

## Carbon Stored on Seagrass Community in Marine Nature Tourism Park of Kotania Bay, Western Seram, Indonesia

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### Abstract

Currently, the function of seagrass community as carbon storage has been discussed in line with “blue carbon” function of that seagrass has. Seagrass bed are a very valuable coastal ecosystem, however, seagrass bed is threatened if compared to other coastal ecosystems, such as mangroves and coral reefs. The threatened seagrass experienced also contributes to its capacity in absorbing CO<sub>2</sub> emission from greenhouse gasses such as CO<sub>2</sub> emission. Temporal estimation shows that CO<sub>2</sub> emission will increase in the coming decade. On the other side, efforts to decrease climate change can be influenced by the existence of seagrass. Informations about existence of seagrass as carbon storage are still very rare or limited. This study was aimed to estimate carbon storage on seagrass community in Marine Nature Tourism Park of Kotania Bay Area, Western Seram, Maluku Province. The quadrat transect method of 0.25 m<sup>2</sup> for each plot was used to collect seagrass existence. The content of carbon in the sample of dry biomass of seagrass was analyzed in the laboratory using Walkley & Black method. The results showed that total carbon stored was higher in both Osi and Burung Islands of Kotania Bay than other studied areas (Buntal and Tatumbu Islands, Marsegu Island, Barnusang Peninsula, Loupessy and Tamanjaya Village). The average carbon stored in Kotania Bay waters was 2.385 Mg C ha<sup>-1</sup>, whereas the total of carbon stored was 2054.4967 Mg C.

Keywords: biomass, seagrass, blue carbon, carbon stock

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### Introduction

Climate change is caused by increasing the concentration of green house gasses (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFC, PFC, and SF<sub>6</sub>) and particles in the atmosphere. There are 3 mechanisms in which the gasses are increase: (1) increases come from burning fossil fuel, realizing green house gasses, CO<sub>2</sub> (brown carbon), and ash particle (black carbon), (2) secondly, originates emission from cutting forest vegetation, burning forest, and using fertilizer in agricultural activities, (3) thirdly, the changing of climate is also led by lessening the capability of natural ecosystem to absorb carbon in photosynthesis capacity and saving process, as known *green carbon* (Trumper *et al.* 2009). Impact of climate change can lead to increase global temperature above 2 °C threshold value (Nellemann *et al.* 2009). In the last several years, scientist have worked together to overcome problems of *green carbon*, content of carbon stored globally in forest area and soil, through *Reduced Emissions from Deforestation and forest Degradation* (REDD) program. Degradation of forest in terrestrial area has no far different to coastal area.

The most current issue that become a global issue is a document known as *blue carbon* launched on 14<sup>th</sup> October

2009 in Johannesburg, South Africa, by United Nations, UNEP, FAO, and UNESCO. One of the recommendatio is the protection of three coastal ecosystems, mangrove, seagrass, and salt marsh (Hutomo 2009). According to that document, these three coastal ecosystems cover less than 1% of marine area in the world, however, they have an important role as carbon sink from atmosphere, and through all processes within these ecosystems like photosynthesis directly knock (store) binded carbon from atmosphere in basin waters as many as 50% (Larkum *et al.* 2006).

Absorbing carbon from atmosphere seems to be different to phytoplankton which only absorb about 10% in water basin. Seagrass, therefore, has an essential role as carbon store, and contributes significantly in mitigating global warming due to climate change that happens currently. Protecting organic stored carbon in the forest is assumed as an important method in mitigating climate change. Carbon accumulation in marine sediments provides longterm storage of organic carbon and has been referred to as *blue carbon* to distinguish it from carbon in terrestrial sinks (Nellemann *et al.* 2009). Unlike terrestrial systems that store organic carbon primarily in living biomass and soil organic matter, coastal

vegetated systems store the majority of organic carbon in sediment (Duarte *et al.* 2005; McLeod *et al.* 2011; Fourqurean *et al.* 2012). In addition, terrestrial habitats lose carbon stocks to the atmosphere as CO<sub>2</sub> via decomposition or by disturbances such as fires (Schlesinger & Lichter 2001; Duarte *et al.* 2011). Because marine sediments are often anoxic and continually accumulate sediment (Kennedy *et al.* 2010), organic carbon can be preserved within them over decadal to even millennial time scales where the organic carbon, though subjected to some diagenesis, is still considered a carbon sink (McKee *et al.* 2007).

As same as terrestrial ecosystem, coastal ecosystem also save a huge number of carbon, and has been an initiative for protecting blue carbon source particularly in seagrass (Fourqurean *et al.* 2012). Seagrass habitat can also save carbon for years as similar as some rooted plant species (Russell *et al.* 2013). Organic carbon in seagrass sediment, known as *blue carbon*, accumulates from both *in situ* production and sedimentation of particulate carbon from the water column (Greiner *et al.* 2013).

Nowadays facts have already proved that the area of seagrass areas has decreased globally due to threaten of environmental unfriendly development. According to Waycott *et al.* (2009), lost of seagrass condition and average decrease width tend to increase dramatically over years. Seagrass ecosystems are lost each year through habitat destruction, eutrophication, and other anthropogenic stressors.

Seagrass bed is one of the coastal ecosystem that has an ecological and physical function with economic value and habitat for many marine organism (Jackson *et al.* 2006). Some of ecological function of seagrass are spawning ground of many organism, feeding ground, nursery ground, connected terrestrial and marine habitat, sediment stabilization that protect coastal erosion *etc.* (Green & Short 2003; Eklof *et al.* 2006; Fonseca & Koehl 2006; Kennedy & Bjork 2009). Average of fish abundance was higher in vegetated area than unvegetated area (Rahmawati *et al.* 2012). Seagrass meadows are highly productive habitats that provide important ecosystem services in the coastal zone, including carbon and nutrient sequestration (Greiner *et al.* 2013). Moreover, seagrass also has an important function to be considered as carbon storage in accordance to blue carbon concept currently discussed intensively. Seagrass as a valuable coastal ecosystem, however, has undergo more threatened than any other coastal ecosystems (Waycott *et al.* 2009; Fourqurean 2012).

Due to threaten faced by seagrass ecosystem, the capability to absorb carbon emission has also under threat. Currently, CO<sub>2</sub> emission globally will tend to increase in the coming decade (Russell *et al.* 2013), however, efforts to decrease climate change currently are influenced by sustainability of seagrass. Recently, seagrass meadows have been acknowledged for their carbon storage potential and it has been estimated that globally as much as 19.9 Pg of organic carbon are stored in seagrass meadows. Unlike terrestrial systems that store organic carbon primarily in living biomass and soil organic matter, coastal vegetated systems store the majority of organic carbon in sediment (Fourqurean *et al.* 2012). Information on seagrass existence

related to its capability as carbon storage is still limited particularly in eastern part of Indonesia, therefore, the research on the measurement of carbon stored urgently needed. The research was aimed to measure the content of carbon stored on seagrass community in Marine Nature Tourism Park of Kotania Bay, Western Seram, Maluku Province.

## Methods

The research was conducted during May–July 2011 in Kotania Bay, Western Seram, Maluku Province. Kotania Bay is an area of Marine Nature Tourism Park (MNTP) established since 1999 by Ministry of Forest and Plantation. There are many aspects in every marine conservation area, such as biophysical factors, governance, and social economy, that directly or indirectly affect the total management performance (Dangeubun *et al.* 2013). In cases where there are multiple user competing and over scarce resources, participation may offer support to decision makers in developing or implementing management plans. Participatory rural approach (PRA) is a approach has been written as “how to” guide stakeholders to employing participatory decision making techniques for resource management in coastal zone (Brown *et al.* 2001). Sampling sites were determined through PRA activity using *community mapping* approach that relates to resource uses on seagrass ecosystem by coastal communities. Quadrat transect method was used to collect the data. This method assess the community structure of seagrass meadows along transects (English *et al.* 1994). A transect was placed perpendicularly to coastline along seagrass area in all research sites. Plot or quadrat was placed along transect with interval of 10 m (Duarte & Krikman 2003). Measurement on seagrass coverage area, density and biomass was conducted at a plot of 0.25 m<sup>2</sup> width (Short *et al.* 2004). The measurement of physical data covering site position, temperature, salinity, pH, substrates, was also done simultaneously. There are totally 42 research sites and 437 plots. These plots located were representatively in each site.

Biomass and carbon content were measured on above-ground (Abg) parts of seagrass, covering leaf sheaths and leaf blades, while below-ground (Blg) parts of seagrass, such as roots and rhizomes (Kaldy & Dunton 2000). The measurement of biomass from 7 species of seagrass were conducted by collecting 2 samples from each species. All of the 14 samples were then weighed to determine their total and partial wet weight (roots, rhizomes, leaf sheaths, and leaf blades). According to Short *et al.* (2004), sample was then dried up on temperature of 60 °C to obtain constant weight as dry weight. Carbon contain in the dry weight seagrass samples were then analyzed using method according to Walkley and Black (Schumacher 2002) at the laboratory of Soil Science and Land Resources Department, Bogor Agricultural University. The total dry weight of every parts of each species were obtained by multiplying the number of individual seagrass with the dry weight of the parts. Measuring biomass in gram carbon per meter square (g C m<sup>-2</sup>) was conducted according to Barron *et al.* (2004) which count carbon weight biomass m<sup>-2</sup> of seagrass plant from gram dry

weight which then converted to mol C with percentage of carbon contain dry weight as shown in Equation [1]. Seagrass biomass can be determined in g C m<sup>-2</sup>. Carbon stored on each part of seagrass was calculated by multiplying dry biomass to content of carbon.

$$\text{Carbon stored (g C m}^{-2}\text{)} = \text{carbon contained (\% C)} \times \text{dry weight (g m}^{-2}\text{)} \quad [1]$$

## Results and Discussion

Seagrass in Kotania Bay area covers 823.615 ha based on recalculation of map figured by Supriyadi (2009). According to the width of seagrass covers, seagrass area was then divided by local communities in mapping area based on their livelihood in seagrass areas as can be seen in Table 1. The existing seagrass in Buntal and Tatumbu Islands as well as Osi and Burung Islands could not be calculated separately due to no boundary among all of the islands.

In general, there were 7 species of seagrass found in this area that belong to 2 families. Seagrass species of *Hydrocharitaceae* family consists of three species *i.e.*, *Enhalus acoroides*, *Thalassia hemprichii*, and *Halophila ovalis*, whereas, 4 species of seagrass, *Cymodocea rotundata*, *Cymodocea serrulata*, *Halodule pinifolia*, and *Syringodium*

*isoetifolium*, belong to *Cymodoceaceae* or *Potamogetonaceae* family (Table 2). Seagrass species distributed variously in all research sites. Five species of seagrass were found in 6 sites, namely Buntal, Tatumbu, Osi, Burung, and Marsegu Islands as well as Barnusang Peninsula, while only 6 and 7 species were existed in Loupessy and Tamanjaya Villages, respectively.

Total density of seagrass species in all research sites was higher than 100 shoot m<sup>-2</sup>. Marsegu Island was the highest number of seagrass species density which was as many as 556.48 shoot m<sup>-2</sup>, whereas the lowest number of seagrass species density was Loupessy Village which had 187.83 shoot m<sup>-2</sup>. The average of seagrass percent cover in the Kotania Bay was generally as many as 50.59% which ranged 29.23% (Loupessy Village)–65.17% (Marsegu Island). The highest seagrass percent cover tends to exist on opened waters area as Marsegu Island if compared to waters of bay intended to land. This condition seems to relate to local community activity that tends to use resource existing in waters of bay far from land.

As can be seen on Table 3, the highest percentage content of carbon in part of seagrass is rhizome belonged to *C. rotundata* (54.45%), whereas, the lowest is leaf sheath owned by *H. ovalis* (32.22%). This result is also similar to

Table 1 Seagrass area based on local communities mapping in Kotania Bay waters

Research site	Area (ha)
Buntal and Tatumbu Islands	203.0905
Osi and Burung Islands	457.0375
Marsegu Islands	58.1730
Barnusang Peninsula	94.1635
Loupessy Village	4.5535
Tamanjaya Village	6.5970
Total	823.6150

Table 2 Distribution of seagrass species in all research sites

Family	Species	Sites							
		1	2	3	4	5	6	7	8
<i>Hydrocharitaceae</i>	<i>Enhalus acoroides</i>	+	+	+	+	+	+	+	+
	<i>Halophila ovalis</i>	+	+	+	+	+	+	+	+
	<i>Thalassia hemprichii</i>	+	+	+	+	+	+	+	+
<i>Potamogetonaceae</i>	<i>Cymodocea rotundata</i>	+	+	+	+	+	+	+	+
	<i>Cymodocea serrulata</i>	+	+	+	+	+	+	+	+
	<i>Halodule pinifolia</i>	-	-	-	-	-	-	+	+
	<i>Syringodium isoetifolium</i>	-	-	-	-	-	-	-	+
Total		5	5	5	5	5	5	6	7

1: Buntal Island; 2: Tatumbu Island; 3: Osi Island; 4: Burung Island; 5: Marsegu Island; 6: Barnusang Peninsula; 7: Loupessy Village, and 8: Taman Jaya Village

result of Kiswara (2010) that rizhome, a part of seagrass, has the highest percentage of carbon stored which is as many as 50.62% in *E. acoroides*, while the lowest is in roots owned by *T. hemprichii* (26.79%). Carbon stored and seagrass biomass have correlate to seagrass growth. According to Bjork *et al.* (2008), variation in characteristic of seagrass growth leads to significant difference of seagrass species from pioneered species to climax species. Pioneered species of seagrass tend to expansively growth, and produce new shoots quickly, therefore, they store a lesser amount of carbon, like *Halodule* and *Halophila* spp. In contrast, climax species of seagrass tend to expand slowly, and save massive carbon, namely *Thalassia* spp and *Posidonia oceanica*. Kennedy and Bjork (2009) stated that seagrass species that have morphologically large size tend to have more below-ground biomass, therefore they can accumulate an enormous number of carbon. For instance, *P. oceanica*, a climax species, needs a slowly longer time to replace roots and rizhomes (taking from 40 days to 19 years) therefore, it can sink a large amount of carbon (40%) below ground for a longer period. *Posidonia oceanica* in this example differed to *H. ovalis* in this result which has a smaller percentage of

carbon stored if compared to other seagrass species.

According to Kaldy and Dunton (2000), carbon contained is the percentage of carbon element towards dry weight of seagrass in each seagrass species. The result shows below-ground parts of seagrass contain a large amount of carbon especially *E. acoroides* as much as 47.03%. This is in line with the result done by both Duarte (1990) and Rahmawati (2011; 2012) that *E. acoroides* had also a huge carbon stored on below-ground, as can be seen in Table 4. Barnusang Peninsula has a lower carbon stored as much as 198.0147 g C m<sup>-2</sup> than Loupessy Village (208.7629 g C m<sup>-2</sup>) that has a smaller seagrass coverage (Table 5). Moreover, the average biomass (g dry weight) per area unit in Barnusang Peninsula has also a lower value than other research sites (Table 6). Barnusang Peninsula, therefore, has a lesser contribution for saving carbon.

According to Table 5, the average of carbon stored from seven species of seagrass in the waters of Kotania Bay is as much as 2.385 Mg C ha<sup>-1</sup>, whereas, the total of carbon stored is 2054.4967 Mg C. The average of carbon stored in Kotania Bay is higher than Belitung Island, eventhough its seagrass coverage has no wider than Belitung Island (Table 7). The

Table 3 Percentage of carbon content (% C) in all parts of seagrass

Seagrass species	Roots	Rhizomas	Blg	Leaf sheaths	Leaf blades	Abg
<i>Cymodocea serrulata</i>	49.79	44.05	46.92	38.84	44.06	41.45
<i>Cymodocea rotundata</i>	34.55	54.45	44.50	45.16	46.29	45.73
<i>Enhalus acoroides</i>	41.91	52.15	47.03	40.04	43.67	41.86
<i>Thalassia hemprichii</i>	36.26	49.18	42.72	43.92	36.74	40.33
<i>Syringodium isoetifolium</i>	43.50	46.40	44.95	46.40	40.60	43.50
<i>Halodule pinifolia</i>	34.80	46.40	40.60	32.80	43.50	38.15
<i>Halophila ovalis</i>	34.80	41.43	38.12	32.22	43.50	37.86
Average	38.75±5.95	47.72±4.45	43.55	39.91±6.03	46.62±3.26	41.17

Blg: Below-ground; Abg: Above-ground

Table 4 Percentage of carbon content (% C) based on below-ground (Blg) and above-ground (Abg) part of seagrass from different researchers

Seagrass species	Percentage of carbon content (% C)							
	Blg				Abg			
	2011	2012	2011 *	1990	2011	2012	2011 *	1990
<i>Cymodocea serrulata</i>	46.92	26.46	33.5	-	41.45	29.04	32.5	-
<i>Cymodocea rotundata</i>	44.50	-	41.6	-	45.73	-	40.3	-
<i>Enhalus acoroides</i>	47.03	33.26	41.5	-	41.86	32.26	40.2	-
<i>Thalassia hemprichii</i>	42.72	22.54	35.6	-	40.33	25.22	36.4	-
<i>Syringodium isoetifolium</i>	44.95	-	-	-	43.50	-	-	-
<i>Halodule pinifolia</i>	40.60	-	-	-	38.15	-	-	-
<i>Halophila ovalis</i>	38.12	-	18.9	33.6	37.86	-	25.2	33.6
<i>Halodule uninervis</i>	-	29.95	30.4	-	-	31.83	33.4	-

Source: Duarte (1990), Rahmawati (2011\*; 2012)  
 Blg: Below-ground; Abg: Above-ground

Table 5 The total of carbon stored in seagrass of all research sites

Sites	CS (g C m <sup>-2</sup> )	Area (ha)	CS (Mg C ha <sup>-1</sup> )	Total CS (Mg C)
Buntal and Tatumbu Islands	330.5509	203.091	3.306	671.317
Osi and Burung Islands	227.8001	457.038	2.278	1041.132
Marsegu Island	223.6687	58.173	2.237	130.115
Barnusang Peninsula	198.0147	94.164	1.980	186.458
Loupepsy Village	208.7629	4.554	2.088	9.506
Tamanjaya Village	242.0653	6.597	2.421	15.969
Average	238.4771		2.385	
Total		823.615		2054.4967

CS: Carbon stored

Table 6 The average of biomass dry weight in seagrass

Sites	g DW m <sup>-2</sup>	g DW ha <sup>-1</sup>
Buntal Island	620.24	6202370.64
Tatumbu Island	760.76	7607579.66
Osi Island	509.06	5090595.12
Burung Island	431.06	4310561.01
Marsegu Island	455.90	4559016.80
Barnusang Peninsula	415.70	4156988.71
Loupepsy Village	431.45	4314505.31
Tamanjaya Village	504.31	5043092.48
Total	4128.47	41284709.73

Table 7 The average of carbon stored in seagrass community at the different sites in Indonesia waters

Site	Width of seagrass (ha)	Number of species	Average of covers (%)	Average of carbon stored (g C m <sup>-2</sup> )	Source
Pari Island, Seribu Islands	32.706	6	23.01	200.5	Rahmawati 2011
Belitung Island	1,699.000	5	13.89	54.0	Rahmawati 2012
Kotania Bay	823.615	7	50.59	238.5	

balance of carbon contained has been widespread depending on dominant species, interspecific competition, climatic factors (temperature and light), nutrient availability, herbivore pressure, and anthropogenic disturbance (Gattuso *et al.* 1998). Therefore, seagrass species composition as community compiler can influence carbon stored value of a seagrass community. Carbon accumulation rates for established seagrass meadows vary depending on the seagrass species, sediment characteristics, and depth range of the seagrass habitats (Greiner *et al.* 2013). The high capacity of seagrass meadows to store C has been explained to result from the high primary production of seagrass meadows and their capacity to filter out particles from the

water column and store them in soils, combined with low decomposition rates in the oxygen-poor seagrass soils and the lack of fires underwater (Hendriks *et al.* 2007).

According to Nellemann *et al.* (2009), the amount of CO<sub>2</sub> stored can be calculated by converting carbon stored value using the formula of C = 44/12 CO<sub>2</sub>. The amount of CO<sub>2</sub> stored, therefore, in Kotania Bay is as many as 559.8 Mg CO<sub>2</sub>. The capability to save and to absorb CO<sub>2</sub> on seagrass community shows seagrass community can play important roles in mitigating climate change in forthcoming years. Russell *et al.* (2013) stated seagrass is a vegetation that can be used to reduce the CO<sub>2</sub> leakage because it can be saveable carbon for years. *P. oceanic*, for instance, can store carbon as

much as 12% in the sea area. It, however, immediately will release CO<sub>2</sub> to waters if seagrass has died. Therefore, carbon storage service provided by seagrass can be sustainable through maintaining seagrass coverage and seagrass health (Kennedy & Bjork 2009). These carbon accumulation rates will be useful for planners and policy makers in assessing the potential of restored seagrass ecosystems to sequester blue carbon (Greiner *et al.* 2013).

### Conclusion

The rizhome, a part of seagrass, has the highest percentage of carbon stored which is as many as 54.45% in *C. rotundata*, while the lowest is in leaf sheath owned by *H. ovalis* (32.22%). Seven different species of seagrass found in the waters of Kotania Bay has the average of carbon stored as many as 2.385 Mg C ha<sup>-1</sup>, as well as the total carbon contained as many as 2054.4967 Mg C. Osi and Burung Islands have the highest total of carbon stored. With relatively small in size and specific seagrass species, Kotania Bay had the capacity to store substantial amount of carbon. For that reason, the management of seagrass at Kotania Bay should compulsory be improved to maintain its capacity to store carbon.

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