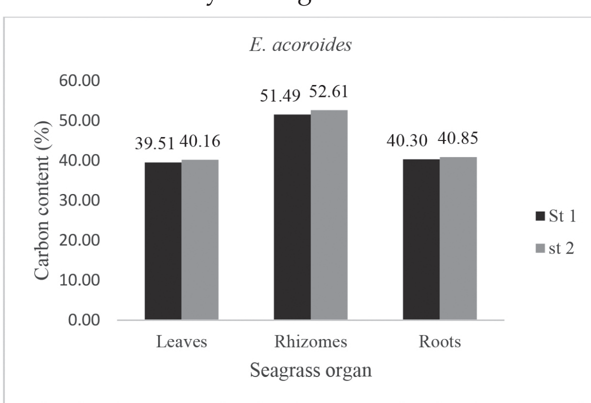

Fig. 4. The carbon content of each *E. acoroides* organ

Table 3. Productivity of seagrasses

Species	Productivity gC.m^{-2}.d^{-1}	
	St 1	St 2
T. hemprichii	1.15	1.51
E. acoroides	1.42	1.62
Total	2.57	3.13

Discussion

Seagrass has a very important role in the surrounding ecosystem and environment. The assessment of the biomass and productivity of seagrass communities proves that seagrasses are quite productive and fertile ecosystems (Duarte and Chiscano, 1999). Seagrass beds at Suli coastal waters are one of the seagrass beds that were classified as good and healthy on Ambon Island (Sinmiasa, 2014). Two species of the dominant species were *T. hemprichii*, and *E. acoroides,* so both species were used in this study. The results of carbon stock analysis indicated that *T. hemprichii* had a higher density than that of *E. acoroides*. Otherwise, the value of biomass and carbon stock was higher in *E. acoroides* than that of *T. hemprichii*. This is because *E. acoroides* has a morphological structure that is much larger than that of *T. hemprichii*, including leaves, rhizomes, and roots. So that, despite having a low density, the biomass and carbon value were high in *E. acoroides*. According to Fortes (1989) that the amount of seagrass biomass is a function of the density of seagrass in a certain area and plant size. Thus, if the density of a seagrass species at a location is high, the morphology is small, the biomass it contains would be small.

Biomass and carbon content in both seagrass species were high in rhizome organs. This is because rhizome is a larger part than the other seagrass organs. Laffoley and Grimsditch (2009) stated that species of seagrass having large morphology tends to develop high biomass under the substrate, and therefore has the capacity to accumulate higher carbon. Besides that, carbon under the substrate is a place to store photosynthesis products wish would support the growth of seagrass if the photosynthesis process is not running optimally (Alcoverro *et al.*, 2001). Furthermore, Fourqurean *et al.* (2012) stated that globally, organic carbon was stored in seagrass biomass by an average of 2.52 ± 0.48 $MgC.ha^{-1,}$ and two-thirds were stored in rhizomes and roots.

The results of this study also found that total carbon stocks for the *T. hemprichii* ranged from 74.75-119.98 $gC.m^{-2}$ and *E. acoroides* 92.69-159.86 $gC.m^{-2}$ (Table 4). The results of this study are higher than the results of research in Pegudang and Bakau Bay, Bintan Island by Indriani *et al.*, (2017). They found total carbon stock range from 36.51 $gC.m^{-2}$- 71.04 $gC.m^{-2}$ for *T. hemprichi* and 73.64 - 82.84 $gC.m^{-2}$ for *E. acorides*. However, the finding in this study is lower than some previous studies, namely in Pari Island (Kiswara, 2010); (Rahmawati and Kiswara, 2012) (Table 4). The high value of carbon stocks is supported by high density and biomass values.

The productivity of *T. hemprichii* and *E. acoroides* in this study was in the range found by Kiswara (2010) on Pari Island, namely 0.75 - 1.83 $gC.m^{-2}.d^{-1}$ for *T. hemprichii* and 1.19 -1.70 $gC.m^{-2}.d^{-1}$ for *E. acoroides* (Table 4). The results of this study are higher than the results in Bakau Bay, Bintan Island which *T. hemprichii* productivity values was 0.10 $gC.m^{-2}.d^{-1,}$ and *E. acoroides* was 0.41 $gC.m^{-2}.d^{-1}$ (Irawan, 2017) (Table 4). High productivity values are supported by high growth rates and biomass. This carbon stock and productivity research have been carried out in several regions in Indonesia, as shown in Table 4.

The results of this study also indicated that station 2 with a muddy substrate has a higher carbon stock value and productivity than station 1 with a sandy substrate. It could be assumed that it was related to the higher organic matter content in the muddy substrate than in the sandy substrate so that it affects the level of fertility. According to Erftemeijer and Middelburg (1993), the smaller the size of the sediment grains, the greater the availability of nutrients N and P on the substrate so that it would affect the growth of seagrass which is getting bigger as well. Thus, the substrate with small or muddy grains would be better support for the growth of seagrass. So that, it affects its density and biomass and carbon stock.

Conclusion

Seagrass bed of Suli coastal waters with two species *T. hemprichii* and *E. acoroides* have a total carbon stock of 447.28 gCm^{-2} and were able to absorb carbon of 5,70 $gC.m^{-2}.d^{-1}$. The largest carbon stock and carbon sequestration was in *E. acoroides*, especially for muddy substrates.

Acknowlegements

The study was funded by a research grant under the scheme Basic Research, National Competitive. The authors greatly acknowledged the Directorate General of Strengthening Research and Development, the Ministry of Research, Technology and Higher Education, Republic of Indonesia.

Table 4. Carbon stock and Productivity of Seagrass in several locations

Species and Location	Carbon stock $gC.m^{-2}$	Productivity $gC.m^{-2}.d^{-1}$	Sources
T. hemprichii			
PulauBintan	22,83 - 27,46	0,1	Irawan (2017)
Pulau Pari	113,38 - 207,50	0,75 - 1,83	Kiswara (2010)
Suli, Pulau Ambon	74,75 - 119,98	1,15 - 1,51	This study
E. acoroides			
PulauBintan	102 ,20 - 105,77	0,10 - 0,41	Irawan (2017)
Pulau Pari	343,39 - 545,33	1,19 - 1,70	Kiswara (2010)
Pulau Pari	227,06	1,75	Rahmawati and Kiswara
(2012)			
Banten	3,426		Rustam et al. (2015)
Suli, Pulau Ambon	92,69 - 159,86	1,42 - 1,62	This study

References

Alcoverro, T., Manzanera, M. and Romero, J. 2001. Annual metabolic carbon balance of the seagrass *Posidonia oceanica*: The importance of carbohydrate reserves. *Mar Ecol Prog Ser*. 211 : 105-116.

Bala, G. 2014. Can planting new trees help to reduce global warming? *Current Science*. 106(12): 1623-1624.

Barrón, C., Marba, N., Terrados, J., Kennedy, H. and Duarte, C.M. 2004. Community metabolism and carbon budget along a gradient of seagrass (*Cymodoea nodosa*) colonization. *Limnol. Oceanogr*. 49(5): 1642-1651.

Beer, S., Bjork, M., Hellblom, F. and Axelsson, L. 2002. Inorganic carbon utilization in marine angiosperms (seagrass). *Funct Plant Biol*. 29 : 349-354.

Duarte, C.M. and Chiscano, C. L. 1999. Seagrass biomass and production: A Reassessment. *Aquatic Botany*. 65: 159-174.

Duarte, C. M., Marbà, N., Gacia, E., Fourqurean, J. W., Beggins, J., Barrón, C. and Apostolaki, E. T. 2010. Seagrass community metabolism: Assessing the carbon sink capacity of seagrass meadows. Global Biogeochemical. *Cycles.* 24 (GB4032): 1-8.

Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I. and Marba, N. 2013. The role of coastal plant communities for climate change mitigation and adaptation. *Nature Climate Change*. 3 : 961-968.

Erftemeijer, P.L.A. and Middleburg, J.J. 1993. Sediment-nutrient interactions in tropical seagrass beds: a comparison between a terrigenous and a carbonate sedimentary environment in South Sulawesi (Indonesia). *Marine Ecology Progress Series* 102. pp. 187-198

Fortes, M. D. 1989. Seagrasses: A Resource Unknown in the ASEAN Region. *ICLARM Education* Ser 5. International Center for Living Aquatic Resources Management, Manila, Philippines. 361 pp

Fourqurean, J.W., Duarte, C.M., Kennedy, H., Marba, N., Holmer, M., Mateo, M.A., Apostolaki, E.T., Kendrick, G.A., Krause-Jensen, D., McGlathery, K.J. and Serrano, O. 2012. Seagrass ecosystems as a globally significant carbon stock. *Nature Geoscience*. 5(7): 505-509.

Fourqurean, J., Johnsos, B., Kauffman, J. B., Kennedy, H. and Lovelock, C. 2014. Field Sampling of Soil Carbon Pools in Coastal Ecosystems. Pages 39-66 In: *Coastal Blue Carbon: Methods for assessing carbon stocks and emissions factors in mangrove, tidal salt marshes, and seagrass meadows.* Conservation International, Intergovernmental Oceanographic Commission, IUCN. Arlington, Virginia.

Harris, J. and Feriz, M. 2011. Forest, Agriculture, and Climate: Economics and Policy Issues. Global Development and Environment Institute, Tufts University, Medford.

Hutomo, M. and Azkab, M.H. 1987. Peranan lamun pada perairan laut dangkal. *Oseana.* XII (1) : 13-23.

Indriani., Wahyudi, A.J. and Yona, D. 2017. Cadangan karbon di area padang lamun pesisir Pulau Bintan, Kepulauan Riau. *Oseanologi and Limnologi di Indonesia*. 2 (3) : 1-11.

Irawan, A. 2017. Potensi cadangan dan serapan karbon oleh padang lamun di bagian utara dan timur Pulau Bintan. *Oseanologi and Limnologi di Indonesia.* 2 (3) : 35-48.

Kennedy, H. and Björk, M. 2009. Seagrass meadows. In: Laffoley, D. and Grimsditch G. (ed). *The Management of Natural Coastal Carbon Sinks*. IUCN, Gland, Switzerland: 23-29.

Kiswara, W. 2010. Studi pendahuluan: potensi padang lamun sebagai karbon rosot dan penyerap karbon di Pulau Pari, Teluk Jakarta. *Oseanologi and Limnologi di Indonesia*. 36 (3) : 361-376.

Laffoley, D. and Grimsditch, G. (ed). 2009. *The Management of Natural Coastal Carbon Sinks. Gland Switzerland*: IUCN

Macreadie, P. I., Baird, M. E., Trevathan-Tackett, S. M., Larkum, A. W. D. and Ralph, P. J. 2014. Quantifying and modeling the carbon sequestration capacity of seagrass meadows – A critical assessment. *Marine Pollution Bulletin*. 83 (2) : 430–439.

Nellemann, C., Corcorn, E., Duarte, C.M., Valdes, L. de Young, C., Fonseca, L. and Grimsditch, G. 2009. Blue carbon. A rapid response assessment. United Nations Environment Programme. Norway. 78 pp.

Rahmawati, S. and Kiswara, W. 2012. Cadangan karbon dan kemampuan sebagai penyimpan karbon pada vegetasi tunggal *Enhalus acoroides* di Pulau Pari, Jakarta. *Oseanologi dan Limnologi di Indonesia*. 38 (1): 143-150.

Schumacher, B.A. 2002. Methods for the determination of total organic carbon (TOC) in soils and sediments. United States Environment Protection Agency. Environmental Science Division National. 25 pp.

Short, F. T. and Duarte, C. M. 2001. Methods for the measurement of seagrass growth and production. Pages 155-182 in: Short, F.T. and Coles, R. G. (ed). *Global Seagrass Research Methods*. Elsevier Science B.V. Amsterdam.

Sinmiasa, V.C. 2015. Status keberlanjutan komunitas lamun di perairan pesisir Negeri Suli, Kecamatan Salahutu, Kabupaten Maluku Tengah. Tesis. Pascasarjana Universitas Pattimura. Ambon.