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Carbon storage variability in seagrass meadows of Marine Poton Bako, East Lombok, West Nusa Tenggara, Indonesia

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Abstract. *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: 1626-1631.* The increase of atmospheric CO_2 concentration in the last decades leads to global warming, having an adverse effect on the environment condition on the Earth. One of the natural mechanism as an effort to reduce the impact of global warming is carbon absorption and storage through photosynthesis mechanism of seagrass vegetation. Research conducted at Poton Bako, a district in East Lombok was aimed to reveal the composition of seagrass species, density, seagrass coverage, the biomass of seagrass tissue, content of carbon storage in seagrass tissue (above and below substrates), carbon content in seagrass sediments, and estimation of carbon stock in the area. The research included observation of species composition, and the sample was collected from 0.5 m × 0.5 m plot area. The total plot area was 36 on six lanes with the space between plots 25 m and between lanes 100 m. Six species from two families were found in the seagrass meadows, i.e., *Cymodocea rotundata, Enhalus acoroides, Halophila minor, Holodule uninervis, Thalassia hemprichii* and *Thalassodendron ciliatum*. The three highest total densities were *C. rotundata* 214.67±110.469 stands m^{-2}, *T. hemprichii* 85.11±41.471 stands m^{-2}, and *H. minor* 42.22±44.204 stands m^{-2}. Species with the highest coverage value at all observation plots was *C. rotundata* (33.47±26.748 %), and *T. ciliatum* had the lowest value (2.12±5.071 %). The total biomass was 676.32 g DW m^{-2} with biomass above substrate 329.94±57.725 g DW m^{-2} and below substrate 654.88±81.199 g DW m^{-2}. The carbon content of substrate ranged from 0.11% to 0.51% with the average of 0.35±0.081%, which was categorized low. The total average of carbon storage in seagrass was 447.92 g C m^{-2} comprising 142.77 g C m^{-2} of their tissue above substrate and 305.15 g C m^{-2} below substrate. Regarding the area, the total carbon stored in seagrass meadows with 56.65 ha area was 249.27 t C ha^{-1}.

Keywords: Biomass, carbon dioxide emission, carbon storage, seagrass bed, substrate

INTRODUCTION

The increase of atmospheric CO_2 concentration in the last decades leads to global warming, having an adverse effect such as the increase in earth temperature, drought, the rise of sea level, and ocean acidity. Generally, global warming does not only provide adverse impacts to the environment but also to the human life, and it will affect metabolisms of terrestrial and marine biota (Goel and Bhatt 2012; Brath et al. 2015).

One of the natural mechanisms reducing the increase of CO_2 concentration is CO_2 absorption through phot-osynthesis mechanism of seagrass vegetation (Sunquist et al. 2008; Bala 2014). Seagrass meadows in Indonesia is one of the widest in the world, which is 30000 km^2 consisting of thirteen species (Romomohtarto and Jumana 1999; Green and Short 2003). The ecological role of seagrass meadows is not only as habitat for various marine biota but also as a part of vegetation that can absorb and store the carbon as the implementation of blue carbon concept of coastal area. The potential of carbon storage in seagrass meadows is 2-4 times greater (4 t C ha^{-1} yr^{-1}) than that in the tropical forest (1.8-2.7 t C ha^{-1} yr^{-1}) (Lewis et al. 2009; Kennedy et al. 2010; Murray 2011).

West Nusa Tenggara is one of the provinces having the potential of seagrass meadows with a total area of 9379 ha (Imran et al. 2015). The primary metabolism processes (photosynthesis) in seagrass ecosystem might be affected by 60% of the organic and inorganic carbon from the sediment of river flow running to the ocean (Triatmodjo 1999; Bouillon and Connoly 2009; Rustam et al. 2014). Tt is expected, therefore, that it will also affect the storage of carbon content in seagrass biomass and carbon content in seagrass sediments.

The objective of the study was to dtermine number of seagrass species, its density, percentage of seagrass coverage, biomass of seagrass tissue, carbon content of seagrass tissue (above substrate and below substrate), and carbon content in seagrass sediments as well as estimation of carbon stock area in the coastal area of Poton Boko, East Lombok, West Nusa Tenggara, Indonesia.

MATERIALS AND METHODS

This research was performed in the coastal areas of Poton Bako, East Lombok - West Nusa Tenggara with the area of seagrass bed, was 55.65 ha. The site is affected by two river flows, and there are also mangrove forests so that the water condition of seagrass is turbid. This study was carried out from September to December 2017, including site observation and laboratory analysis. Site observation included identification of seagrass species following den Hartog (1970) and Azkab (1999). In the field, the seagrass coverage was estimated by using the Seagrass-Watch method (McKenzie et al. 2001) and by counting the number of stands in each observation plot (0.25 m^2 area). The number of observation plot was 36 in six lanes with the distance between plots was 25 m and between lines was 100 m.

Data collection and analysis

The data was collected by taking the entire stands to the depth of root penetration in each plot (0.25 m^2) as the sample of tissue biomass and carbon content of seagrass tissue that were above substrate (leaf sheaths and blades) and below substrate (rhizomes and roots). The calculation of top and below substrate was performed using oven drying method at a temperature of 60°C until dry weight stable was achieved (Kaldy and Dunton 2000). Meanwhile, the calculation of the carbon content of seagrass tissue was performed using Loss On Ignition method Helrich (1990). The sediment sample was collected in each plot to a depth of root penetration of 30 cm with the slope of 30° using a pipe having a diameter of 5 cm and length of 35 cm. The carbon content in seagrass sediments was analyzed using Kurmis method (Helrich 1990). Analysis of seagrass carbon and sediments was performed at the Soil Laboratory of Assessment Institute for Agricultural Technology, West Nusa Tenggara.

Analisis data

Density

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

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

Where:
D : density of seagrass, species *i* (stands m^{-2})
Ni : number of seagrass with species *i*
A : area of observation plot (m^2)

Biomass of seagrass species

Biomass is an organic material produced through photosynthesis process, either product or waste. Seagrass biomass (g DW m^{-2}) is a result of oven drying method calculated by using Azkab (1999) formula:

$$\text{Biomass (g DW m}^{-2}) = \frac{\text{Dry Weight (g DW)}}{\text{Wide area of observation area (m}^2)}$$

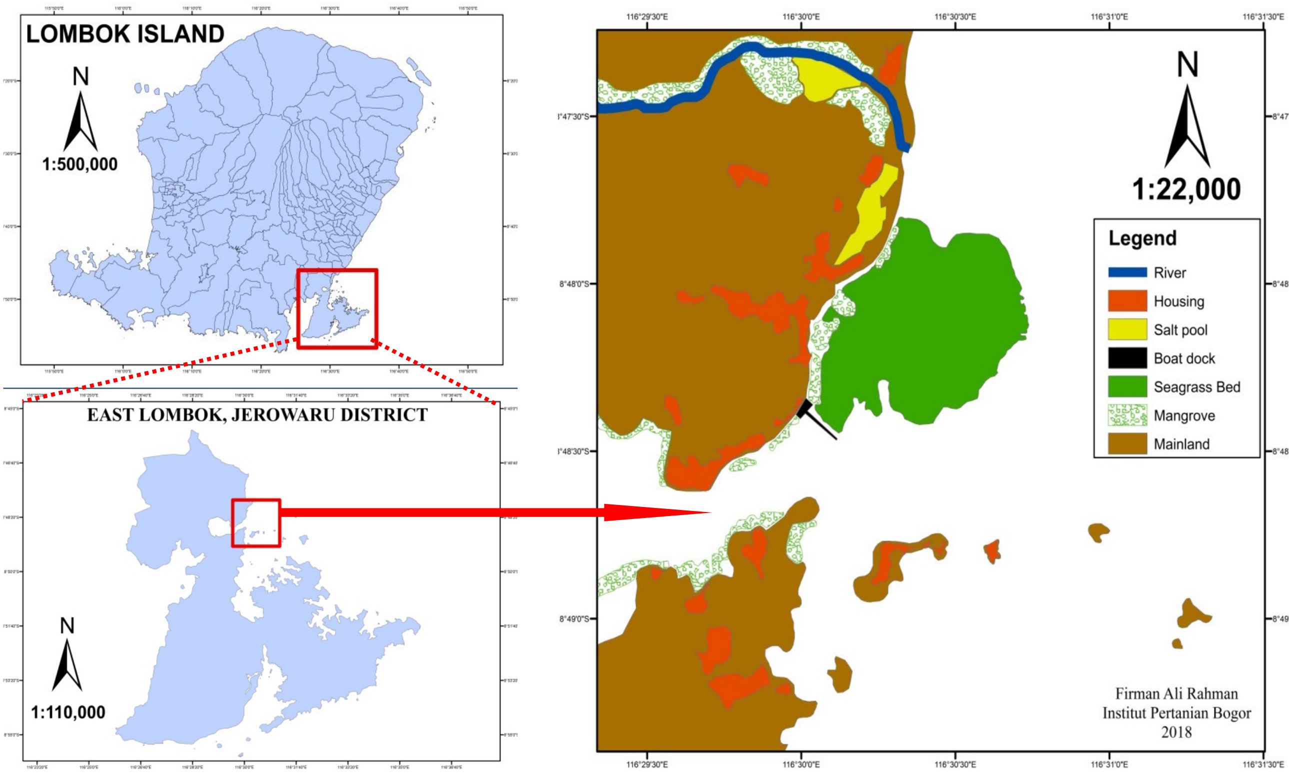

Figure 1. The study location at marine Poton Bako, East Lombok, Indonesia

Seagrass tissue carbon

Analysis of seagrass tissue carbon was calculated using Helrich (1990) formula:

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

Where:
a : Cup weight
b : Cup weight + dry weight of seagrass tissue
c : Cup weight + ash weight of seagrass tissue

Organic carbon material as a result of weight reduction while digestion process using Helrich (1990) formula:

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

Where:
a : Cup weight
b : Cup weight + dry weight of sample
c : Cup weight + ash

Value of organic carbon content of seagrass tissue was calculated using Helrich (1990) formula and the value as result of the carbon content was then calculated as the value of carbon content of seagrass tissue.

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

Where:
1.724 : Constant value of the organic material

Carbon content in seagrass sediments

Carbon content in seagrass sediments was calculated using Sulaeman et al. (2005) formula:

$$\text{Organic carbon content in sediments (\%)} = \frac{\text{ppm curve x 10}}{\text{500 x correction factor}}$$

Where:
ppm curve : Sample content obtained from the relationship curve between the standard serial content and the reading after correction
Correction factor : 100/ (100 - % water content)

Total carbon stock area

The calculation of carbon stored (g C m^{-2}) of seagrass tissue was performed using the approach of seagrass biomass weight (g DW m^{-2}) using Barron et al. (2004) formula:

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

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

$$Ct = \sum (Li \times Ci)$$

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

RESULTS AND DISCUSSION

Seagrass density and coverage

Density is a type of structure that can be used to estimate the production capability of a primary seagrass based on the number of individuals in the research sites. Based on the result of observations and calculations, *C. rotundata* (214.67±110.469 stands m^{-2}) was the species having the highest density found in coastal habitats; this was in line with Hartati et al. (2012) that there was a single highly associated species in the coastal area. Besides, *T. hemprichii* had the second highest density because it was able to adapt well in the Indonesian ocean environment (Larkum et al. 1989). This result was different from the density of *E. acoroides* (20.44±12.217 stands m^{-2}) that was lower than *C. rotundata* and *T. hemprichii*, but it had a wide variety of species in Poton Bako. This was because the morphology of *E. acoroides* was big and each of them required a wider space area. The lowest density value belonged to *H. uninervis* (16.67±25.000 stands m^{-2}) and *T. ciliatum* (5.56±8.333 stands m^{-2}) since these species were found only on one observation plot with low distribution value.

The percentage of seagrass coverage was related to the level of species capability and distribution. *C. rotundata* had the highest coverage value of 33.47±26.748%, and it had a positive correlation on high density value while the lowest seagrass coverage value belonged to *T. ciliatum* 2.12±5.07% (Table 1).

Seagrass tissue biomass

Biomass is the product of plant metabolism stored in its morphological part. The total biomass of six seagrass species in Poto Bako was 984.82±138.940 g DW m^{-2}. Overall, seagrass biomass of below substrate (654.88±81.199 g DW m^{-2}) had greater biomass content than the above substrate (329.94±57.725 g DW m^{-2}) (Table 2). *E. acoroides* had the highest biomass (628.57±57.67 g DW m^{-2}), and the lowest biomass belonged to *H. uninervis* (22.56±2.476 g DW m^{-2}) and *H. minor* (11.54±0.269 g DW m^{-2}) due to its small morphology type; whereas the low biomass of *T. ciliatum* (23.08±4.242 g DW m^{-2}) was caused by low species distribution and the low number of stands.

Table 1. Density and seagrass coverage at marine Poton Bako, East Lombok, Indonesia

Seagrass species	Density (stands m^{-2})	Seagrass coverage (%)
C. rotundata	214.67±110.469	33.47±26.748
T. hemprichii	85.11±41.471	23.07±18.161
H. minor	42.22±44.204	7.78±12.833
E. acoroides	20.44±12.217	31.07±16.241
H. uninervis	16.67±25.000	2.48±5.833
T. ciliatum	5.56±8.333	2.12±5.071

Table 2. Seagrass biomass at marine Poton Bako, East Lombok, Indonesia

Lane	Species	Number of plot	Seagrass biomass (g DW m^{-2}) Leaf sheaths and blades	Rhizomes	Roots	Total biomass
1	*C. rotundata*	4	34.80±10.886	33.64±10.796	16.27±4.156	84.72±25.840
	E. acoroides	1	9.85±0.990	13.73±0.134	3.56±2.121	27.15±3.250
	T hemprichii	1	6.69±0.509	7.25±1.485	4.12±1.549	18.06±3.540
2	*C. rotundata*	2	15.88±7.616	9.10±1.796	7.12±1.782	32.10±11.190
	T. hemprichii	5	28.65±4.158	24.48±3.413	16.06±1.930	69.19±9.500
3	*C. rotundata*	1	5.55±0.877	5.12±1.563	4.12±1.393	14.78±3.830
	E. acoroides	3	35.70±6.390	94.94±7.313	13.42±2.622	144.06±16.33
	T. hemprichii	3	17.55±3.563	15.60±4.625	9.20±2.149	42.35±10.340
4	*C rotundata*	2	9.52±2.503	9.68±0.870	7.12±1.782	26.32±5.160
	E. acoroides	4	61.92±3.802	123.99±5.308	16.56±0.758	202.47±9.870
5	*C. rotundata*	1	3.97±1.414	4.57±2.121	3.00±1.344	11.54±4.880
	E. acoroides	2	25.60±8.577	50.81±4.059	9.60±1.393	86.02±14.03
	H. uninervis	1	8.03±0.778	9.59±0.849	4.95±0.849	22.56±2.480
	T. ciliatum	1	7.95±0.707	9.14±2.121	6.00±1.414	23.08±4.240
6	*E. acoroides*	6	54.30±4.835	92.28±8.335	22.29±1.020	168.88±14.190
	H. minor	2	3.97±0.120	4.57±0.078	3.00±0.071	11.54±0.27

Table 3. Percentage of carbon content in all parts of seagrass at the coastal area of Poton Bako, East Lombok, Indonesia

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})
C. rotundata	49.05±1.369	34.20	45.77±14.097	28.43	44.79±9.443	16.85
E. acoroides	41.27±3.699	77.33	49.09±4.444	184.46	44.98±5.329	29.43
T. hemprichii	46.33±4.696	24.50	48.73±6.955	23.06	35.80±4.583	10.52
T. ciliatum	36.27±0.000	2.88	46.70±0.000	4.27	36.46±0.000	2.19
H. uninervis	35.00±0.000	2.81	32.10±0.000	3.08	28.70±0.000	1.42
H. minor	26.40±0.000	1.05	19.87±0.000	0.91	17.93±0.000	0.54

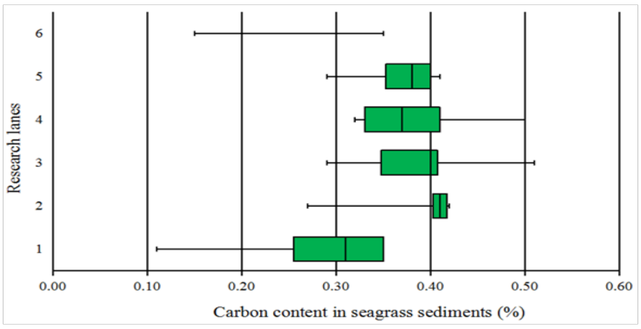

Figure 2. Carbon content in seagrass sediments at marine Poton Bako, East Lombok, Indonesia

Carbon content in seagrass sediments

The carbon content in seagrass sediments was the result of animals and litter corrosion decomposed by microorganisms (Purnama 2013). Carbon content in seagrass sediments in Poton Bako ranged from 0.11% to 0.51%, with an average of 0.35±0.081% (Figure 2). The carbon content in seagrass sediments of sandy clay and clay containing sand were relatively higher than sand substrate. In general, the value of carbon content in seagrass sediments of Poton Bako marine was categorized as very low because it was < 1% (Sulaiman et al. 2005).

Seagrass tissue carbon

The carbon content of seagrass tissue (leaf sheaths and blades, rhizomes and roots) was able to show the seagrass potential as blue carbon in each part of its morphology. *E. acoroides* had the highest carbon content (291.22 g C m^{-2}), while *H. minor* (2.50 g C m^{-2}) had the lowest carbon content. The level of seagrass carbon content can be related to the species biomass by considering the research sites. The carbon content stored in biomass of below substrate (rhizomes and roots) was higher than the biomass of the above substrate (leaf sheaths and blades) in the six types of seagrass with a ratio of 2:1, which was a good potential for seagrass as blue carbon because biomass of below substrate can be stored for thousands of years (Mateo et al. 1997).

Discussion

East Lombok is one of the areas where the seagrass bed area of 784.3 ha and it has the potential to be blue carbon area of Indonesia (Imran et al. 2015). Based on observations, there were six species of seagrass (two families, 6 genera) of the thirteen Indonesian seagrass species in Poton Bako, including *Cymodocea rotundata, Enhalus acoroides, Halophila minor, Holodule uninervis, Thalassia hemprichii* and *Thalassodendron ciliatum*. The composition of seagrass in Poton Bako was lower than the composition of nine species in Tanjung Luar East Lombok (Syukur et al. 2017), eight species in Sanur Bali (Graha et al. 2015), eight species in Menjangan Kecil Island, eight species in Pintok Karimunjawa Archipelago (Hartati et al. 2017), seven species in Tanjung Lesung, Miskam Bay Banten (Rustam et al. 2014), seven species in Kotania Seram Tenggara Bay (Wawo et al. 2014), seven species in Pari Island (Husodo etal. 2017), and seven species in West Bali National Park (Purnomo et al. 2017). The low composition of seagrass in Poton Bako was suspected because the effect of two river flow causing turbid water so that it became the factor why the growth and development, especially in photosynthesis process as well as the distribution of seagrass became limited.

The composition and structure of the seagrass were related to the density value, distribution, and percentage of seagrass coverage in the five seagrass species, except *E. acoroides*, which had the fourth highest density with the second highest coverage value because *E. acoroides* had a big morphological size but with a low number of stands. This supported Short and Coles (2003) that the size of the species morphology can affect the coverage and individual values having small morphology size such as *H. minor* having a low coverage value. Composition value and structure of the seagrass can be affected by the depth, substrate type, light intensity, current, temperature, pH, turbidity, nutrients and salinity (McRoy and McMillan 1977; Zieman and Wetzel 1980).

Overall, there was no seagrass species having a ‘rich' status based on the Decree of the Minister of Environment No. 200 of 2004 on six types of Poto Bako seagrass because they had coverage value that was less than 60%, and there were only two species with less rich status: *C. rotundata* (33.47±26.748%) and *E. acoroides* (31.07±16.241%); while the other four seagrasses were classified as poor (< 29.9%).

Biomass was related to density value in Poton Bako. The present research result revealed that total biomass of *C. rotundata* (169.47 g DW m^{-2}) was higher than that of *T. hemprichii* (129.60 g DW m^{-2}), although *T. hemprichii* had bigger morphology size than *C. rotundata*. Azkab (1999) saying that biomass may be affected by morphological and density factors. The biomass content of below substrate had a higher value than that of above substrate on all seagrass species in Poton Bako with a ratio of 2:1, because the biomass material of below substrate was generally more solid and larger morphological sizes.

Carbon content in seagrass sediment can be affected by the characteristics of the substrate fraction, the growing seagrass species, the environmental factors and the activity of the littering organisms. Large diameter sand substrate allowed the occurrence of oxidation mechanisms which can lead to the detached organic material content and low carbon storage, whereas higher carbon content can be found in clay or fine substrate fractions (Azkab and Kiswara 1999; Yunitha et al. 2014). The low carbon content of the low substrate in Poton Bako was because the lather of seagrass was not drowned and decomposed but was carried away to the coastal area. Besides, the anaerobe condition and high pH can affect the low corrosion activity and mineralization of organic material by microorganisms in the substrate (Poljakoff-Mayber and Gale 1975; Tangketasik et al. 2012).

Overall, *E. acoroides* had the highest carbon content because it had the highest biomass with a larger morphological size than other species. Kennedy and Bjork (2009) and Rahmawati (2011) reported that seagrass with large morphology size could accumulate larger carbon such as *E. acoroides*, that was about 40% of its biomass, and vice versa. Björk et al. (2008) reported that *Halophila sp* had a low carbon content that was suspected to be pioneering species with small morphological size. In addition to morphological factors, high density factor can affect the value of biomass species having implications on carbon content such as in *C. rotundata* (79.48 g C m^{-2}) that was the second highest species in Poton Bako.

In general, the total seagrass carbon content stored in tissue on the top and below substrate was 447.92 g C m^{-2}; above substrate was 142.77 g Cm^{-2} and below substrate was 305.15 g C m^{-2}. The estimation of carbon stock in Poton Bako seagrass beds was 249.27 t C or equivalent to 4.48 t C ha^{-1}. The higher total carbon content was dominated on the below substrate (169.82 t C) than the above substrate (79.45 t C). The total amount of this storage was much higher than that found by Graha et al. (2015) at Sanur Beach Bali with a total carbon stock of 66.60 t C on an area of 322 ha or equivalent to storage of 0.21 t C ha^{-1}. Similarly, the result of research performed by Supriadi (2012) in Baranglompo Island area of 58.05 ha revealed that E. acoroides also dominated the *is*land with the total carbon storage of 52.06 t C or equivalent to 0.9 t C ha^{-1}.

To conclude, there were six types of seagrass (two families, six genera) at Poton Bako, East Lombok, including *Cymodocea rotundata, Enhalus acoroides, Halophila minor, Holodule Uninervis, Thalassia hemprichii* and *Thalassodendron ciliatum*. The highest density value and coverage percentage were found in *C. rotundata* with the respective value of 214.67±110.469 stands m^{-2}, and 33.47±26.748%. The average of above substrate total biomass was 329.94±57.725 g DW m^{-2}, and the below substrate was 654.88±81.199 g DW m^{-2}. The average carbon content in seagrass sediments of 0.35±0.081% was included in the category of very low because it was less than 1%. The total carbon stock storage in seagrass ecosystem of 55.65 ha was 249.27 t C or equivalent to 4.48 t C ha^{-1}.

REFERENCES

Azkab MH. 1999. Guidelines for seagrass inventory. Oseana 24 (1): 1-16 [Indonesian].

Azkab MH, Kiswara W. 1999. Growth and production of seagrasses in Kuta Bay, South Lombok. Balitbang Biologi, Pusat Penelitian dan

Pengembangan Oseanologi Lembaga Ilmu Pengetahuan Indonesia [Indonesian].
Bala G. 2014. Can planting new trees help to reduce global warming?. Curr Sci 106 (12): 1623-1624.
Barron C, Marba N, Terrados J, Kennedy H, Duarte CM. 2004. Community metabolism and carbon budget along a gradient of seagrass (*Cymodoea nodusa*) colonization. Limnol Oceanogr 49 (5): 1642-1651.
Björk M, Short F, McLeod E, Beer S. 2008. Managing seagrasses for resilience to climate change. IUCN, Gland.
Bouillon S, Connoly RM. 2009. Carbon exchange among tropical coastal ecosystems. In: Nagelkerken I (ed.). Ecological connectivity among tropical coastal ecosystems. Springer, Berlin.
Brath B, Friesen T, Guerard Y, Jacques-Brissette C, Lindman C, Lockridge K, Mulgund S, Walke BJ. 2015. Climate change and resource sustainability: An overview for actuaries. Canadian Institute of Actuaries, Canada.
Brower JE, Zar NJ. 1977. Field and laboratory methods for general ecology. Wm.C Brown Publ., Dubuque, Iowa, USA.
den Hartog C. 1970. The Seagrasses of the world in: Azkab MH. 1999. Guidelines for seagrass inventory. Oseana 24 (1): 1-16.
Goel A, Bhatt R. 2012. Causes and consequences of global warming. Intl J Life Sci Biotechnol Pharma Res 1 (1): 27-31.
Graha YI, Arthana IW, Karang IWGA. 2015. Carbon stored of seagrass beds in Sanur Beach, Denpasar City. Ecotrophic 10 (1): 46-53 [Indonesian].
Green EP, Short FT. 2003. World atlas of seagrasses. University of California Press, USA.
Hartati R, Djunaedi A, Haryadi, Mujianto. 2012. Structure of seagrass community in Kumbang Island, Karimunjawa Archipelago. Ilmu Kelautan 17 (4): 217-225. [Indonesian].
Hartati R, Pratikto I, Pratiwi TN. 2017. Biomass and estimation of carbon stored on seagrass ecosystems on Menjangan Kecil Island and Sintok Island, Karimunjawa Archipelago. Buletin Oseanografi Marina 1:74-81 [Indonesian].
Helrich K. 1990. Method of Analysis of the association of official analytical chemists. Agricultural Chemicals, Contaminants, Drugs. 15th. Volume 1. Association of Official Analytical Chemists, Inc Publ. Arlington, Virginia, USA.
Husodo T, Palabbi SDG, Abdoellah OS, Nurzaman M, Fitriani N, Partasasmita R. 2017. Short Communication: Seagrass diversity and carbon sequestration: Case study on Pari Island, Jakarta Bay, Indonesia. Biodiversitas 18 (4): 1596-1601.
Imran Z, Wibowo P, Rustadi Y, Komaruddin M, Albery, Perkasa A, Kurniawan F, Amin MAA, Perdana I. 2015. Strategic of environmental assessment, zoning plan for coastal zone and small islands of West Nusa Tenggara Province, West Nusa Tenggara. [Indonesian].
Indonesian of Minister Decree of Environment No. 200 of 2004. New criteria of damage and guidelines on determination of seagrass beds status. Jakarta. [Indonesian].
Kaldy JE, Dunton KH. 2000. Above and below ground production, biomass and reproduction ecology of *Thalassia testudinum* (Turtle Grass) in a subtropical coastal lagoon. Mar Ecol Prog Ser 193: 271-283.
Kennedy H, Beggins J, Duarte CM, Fourqurean JW, Holmer M, Marbà N, Middleburg J. 2010. Seagrass sediments as a global carbon sink: Isotopic constrain. Global Biogeochem 24: 1-8.
Kennedy H, Björk M. 2009. Seagrass Meadows. In: Laffoley D, Grimsditch G (eds.). The management of natural coastal carbon sinks. IUCN, Gland, Switzerland.
Larkum AWD, Comb AJMc, Shepherd SA. 1989. Biology of seagrass: a treatise on the biology of seagrasses with special reference to the australian religion. In: Aquatic Plant Studies 2. Elsevier. Amsterdam.
Lewis SL, Gonzalez GL, Sonke B, Baffoe KA, Baker TR, Ojo LO, Philips OL, Reitsma JM, White L, Comiskey JA, Djuikou MN, Ewango CEN, Feldausch TR, Hamilton AC, Gloor M, Hart T, Hladik A, Lloyd J, Lovett JC, Makana JR, Malhi Y, Mbago FM, Ndangalasi HJ, Peacock J, Peh KSH, Sheil D, Sunderland T, Swaine MD, Taplin J, Taylor D, Thomas CD, Votere R, Woll H. 2009. Increasing carbon storage in intact African tropical forests. Nature 457 (7232): 1003-1007.
Mateo MA, Romero J, Perez M, Littler MM, Littler DS. 1997. Dynamics of millenary organic deposits resulting from the growth of the Mediterranean seagrass *Posidonia oceanica*. Estuar Coast Shelf Sci 44: 103-110.
McKenzie LJ, Finkbeiner MA, Kirkman H. 2001. Methods for mapping seagrass distribution. In: Short FT, Coles RG (eds.). Global Seagrass Research Methods. Elsevier, Amsterdam.
McRoy CP, McMillan C. 1977. Production ecology and physiology of seagrass. In: McRoy CP, Helffrich C (eds.). Seagrass Ecosystem: a Scientific Perspective. Dekker, New York.
Murray BC, Pendleton L, Jenkins WA, Sifeet S. 2011. Green payments for blue carbon: economic incentives for protecting threatened coastal habitats NI R 11-04 Nicholas Institute for Environmental Policy Solutions. Duke University, UK.
Poljakoff-Mayber A, Gale J. 1975. Morphological and anatomical changes in plants as a response to salinity stress. In: Poljakoff-Mayber A, Gale J (Eds.). Plants in Saline Environments. Springer-Verlag Berlin Heidelberg New York.
Purnama D. 2013. Analysis of seagrass structure and community as turtle habitat at Kahyapu Beach, Enggano Sub-district, Bengkulu Province. Akuatik-Jurnal Sumberdaya Perairan 7 (2): 1978-1652 [Indonesian].
Purnomo HK, Yusniawati Y, Putrika A, Handayani W, Yasman. 2017. Seagrass species diversity at various seagrass bed ecosystems in the West Bali National Park Area. Pros Sem Nas Masy Biodiv Indon 3 (2): 236-240. [Indonesian].
Rahmawati S. 2011. Estimation of carbon reserves at seagrass community on Pari Island, National Park of Seribu Archipelago, Jakarta. J Segara 7 (1): 65-71. [Indonesian].
Romomohtarto K, Jumana S. 1999. Marine biology: science of marine biota. Pusat Penelitian dan Pengembangan Oseanologi, Lembaga Ilmu Pengetahuan Indonesia, Jakarta. [Indonesian].
Rustam A, Bengen, DG, Zainal A, Jonson LG. 2014. Contribution of seagrass in carbon regulation and ecosystem stabilization. [Dissertation]. Bogor Agricultural University. Bogor. [Indonesian].
Short FT, Coles R. 2003. Global Seagrass Research Method. Elsevier, Amsterdam.
Sulaeman, Suparto, Eviati. 2005. Technical guidance for analysis on soil, water, and fertilizers. Indonesian Soil Research Institute, Agricultural Research and Development Agency, Ministry of Agriculture. Bogor. [Indonesian].
Sunquist E, Burruss R, Fulkner S, Gleason R, Harden J, Kharaka Y, Tieszen L, Weldrop M. 2008. Carbon sequestration to mitigate climate change. United States Geological Survey, Washington, DC.
Supriadi, Richardus F, Kaswadji, Bengen DG, Malikusworo H. 2012. Seagrass stocks and carbon community accounts on Baranglompo Island, Makassar. Jurnal Akuatika 3 (2): 159-168. [Indonesian]
Syukur A, Wardiatno Y, Muchsin I, Kamal MM. 2017. Threats to seagrass ecology and indicators of the importance of seagrass ecological services in the coastal waters of East Lombok, Indonesia. Amer J Environ Sci 13 (3): 251-265.
Tangketasik A, Wikarniti NM, Soniari NN, Narka IW. 2012. Organic content levels on rice fields and types in Bali and its relation to soil texture. Agrotrop 2 (2): 101-107. [Indonesian].
Triatmodjo B. 1999. Coastal Techniques. Beta Offset, Yogyakarta. [Indonesian].
Wawo M, Wardiatno Y, Adrianto L, Bengen DG. 2014. Carbon stored on seagrass community in Marine Nature Tourism Park of Kotania Bay, Western Seram, Indonesia. J Trop For Manag 20 (1): 51-57.
Yunitha A, Wardiatno Y, Yuliandi F. 2014. Substrates diameter and seagrasses species in Bahoi Coastal North Minahasa: A correlation analysis. Jurnal Ilmu Pertanian Indonesia 19 (3): 130-135 [Indonesian].
Zieman JC, Wetzel NG. 1980. Productivity in seagrasses: Methods and rates. In: Phillips RC, Mc Roy CP (eds.). Handbook of seagrass biology: an Ecosystem Perspective. Garland Publ.Inc. New York.