 DOI: 10.11598/btb.2023.30.1.1776

CARBON STORED ON SEAGRASS BEDS IN GILI MARINGKIK, LOMBOK, INDONESIA

FIRMAN ALI RAHMAN[1*], IBNUL QAYIM[2] AND YUSLI WARDIATNO[3&4]

[1]*Department of Biology Education, Faculty of Education and Teacher Training, Universitas Islam Negeri Mataram, Mataram 83116, Indonesia*
[2]*Department of Biology, Faculty of Mathematics and Natural Sciences, Institut Pertanian Bogor, Bogor 16680, Indonesia*
[3]*Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Institut Pertanian Bogor, Bogor 16680, Indonesia*
[4]*Environmental Research Center, Institut Pertanian Bogor, Bogor 16680, Indonesia*

Received 2 July 2022/Accepted 18 February 2023

ABSTRACT

Seagrass are among important vegetation as carbon mitigation in coastal areas as an effort to reduce the impact of global warming. This study aims to determine the composition of seagrass species, density, coverage percentage, biomass content of seagrass species, C-organic content of seagrass and C-organic content of sediments found under stands of seagrass ecosystems. The research was conducted in the small island of Gili Maringkik, Lombok, Indonesia. The research included observation of seagrass species composition. The samples were collected from 0.5 × 0.5 m plot area. The total plot area was 25 arranged on five lanes with 25 m space between plots and 100 m between lanes on the research area of 31.82 ha. Our research found eight seagrass species (two families, six genera) namely: *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides, Halodule pinifolia, Halophila minor, Halophila spinulosa, Syringodium isoetifolium,* and *Thalassia hemprichii*. The highest density value (stand/m^2) was found in *C. rotundata* (506.40 ± 187.809) and the lowest was found in *C. serrulata* (6.24 ± 5.401). The highest cover percentage value (%) was found in *T. hemprichii* (36.52 ± 30.004) and the lowest was found in *H. pinifolia* (0.28 ± 4.766). The total biomass content (g DW/m^2) of Gili Maringkik seagrass was 1081.85 g DW/m^2 with the highest total biomass content was found in *E. acoroides* (463.41) and the lowest was found in *H. pinifolia* (12.41). The carbon stock of the seagrass beds was found to be 483.86 g C/m^2, while the range of carbon stock in substrate of the seagrass beds ecosystem was 0.09 – 0.49 or with an average of 0.30 ± 0.108%. The estimated total carbon stock of Gili Maringkik seagrass ecosystem in the area of 31.82 ha was 153.96 ton C or was equivalent to 4.84 ton C/ha.

Keywords: biomass, carbon sink, carbon stores, seagrass beds, substrate

INTRODUCTION

Industrial revolution, which happens in the last few decades, causes the increase of greenhouse gases emissions, such as carbon dioxide (CO_2), methane (CH_4), nitrogen dioxide (NO_2) and Chlorofluorocarbons (CFC). The increased emissions contribute to global warming which has an adverse impact on environment, among others are the increase of earth temperatures earth, the rise of sea level rise, drought, changes in hydrological cycle, and climate change (Irawan 2017; Rivera-Monroy *et al.* 2017; Rahman *et al.* 2019; Jannah *et al.* 2021; Rahman & Hadi 2021). This condition is further exacerbated by the minimum efforts of forest conservation, although forest conservation plays an important role in the development of carbon mitigation areas as an alternative to absorb emissions in the atmosphere.

The development of carbon mitigation area in Indonesia is still focused on terrestrial forests and mangrove forests, while the potential utilization of seagrass ecosystems, also known as blue carbon, has not been widely studied (Murdiyarso *et al.* 2015; Alongi *et al.* 2016; Mazarrasa *et al.* 2018; Rahman *et al.* 2019; Costa *et al.* 2019; Hilyana & Rahman 2022), especially

*Corresponding author, email: firmanalirahman@uinmataram.ac.id

on the potential of seagrass beds in small-island areas in Indonesia.

The use of seagrass beds as carbon sinks and carbon storage can be done through the mechanism of photosynthesis. Results of photosynthesis can be stored as biomass that can last for thousands of years (Miyajima *et al.* 2015; Phang *et al.* 2015; Jiang *et al.* 2017; Ricart *et al.* 2017; Sophianto *et al.* 2020; Monnier *et al.* 2021, 2022; Codur *et al.* 2022). The photosynthesis results make seagrass beds become one of the richest carbon sinks and carbon storage in the biosphere, which average capacity of carbon storage in seagrass is greater (4 tons/ha/yr) compared to the total average carbon storage of terrestrial forests (1.8 - 2.7 tons/ha/yr) (Lewis *et al.* 2009; Murray *et al.* 2011; Alongi 2014; Marbà *et al.* 2018).

Meanwhile, information on carbon stocks of seagrass beds found in the coastal ecosystems of small Indonesian islands is still lacking, especially on Lombok Island, West Nusa Tenggara Province. Several previous studies in the coastal area of Lombok Island are still focused on the interaction of seagrass beds with marine biota, distribution and diversity of seagrass species, seagrass conservation status and analysis of seagrass damage (Rahman *et al.* 2018; Syukur *et al.* 2020; Syukur *et al.* 2021; Zulkifli *et al.* 2021).

Conservation and utilization of seagrass surrounding Lombok Island (2,313.2 ha) is important for implementing the Indonesian blue carbon concept. Therefore, information on the carbon stock of Gili Maringkik seagrass beds can be used as comparison data with seagrass ecosystems in Indonesia and other tropical coastal areas in the world at different characteristics and locations. This study aims to determine seagrass species, density, coverage percentage, biomass, C-organic content of seagrass beds, C-organic content of seagrass ecosystem substrates, and estimation of carbon stock of seagrass ecosystems in Gili Maringkik, Lombok, Indonesia.

MATERIALS AND METHODS

Geographically, Gili Maringkik is a small island in the southern part of East Lombok and located at 116°37' - 116°45' E and 8°17' - 8°18' S. The island has 31.82 ha potential seagrass ecosystem (Fig 1).

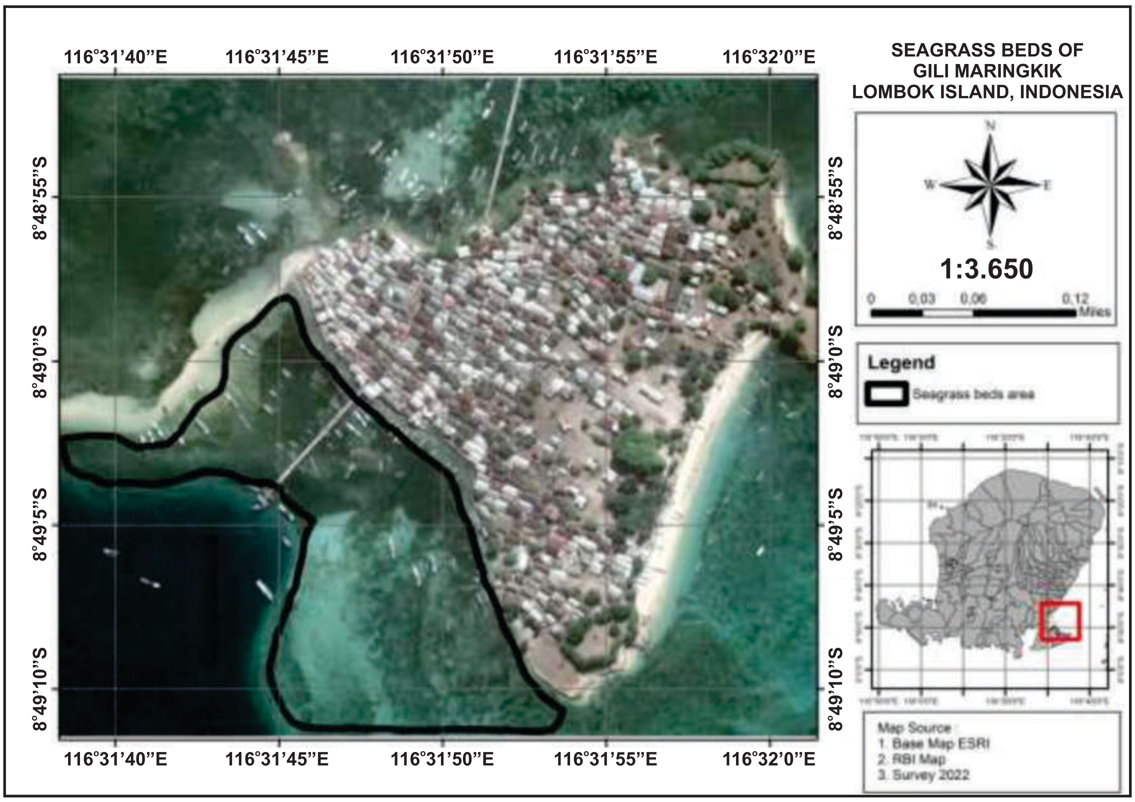

Figure 1 Seagrass ecosystem surrounding Gili Maringkik Island, East Lombok, Indonesia

Sampling Strategy

The research was carried out through field observation and laboratory analysis. Field research included seagrass species identification (Azkab 1999; Hartog & Kuo 2006) and determining the seagrass coverage percentage by using the Seagrass Watch Standard Guidances for Seagrass Covering (McKenzie *et al.* 2001). Within the 31.82 ha seagrass bed, the samples were collected from 0.5 × 0.5 m plot area. The total plot area was 25 arranged on five lanes with 25 m space between plots and 100 m between lanes.

Samples of seagrass species included leaves, rhizomes, roots and substrates for each species in each quadrant of observation. The samples were taken as material for further testing in the laboratory.

Seagrass biomass content was determined by using the oven method at a temperature of 60 °C until dry weight was stable. The c-organic content of seagrass on the top of the substrate (leaf sheaths and blades) and bottom substrate (rhizoma and roots) was determined based on the Loss On Ignition method.

In addition, sampling of the substrate as a test material for the carbon content of the substrate were carried out using the curd method. The samples were carried out in each quadrant with a sample depth of up to 30 cm and a slope of 30° using a pipe with a diameter of 5 cm and a length of 35 cm.

Data Analysis

Density

Seagrass density is the sum of all seagrass individuals per unit area. Value of seagrass ecosystem density was calculated by using the following formula (Brower & Zar 1977):

$$D = \frac{Ni}{A}$$

where:
D = density of segrass, species i (stands/m^2)
Ni = number of seagrass with species i (stand)
A = area of observation plot (m^2)

Biomass

Biomass is an organic material produced through photosynthesis process, either the primary product or waste. Seagrass standing biomass is a result of oven drying method which was calculated by using the following formula (Helrich 1990):

$$\text{Biomass (g DW/m}^2) = \frac{\text{Dry weight (g DW)}}{\text{Observation area (m}^2)}$$

Seagrass Carbon

Seagrass standing carbon was calculated by using the following formula (Helrich 1990):

$$\text{Ash content (\%)} = \frac{c - a}{b - a} \times 100\%$$

where:
a = cup weight
b = cup weight + dry weight of seagrass sample
c = cup weight + ash weight of seagrass sample

Organic Material Content

Organic material as a result of weight reduction while digestion process was calculated by using the following formula (Helrich 1990):

$$\text{Organic material content (\%)} = \frac{[(b - a) - (c - a)]}{(b - a)} \times 100\%$$

where:
a = cup weight
b = cup weight + dry weight of seagrass sample
c = cup weight + ash weight of seagrass sample

Carbon Content

Value of carbon content of seagrass was calculated from the Organic Material Content divided by a constant value of organic material (1.724), using the following formula:

$$\text{Carbon content (\% C)} = \frac{\text{Organic material content (\%)}}{1.724}$$

where:
1.724 = constant value of organic material

Substrate Carbon

Substrate carbon content was calculated by using the following formula (Sulaeman *et al.* 2005):

$$\text{Substrate carbon} = \frac{\text{ppm curve} \times 10}{500 \times \text{correction factor}}$$

where:
ppm curve = sample content obtained from the relationship curve between standard series content and the reading after corrected by the curve form
Correction factor = 100/(100 - % water content)

Total of Carbon Stock Area

The calculation of carbon content (g C/m^2) of seagrass was performed using the approach of seagrass biomass weight (g DW/m^2) by using the following formula (Barrón *et al.* 2004):

$$\text{Carbon stored (g } C/m^2\text{)} = \frac{\text{Carbon contained (\% C) x Biomass of species (g } DW/m^2\text{)}}{100}$$

Then, the estimation of total carbon stock area was calculated by using the following formula (Sulaeman *et al.* 2005):

$$Ct = \Sigma \text{ (Li x Ci)}$$

where:
Ct = total carbon (ton C)
Li = area of seagrass bed ecosystem (ha)
Ci = the average of seagrass carbon content (g C/m^{-2})

RESULTS AND DISCUSSION

Seagrass Species

Eight species of seagrass were found in Gili Maringkik (two families and six genera) (Table 1). The total composition of seagrass species in Gili Maringkik represents 61.54% of the total 13 species of seagrass found growing in Indonesian marine waters. Species composition in each research path was different. The richest species composition was found in lanes 3 (three) and 5 (five) with the number of seagrass growing as many as five species, which is presumably because the substrate consisted of small diameter sand substrate is suitable for the growth of the 5 species. Overall, *Cymodocea rotundata* and *Enhalus acoroides* could be found in all lines of observation. On the other hand, *Cymodocea serrulata* and *Halophila spinulosa* were found only in one line with a low number of distributions.

One of the important parts of this research is the discovery of seagrass *Halophila spinulosa* in Gili Maringkik Waters. Previous studies reported that *Halophila spinulosa* was found only in Mangrove Bay (Riau Islands), Anyer Sea (Java Island), North Baluran Sea and Irian Sea (Kiswara & Hutomo 1985; Priosambodo 2007); Waters of Hiri Islands, Ternate, Maitara and Tidore, North Maluku (Ramili *et al.* 2018); and Lungkak Waters, East Lombok (Syukur *et al.* 2020). Our study showed that *Halophila spinulosa* was found in Gili Maringkik Waters.

Seagrass Density and Coverage Percentage

The highest species density values were observed for *Cymodocea rotundata* (506.40 ± 187.809 stands/m^2) and *Thalassia hemprichii* (273.28 ± 77.151 stands/m^2). The high value of species density for *C. rotundata* proved that the research location was still categorized as natural environment, while *T. hemprichii* with the second highest species density value proved that the species was well adapted to the surrounding environment (Larkum *et al.* 1989).

At the research location, *T. hemprichii* was associated with *Enhalus acoroides* at the coastal area of Gili Maringkik. The coastal topography of Gili Maringkik is shallow and clear, so that light penetrates the seagrass habitat to support the seagrass photosynthesis process.

Seagrass density value and coverage percentage are influenced by seagrass abundance and size. Having species density value of 115.20 ± 62.471 stands/m^2, *Halophila minor* has small size with large number of stands in each quadrant. Therefore, *H. minor* required smaller space for each stand compared to larger-sized seagrass, such as *Enhalus acoroides* which has low number of stands in each quadrant (Table 2).

The highest coverage percentage were observed in *T. hemprichii* (36.52 ± 30.004%) and *C. rotundata* (31.36 ± 33.747%) stands. The main factor causing the lower coverage percentage of *C. rotundata* compared with that of *T. hemprichii* was the low distribution rate of *C. rotundata*, although the density of *C. rotundata* was higher than that of *T. hemprichii*. Larger-size seagrass, such as E. acoroides, provided the third highest coverage percentage (18.84 ± 20.922%), although it had a low number of stands (Rahman *et al.* 2018).

Table 1 Seagrass species found at Gili Maringkik Waters, Lombok, Indonesia

No	Family	Seagrass species	Lanes				
			1	2	3	4	5
1	*Potamogetonaceae*	*Cymodocea rotundata*	+	+	+	+	+
		Cymodocea serrulata	–	–	+	–	–
		Syringodium isoetifolium	+	–	+	–	+
		Halodule pinifolia	–	+	–	+	+
2	*Hydrocaritaceae*	*Enhalus acoroides*	+	+	+	+	+
		Halophila minor	+	–	+	+	+
		Halophila spinulosa	–	–	–	–	+
		Thalassia hemprichii	+	+	+	+	–

Notes: + = found; - = not found.

Table 2 Density and seagrass coverage at Gili Maringkik Waters, Lombok, Indonesia

No	Seagrass species	Density (stands/m^2)	Coverage percentage (%)
1	*Cymodocea rotundata*	506.40 ± 187.809	31.36 ± 33.747
2	*Cymodocea serrulata*	6.24 ± 5.401	0.79 ± 1.976
3	*Enhalus acoroides*	57.36 ± 40.243	18.84 ± 20.922
4	*Halodule pinifolia*	44.80 ± 49.943	0.28 ± 4.766
5	*Halophila minor*	115.20 ± 62.471	4.84 ± 8.286
6	*Halophila spinulosa*	23.20 ± 22.807	0.75 ± 2.113
7	*Syringodium isoetifolium*	107.20 ± 60.258	6.63 ± 11.893
8	*Thalassia hemprichii*	273.28 ± 77.151	36.52 ± 30.004

High species density and coverage percentage of seagrass beds provide benefits for the survival of marine biota due to the multi-function of seagrass as food source, spawning area, coastal buffer and source of organic carbon in the substrate (Arkham *et al.* 2015; Rahman & Hadi 2021). The density of seagrass beds in coastal areas increases the diversity and abundance of fish as an economic source for coastal communities (Arkham *et al.* 2016). Seagrass habitat has a strong relationship with the abundance of fish species. This statement is supported by the study conducted by Wahyudin *et al.* (2018), in which there were 118 fish species found in seagrass habitat in the waters of Bintan Island.

Seagrass Biomass

The total biomass content stored in the seagrass ecosystem of Gili Maringkik was 1,081.85 g DW/m^2 with *Enhalus acoroides* as the species with the highest biomass value (463.41 g DW/m^2). The highest value of *E. acoroides* was caused by the size of this species of seagrass compared with the other seven seagrass species found in the Gili Maringkik Waters.

This findings are in line with the the results of previous study conducted by Rustam *et al.* (2015) in the coastal waters of Miskam Bay, Tanjung Lesung, Banten; Indriani *et al.* (2017) in the coastal seagrass ecosystem of Bintan Island, Riau Islands; Githaiga *et al.* (2017) in the seagrass ecosystem of Kenya Gazhi; and Rahman *et al.* (2018) in the Poton Bako seagrass ecosystem, East Lombok Regency, West Nusa Tenggara.

Our study also discovered that the standing biomass of *Halodule pinifolia* (12.41 g DW/m^2) was lower than that of *Halophila minor* (24.28 g DW/m^2), although the size of *Halodule pinifolia* is larger than that of *Halophila minor*. This result could have been caused by the lower species density value of *Halodule pinifolia* compared to that of *Halophila minor*, which affected the total species biomass in our research area.

The seagrass biomass content in Gili Maringkik Waters seemed to be not only influenced by the seagrass size but can also by the species density, which contributes to the total dry weight of the seagrass samples (Githaiga *et al.* 2017; Azizah *et al.* 2017).

Comparison of biomass content of each part of seagrass (leaf sheaths and blades, rhizomes and roots) resulted in different biomass content values. Biomass contents of seagrass rhizomes and leaves were higher than those of seagrass roots, with a total ratio of overall biomass as 5 : 4 : 1 or was equivalent to 510.14 g DW/m^2 in rhizome, 382.57 g DW/m^2 in leaves and 189.13 g DW/m^2 in roots.

The highest rhizome biomass was shown in *Enhalus acoroides*, *Cymodocea serrulata*, *Halophila minor* and *Halodule pinifolia*, while the highest leaf biomass was shown in *Thalassia hemprichii, Cymodocea rotundata, Syringodium isoetifolium* and *Halophila spinulosa* (Table 3).

Total biomass of the bottom substrate (rhizomes and roots) in Gili Maringkik Waters was greater than that of the upper substrate (leaf sheaths and blades). This results were similar with the reports of Tasabaramo and Kawaroe (2015) and Wahyudi *et al.* (2016) which stated that biomass of the bottom substrate material is greater than that of the upper substrate material because the material of the bottom substrate is denser compared with material of the upper substrate.

Additionally, material of the bottom substrate comes from the root-absorbed nutrients and organic materials resulting from photosynthesis, which is mostly stored in rhizomes. The bottom substrate material is suitable for seagrass as blue carbon. The biomass contained in the bottom substrate (rhizome and roots) is stored for a long time, as oppose to the biomass contained in the upper substrate (leaf sheaths and blades) which can be wiped-out by water currents and human activities, which release carbon in the form of wastes.

Seagrass Carbon

The highest carbon content (% C) was found in the rhizome with an average of 45.37 ± 3.633 compared to roots (42.22 ± 9.542) and leaf (22.08 ± 25.132). In terms of seagrass species, *Enhalus acoroides* and *Cymodocea serrulata* showed the highest carbon content (both species had the same carbon content of 142.09), followed by *Cymodocea rotundata* (139.25), and lastly *Halophila minor* (79.04) (Table 4).

Table 3 Seagrass biomass content at Gili Maringkik Waters, Lombok, Indonesia

No	Seagrass species	Seagrass biomass (g DW/m^2)			
		Leaf sheath and blade	Rhizome	Root	Total biomass
1	*Cymodocea rotundata*	90.98	81.05	49.12	221.15
2	*Cymodocea serrulata*	8.08	17.72	2.96	28.76
3	*Enhalus acoroides*	138.14	277.02	48.24	463.41
4	*Halodule pinifolia*	4.42	5.27	2.72	12.41
5	*Halophila minor*	10.16	11.88	2.24	24.28
6	*Halophila spinulosa*	11.78	9.47	4.92	26.17
7	*Syringodium isoetifolium*	21.65	20.58	24.87	67.10
8	*Thalassia hemprichii*	97.36	87.15	54.06	238.57
Average		47.82	63.77	23.64	135.23
Standard deviation		52.562	92.095	23.467	160.815

Table 4 Percentage of carbon content in each part of seagrass observed in Gili Maringkik

No	Seagrass species	Leaf sheaths and blades carbon stored		Rhizomes carbon stored		Roots carbon stored	
		(%C)	(g C/m^2)	(%C)	(g C/m^2)	(%C)	(g C/m^2)
1	*Cymodocea rotundata*	47.94	43.62	46.49	37.68	44.82	22.02
2	*Cymodocea serrulata*	48.25	3.90	44.05	7.81	49.79	1.47
3	*Enhalus acoroides*	49.94	68.99	45.97	127.35	46.23	22.30
4	*Halodule pinifolia*	43.45	1.92	48.66	2.56	46.88	1.28
5	*Halophila minor*	41.24	4.19	19.87	2.36	17.93	0.40
6	*Halophila spinulosa*	47.36	5.58	46.65	4.42	34.80	1.71
7	*Syringodium isoetifolium*	45.05	9.75	47.49	9.77	41.13	10.23
8	*Thalassia hemprichii*	39.73	38.68	38.57	33.61	41.18	22.26
Total		362.96	176.63	337.75	225.56	322.76	81.67

Carbon stock of seagrass beds at Gili Maringkik was found to be 483.86 g C/m^2. This value is higher than the carbon stock of seagrass ecosystem in Bintan Island (266.95 g C/m^2) (Irawan 2017); seagrass ecosystem of Poton Bako Lombok (447.92 g C/m^2) (Rahman *et al.* 2018); carbon stock of seagrass beds in Prawean (10.40 - 197.34 g C/m^2) (Septiani *et al.* 2018); carbon stock of seagrass beds in Krakal Beach, Gunungkidul, Yogyakarta (30.42 ± 13.85 g C/m^2) (Pramesti *et al.* 2021); carbon stock of seagrass beds in Sikka, Maumere, East Nusa Tenggara (41.95 g C/m^2) (Wismar *et al.* 2021); and the carbon stock of seagrass beds in Poteran Island, Madura, East Java (2.23 g C/m^2) (Sirait *et al.* 2022).

The high and low carbon content of seagrass stocks in a coastal ecosystem could be affected by the number of species composition, the seagrass coverage area, and the percentage of carbon content in each tested species. Seagrass biomass contributes greatly to the carbon stock content, as is the case with *Enhalus acoroides* (218.64 g C/m^2) which has the highest carbon stock content compared to other species. Similarly, *Halodule pinifolia* (5.76 g C/m^2) and *Halophila minor* (6.95 g C/m^2) are the two species with the lowest carbon stock species because they generally have small size which affect their carbon content. Carbon content is influenced by the large amount of biomass stored in leaves, rhizomes and roots.

Our study showed that carbon stock of *Cymodocea rotundata* (103.32 g C/m^2) was greater than that of *Thalassia hemprichii* (94.55 g C/m^2), although the size of *C. rotundata* is smaller than that of *T. hemprichii*. The high carbon stock of *C. rotundata* was caused by its high total biomass content and species density in the entire study area (31.82 ha) which was greater than that of *T. hemprichii*.

T. hemprichii had low density values affecting its total biomass content which was influenced by unit area for sampling (Kennedy & Björk 2009; Serrano *et al.* 2014). Also, the carbon content (% C) of *C. rotundata* in leaf sheaths and blades, rhizomas and roots (139.25) was higher than that of *T. hemprichii* (119.48).

Substrate Carbon

The substrate carbon content (% C) of seagrass beds in the Gili Maringkik Waters was in the range of 0.09 - 0.49 with an average of 0.30 ± 0.108, which was less than 1% C (very low) (Fig. 2).

The levels of substrate carbon content in the seagrass beds of Gili Maringkik Waters was firstly influenced by the characteristics of the substrate types, which were sandy and coral. The low C-organic content in sandy substrates was caused by the oxidation mechanism that easily released organic matter compared with that in fine sand substrates (Serrano *et al.* 2014; Bañolas *et al.* 2020).

Secondly, substrate carbon content was affected by seagrass density. The higher the seagrass density grown on the substrate, the higher carbon content of the substrate. Thirdly, decomposed seagrass was not stored as organic matter in the substrate (Watanabe & Kuwae 2015; Marquez *et al.* 2017; Marbà *et al.* 2018; Guo *et al.* 2021; Yang *et al.* 2022).

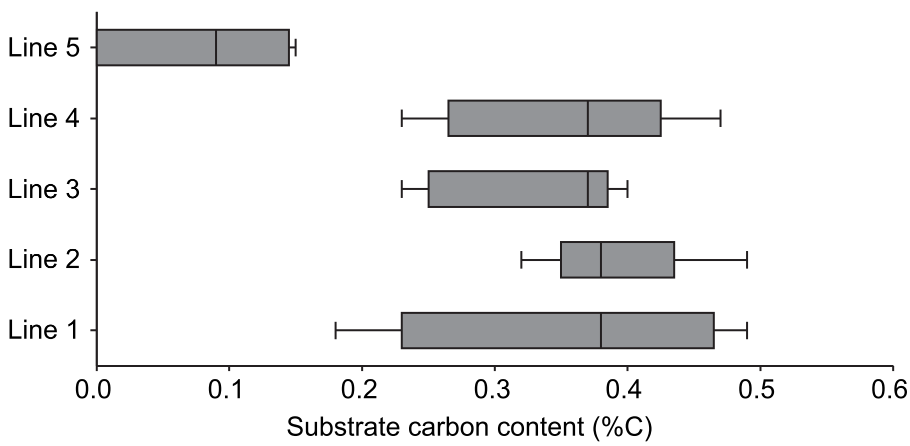

Figure 2 Substrate carbon content of seagrass beds in Gili Maringkik Waters, Lombok, Indonesia

Fourthly, there is no source of organic matter originating from the mainland due to the absence of rivers and mangrove ecosystem in Gili Maringkik Waters (Samper-Villarreal *et al.,* 2016; Prentice *et al.,* 2019; Santos *et al.,* 2019; Dahl *et al.* 2020). This finding is in line with the report by Chen *et al.* (2017) that substrate carbon content is influenced by ecosystems surrounding the seagrass habitat, such as mangrove ecosystem as a source of substrate organic matter. Fifthly, the low weathering and low mineralization mechanisms of organic matter in substrate is caused by anaerobic condition affecting the activity of decomposing organisms (Tangketasik and Narka, 2012; Delgado *et al.* 2017; Potapov *et al.* 2017; Crowther *et al.* 2019; Guo *et al.* 2021).

Carbon Sink Estimation of Seagrass Beds

The estimated total carbon stock of the Gili Maringkik seagrass ecosystem in a total area of 31.82 ha was 153.96 tonnes C or was equivalent to 4.84 tonnes C/ha. The potential carbon stocks of Gili Maringkik seagrass beds is greater than that of several locations in Indonesia. The estimated carbon stock of the seagrass beds in Sintok Island was 4.18 tonnes C/ha (Hartati *et al.* 2017); seagrass beds in Karimunjawa Island ranged from 0.50 to 0.73 tonnes C/ha (Ganefiani *et al.* 2019); seagrass beds at Tanjung Kerasak Beach, South Bangka Regency was 1.1 tonnes C/ha (Sartini *et al.* 2021). However, the carbon stock of seagrass beds in Gili Maringkik was smaller than that of seagrass ecosystem in Menjangan Kecil Island, which was 32.18 tonnes C/ha (Hartati *et al.* 2017).

CONCLUSION

Eight species of seagrass were found in Gili Maringkik Waters, namely: *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides, Halodule pinifolia, Halophila minor, Halophila spinulosa, Syringodium isoetifolium,* and *Thalassia hemprichii*. The highest species density and coverage percentage was found in *Cymodocea rotundata*. There was a correlation between species density, total biomass and carbon content of the seagrass beds in Gili Maringkik Waters. Substrate carbon content of seagrass in Gili Maringkik was very low (< 1%). The estimated total carbon stock of the Gili Maringkik seagrass ecosystem in an area of 31.82 ha was 153.96 tonnes C/ha or was equivalent to 4.84 tonnes C/ha.

REFERENCES

Alongi DM. 2014. Carbon cycling and storage in mangrove forests. Annu Rev Mar Sci 6(1): 195-219. DOI: 10.1146/annurev-marine-010213-135020

Alongi DM, Murdiyarso D, Fourqurean JW, Kauffman JB, Hutahaean A, Crooks S, …, Wagey T. 2015. Indonesia’s blue carbon: A globally significant and vulnerable sink for seagrass and mangrove carbon. Wetlands Ecol Manage 24(1): 3-13. DOI: 10.1007/s11273-015-9446-y

Arkham MN, Adrianto L, Wardiatno Y. 2016. Social-ecological system of seagrass and small-scale fisheries connectivity in Malang Rapat and Berakit Villages, Bintan District, Riau Islands. Jurnal Ilmu dan Teknologi Kelautan Tropis 7. DOI: 10.29244/jitkt.v7i2.10992

Arkham MN, Adrianto L, Wardiatno Y. 2015. Studi keterkaitan ekosistem lamun dan perikanan skala kecil. Studi kasus: Desa Malang Rapat dan Berakit, Kabupaten Bintan, Kepulauan Riau. [The study of seagrass ecosystem and small-scale fisheries linkages. Case Study: Malang Rapat and Berakit Village, Bintan Regency, Riau Islands]. Jurnal Sosial Ekonomi Kelautan dan Perikanan 10(2): 137-48. DOI: 10.15578/jsekp.v10i2.1255

Azizah E, Nasution S, Ghalib M. 2017. Biomass and density of seagrass *Enhalus acoroides* in the Village Waters Jago-Jago of Tapanuli Tengah, North Sumatera Province. Jurnal Online Mahasiswa (JOM) Bidang Perikanan dan Ilmu Kelautan. 4(2): 1-10.

Azkab MH. 1999. Pedoman inventariasi lamun. 24(1): 1-16.

Bañolas G, Fernández S, Espino F, Haroun R, Tuya F. 2020. Evaluation of carbon sinks by the seagrass *Cymodocea nodosa* at an oceanic island: Spatial variation and economic valuation. Ocean Coast Manage 187: 105112. DOI: 10.1016/j.ocecoaman.2020.105112

Barrón C, Marbé N, Terrados J, Kennedy H, Duarte CM. 2004. Community metabolism and carbon budget along a gradient of seagrass (*Cymodocea nodosa*) colonization. Limnol Oceanogr. 49(5): 1642-51. DOI: 10.4319/lo.2004.49.5.1642

Brower JE, Zar JH. 1977. Field and Laboratory Methods for General Ecology. Dubuque (US): William C. Brown Company. 194 p.

Chen G, Azkab MH, Chmura GL, Chen S, Sastrosuwondo P, Ma Z, …, Chen B. 2017. Mangroves as a major source of soil carbon storage in adjacent seagrass meadows. Sci Rep 7(1): 42406. DOI: 10.1038/srep42406

Codur A-M, Harris JM, Feriz MB. 2022. Forests and Climate: Economics and Policy Issues. An ECI Teaching Module on Social and Environmental Issues in Economics, Economics in Context Initiative. Boston (US): Global Development Policy Center. 50 p.

Costa MT, Salinas-de-León P, Aburto-Oropeza O. 2019. Storage of blue carbon in isolated mangrove forests of the Galapagos' rocky coast. Wetlands Ecol Manage 27(4): 455-63. DOI: 10.1007/ s11273-019-09653-8

Crowther TW, van den Hoogen J, Wan J, Mayes MA, Keiser AD, Mo L, …, Maynard DS. 2019. The global soil community and its influence on biogeochemistry. Science. 365(6455): eaav0550. DOI: 10.1126/science.aav0550

Dahl M, Asplund ME, Björk M, Deyanova D, Infantes E, Isaeus M, …, Gullström M. 2020. The influence of hydrodynamic exposure on carbon storage and nutrient retention in eelgrass (*Zostera marina* L.) meadows on the Swedish Skagerrak Coast. Sci Rep 10(1): 13666. DOI: 10.1038/s41598-020-70403-5

Delgado M, Cintra-Buenrostro CE, Fierro-Cabo A. 2017. Decomposition and nitrogen dynamics of turtle grass (*Thalassia testudinum*) in a subtropical estuarine system. Wetlands Ecol Manage 25(6): 667-81.DOI: 10.1007/s11273-017-9543-1

Ganefiani A, Suryanti S, Latifah N. 2019. Potensi padang lamun sebagai penyerap karbon di Perairan Pulau Karimunjawa, Taman Nasional Karimunjawa. Indonesian J Fish Sci Technol. 14(2): 115. DOI: 10.14710/ijfst.14.2.115-122

Githaiga MN, Kairo JG, Gilpin L, Huxham M. 2017. Carbon storage in the seagrass meadows of Gazi Bay, Kenya. Plos One 12(5): e0177001. DOI: 10.1371/journal.pone.0177001

Guo L, Deng M, Yang S, Liu W, Wang X, Wang J, Liu L. 2021. The coordination between leaf and fine root litter decomposition and the difference in their controlling factors. Glob Ecol Biogeogr 30(11): 2286-96. DOI: 10.1111/geb.13384

Hartati R, Pratikto I, Pratiwi TN. 2017. Biomassa dan estimasi simpanan karbon pada ekosistem padang lamun di Pulau Menjangan Kecil dan Pulau Sintok, Kepulauan Karimunjawa. Bul Oseano Mar 6(1): 74. DOI: 10.14710/ buloma.v6i1.15746

Hartog CD, Kuo J. 2006. Taxonomy and Biogeography of Seagrasses. In: Larkum AWD, Orth RJ, Duarte CM (Editors). Seagrasses: Biology, Ecology and Conservation. Dordrecht (NL): Springer. p. 1-23. DOI: 10.1007/978-1-4020-2983-7_1

Helrich K. 1990. AOAC: Official Methods of Analysis. Arlington (US): Association of Official Analytical Chemists. 771 p.

Hilyana S, Rahman FA. 2022. Variabilities of the carbon storage of mangroves in Gili Meno Lake, North Lombok District, Indonesia. Biodiversitas 23(11). DOI: 10.13057/biodiv/d231140

Indriani, Wahyudi AJ, Yona D. 2017. Cadangan karbon di area padang lamun pesisir Pulau Bintan, Kepulauan Riau. OLDI 2(3): 1. DOI: 10.14203/ oldi.2017.v2i3.99

Irawan A. 2017. Potensi cadangan dan serapan karbon oleh padang lamun di bagian utara dan timur Pulau Bintan. OLDI 2(3): 35. DOI: 10.14203/ oldi.2017.v2i3.158

Jannah SW, Rahman FA, Hadi AP. 2021. Analisis kandungan karbon pada vegetasi mangrove di Desa Lembar, Kabupaten Lombok Barat. Bioscientist: Jurnal Ilmiah Biologi 9(2): 11.

Jiang Z, Liu S, Zhang J, Zhao C, Wu Y, Yu S, …, Kumar M. 2017. Newly discovered seagrass beds and their potential for blue carbon in the coastal seas of Hainan Island, South China Sea. Mar Pollut Bull 125(1-2): 513-21. DOI: 10.1016/ j.marpolbul.2017.07.066

Kennedy H, Björk M. 2009. Seagrass Meadows. In: Laffoley D, Grimsditch G (Editors). The management of natural coastal carbon sinks. Gland (CH): IUCN. p. 23-9.

Kiswara W, Hutomo M. 1985. Habitat dan Sebaran Geografik Lamun. Oseana 10(1): 21-30.

Larkum AWD, McComb AJ, Shepherd SA. 1989. Biology of seagrasses: A treatise on the biology of seagrasses with special reference to the Australian region. Amsterdam ; New York: Elsevier. 841 p.

Lewis SL, Lopez-Gonzalez G, Sonké B, Affum-Baffoe K, Baker TR, Ojo LO, …, Wöll H. 2009. Increasing carbon storage in intact African tropical forests. Nature. 457(7232): 1003-6. DOI: 10.1038/ nature07771

Marbà N, Krause-Jensen D, Masqué P, Duarte CM. 2018. Expanding Greenland seagrass meadows Contribute new sediment carbon sinks. Sci Rep 8(1): 1-8. DOI: 10.1038/s41598-018-32249-w

Marquez MA, Fierro-Cabo A, Cintra-Buenrostro CE. 2017. Can ecosystem functional recovery be traced to decomposition and nitrogen dynamics in estuaries of the Lower Laguna Madre, Texas?: Tracing functional recovery in estuaries. Restor Ecol 25(4): 618-28. DOI: 10.1111/ rec.12469

Mazarrasa I, Samper-Villarreal J, Serrano O, Lavery PS, Lovelock CE, Marbà N, …, Cortés J. 2018. Habitat characteristics provide insights of carbon storage in seagrass meadows. Mar Pollut Bull 134: 106-17. DOI: 10.1016/j.marpolbul.2018. 01.059

McKenzie LJ, Campbell SJ, Roder CA. 2001. Seagrass-Watch: Manual for Mapping and Monitoring Seagrass Resources by Community (citizen) Volunteers. Townsville (AU): Seagrass Watch, Department of Primary Industries Queensland. 100 p.

Miyajima T, Hori M, Hamaguchi M, Shimabukuro H, Adachi H, Yamano H, Nakaoka M. 2015. Geographic variability in organic carbon stock and accumulation rate in sediments of East and Southeast Asian seagrass meadows. Glob Biogeochem Cycles 29(4): 397-415. DOI: 10.1002/2014GB004979

Monnier B, Pergent G, Mateo MÁ, Carbonell R, Clabaut P, Pergent-Martini C. 2021. Sizing the carbon sink associated with *Posidonia oceanica* seagrass meadows using very high-resolution seismic reflection imaging. Mar Environ Res 170: 105415. DOI: 10.1016/j. marenvres.2021.105415

Monnier B, Pergent G, Mateo MÁ, Clabaut P, Pergent-Martini C. 2022. Quantification of blue carbon stocks associated with *Posidonia oceanica* seagrass meadows in Corsica (NW Mediterranean). Sci Total Environ 838: 155864. DOI: 10.1016/ j.scitotenv.2022.155864

Murdiyarso D, Purbopuspito J, Kauffman JB, Warren MW, Sasmito SD, Donato DC, …, Kurnianto S. 2015. The potential of Indonesian mangrove forests for global climate change mitigation. Nat Clim Chang 5(12): 1089-92. DOI: 10.1038/ nclimate2734

Murray BC, Pendleton L, Jenkins WA, Sifleet S. 2011. Green Payments for Blue Carbon Economic Incentives for Protecting Threatened Coastal Habitats. Durham (US): Nicholas Institute for Environmental Policy Solutions, Duke University. 42 p.

Phang VXH, Chou LM, Friess DA. 2015. Ecosystem carbon stocks across a tropical intertidal habitat mosaic of mangrove forest, seagrass meadow, mudflat and sandbar: Carbon Stocks in Intertidal Ecosystems. Earth Surf Process Landf 40(10): 1387-400. DOI: 10.1002/esp.3745

Potapov AM, Goncharov AA, Semenina EE, Korotkevich AY, Tsurikov SM, Rozanova OL, …,, Tiunov AV. 2017. Arthropods in the subsoil: Abundance and vertical distribution as related to soil organic matter, microbial biomass and plant roots. Eur J Soil Biol 82: 88-97. DOI: 10.1016/j.ejsobi.2017. 09.001

Pramesti R, Subagiyo S, Setyati WA, Buana T. 2021. Potensi padang lamun (*Thalassia hemprichii*) sebagai penyimpan dan penyerap karbon di Pantai Krakal, Gunungkidul, Yogyakarta. Buletin Oseanografi Marina 10(3): 283-90.

Prentice C, Hessing‾ Lewis M, Sanders‾ Smith R, Salomon AK. 2019. Reduced water motion enhances organic carbon stocks in temperate eelgrass meadows. Limnol Oceanogr. 64(6): 2389-404. DOI: 10.1002/lno.11191

Priosambodo D. 2007. Sebaran jenis-jenis lamun di Sulawesi Selatan. Jurnal Bionature 8: 8-17.

Rahman FA, Hadi AP. 2021. Kandungan C-organik substrat ekosistem mangrove di Danau Air Asin, Gili Meno, Kabupaten Lombok Utara. Bioscientist: Jurnal Ilmiah Biologi 9(2): 516-26.

Rahman FA, Qayim I, Wardiatno Y. 2018. Carbon storage variability in seagrass meadows of Marine Poton Bako, East Lombok, West Nusa Tenggara, Indonesia. Biodiversitas 19(5): 1626-31. DOI: 10.13057/biodiv/d190505

Rahman FA, Rohyani IS, Suripto, Hadi AP, Lestari DP. 2019. Komposisi vegetasi mangrove berdasarkan strata pertumbuhan di Teluk Sereweh, Kabupaten Lombok Timur, Nusa Tenggara Barat. Jurnal Pendidikan Biologi dan Sains 4(2): 53-61.

Ramili Y, Bengen DG, Madduppa H, Kawaroe M. 2018. Struktur dan asosiasi jenis lamun di perairan pulau-pulau Hiri, Ternate, Maitara dan Tidore, Maluku Utara. Jurnal Ilmu dan Teknologi Kelautan Tropis 10(3): 651-65. DOI: 10.29244/jitkt.v10i3.22476

Ricart AM, Pérez M, Romero J. 2017. Landscape configuration modulates carbon storage in seagrass sediments. Estuar Coast Shelf Sci 185: 69-76. DOI: 10.1016/j.ecss.2016.12.011

Rivera-Monroy VH, Lee SY, Kristensen E, Twilley RR. 2017. Mangrove Ecosystems: A Global Biogeographic Perspective: Structure, Function, and Services. New York (US): Springer Cham. DOI: 10.1007/978-3-319-62206-4

Rustam A, Kepel TL, Afiati RN, Salim H, Astrid M, Daulat A, …, Hutahaean AA. 2015. Peran ekosistem lamun sebagai *blue carbon* dalam mitigasi perubahan iklim. Studi kasus Tanjung Lesung, Banten. Jurnal Segara 10(2). DOI: 10.15578/segara.v10i2.20

Samper-Villarreal J, Lovelock CE, Saunders MI, Roelfsema C, Mumby PJ. 2016. Organic carbon in seagrass sediments is influenced by seagrass canopy complexity, turbidity, wave height, and water depth: Drivers of seagrass carbon. Limnol Oceanogr 61(3): 938-52. DOI: 10.1002/lno. 10262

Santos R, Duque-Núñez N, de los Santos CB, Martins M, Carrasco AR, Veiga-Pires C. 2019. Superficial sedimentary stocks and sources of carbon and nitrogen in coastal vegetated assemblages along a flow gradient. Sci Rep 9(1): 610. DOI: 10.1038/ s41598-018-37031-6

Sartini, Adibrata S, Aisyah S. 2021. Biomassa dan estimasi karbon pada ekosistem lamun di Pantai Tanjung Kerasak, Kabupaten Bangka Selatan. Akuatik: Jurnal Sumberdaya Perairan 15(2): 123-31.

Septiani EF, Ghofar A, Febrianto S. 2018. Pemetaan karbon di padang lamun Pantai Prawean Bandengan Jepara. Majalah Ilmiah Globe 20(2): 117. DOI: 10.24895/MIG.2018.20-2.827

Serrano O, Lavery PS, Rozaimi M, Mateo MÁ. 2014. Influence of water depth on the carbon sequestration capacity of seagrasses: Depth influence seagrass carbon stocks. Glob Biogeochem Cycles 28(9):950-61. DOI: 10.1002/2014GB004872

Sirait WK, Hartati R, Widianingsih W. 2022. Simpanan karbon pada padang lamun di Perairan Pulau Poteran, Madura, Jawa Timur. J Trop Mar Sci 5(1): 1-8. DOI: 10.33019/jour.trop.mar.sci.v5i1. 2617

Sophianto RP, Endrawati H, Hartati R. 2020. Simpanan karbon pada ekosistem padang lamun di Perairan Jepara. J Mar Res 9(2):99-108. DOI: 10.14710/jmr.v9i2.25284

Sulaeman, Suparto, Eviati. 2005. Petunjuk teknis analisis kimia tanah, tanaman, air dan pupuk. Bogor (ID): Balai Penelitian Tanah. 136 p.

Syukur A, Al-Idrus A, Zulkifli L. 2020. Ecotourism development based on the diversity of Echinoderms species in seagrass beds on the south coastal of Lombok Island, Indonesia. J Environ Sci Technol 13: 56-68. DOI: 10.3923/jest.2020.57.68

Syukur A, Idrus AAI, Zulkifli L. 2021. Seagrass-associated fish species' richness: Evidence to support conservation along the south coast of Lombok Island, Indonesia. Biodiversitas 22(2): 988-98. DOI: 10.13057/biodiv/d220255

Tangketasik A, Wikarniti NM, Soniari NN, Narka IW. 2012. Kadar bahan organik tanah pada tanah sawah dan tegalan di Bali serta hubungannya dengan tekstur tanah. Agrotrop 2(2): 101-7.

Tasabaramo IA, Kawaroe M. 2015. Laju pertumbuhan, penutupan, dan tingkat kelangsungan hidup *Enhalus acoroides* yang ditransplantasi secara monospesies dan multispesies. Jurnal Ilmu dan Teknologi Kelautan Tropis 7(2): 14.

Wahyudi AJ, Rahmawati S, Prayudha B, Iskandar MR, Arfianti T. 2016. Vertical carbon flux of marine snow in *Enhalus acoroides*-dominated seagrass meadows. Reg Stud Mar Sci 5: 27-34. DOI: 10.1016/j.rsma.2016.01.003

Wahyudin Y, Kusumastanto T, Adrianto L, Wardiatno Y. 2018. A social ecological system of recreational fishing in the seagrass meadow conservation area on the east coast of Bintan Island, Indonesia. Ecol Econ 148: 22-35. DOI: 10.1016/j.ecolecon. 2018.01.013

Watanabe K, Kuwae T. 2015. How organic carbon derived from multiple sources contributes to carbon sequestration processes in a shallow coastal system? Glob Change Biol 21(7): 2612-23. DOI: 10.1111/gcb.12924

Wismar JE, Setyati WA, Riniatsih I. 2021. Potensi penyimpanan karbon pada vegetasi padang lamun di perairan Pulau Besar Utara, Sikka, Maumere, Nusa Tenggara Timur. Buletin Oseanografi Marina 10(1): 51-60. DOI: 10. 14710/buloma.v10i1.27223

Yang K, Zhu J, Zhang W, Zhang Q, Lu D, Zhang Y,…, Wang GG. 2022. Litter decomposition and nutrient release from monospecific and mixed litters: Comparisons of litter quality, fauna and decomposition site effects. J Ecol 110(7): 1673-86. DOI: 10.1111/1365-2745.13902

Zulkifli L, Patech LR, Lestari A, Fidiantara F, Idrus AA, Syukur A. 2021. The sustainability of the diversity of marine macrofauna associated with seagrass through ecotourism in the Mandalika Exclusive Economic Zone Lombok Island, Indonesia. IOP Conf Ser: Earth Environ Sci 913(1): 1-10. DOI: 10.1088/1755-1315/913/1/012053