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SEAGRASS ECOSYSTEM CARBON STOCK IN THE SMALL ISLANDS: CASE STUDY IN SPERMONDE ISLAND, SOUTH SULAWESI, INDONESIA

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ABSTRACT

Small islands are particularly rich with coral reefs, seagrass ecosystems and coastal plants. Seagrass meadow is one of the blue carbon ecosystems, which is able to store CO_2 in the form of organic carbon inside its biomass and sediment. The objectives of this study were to determine the carbon stock of seagrass in Spermonde Island and to review its essential role in climate change mitigation strategies. The purposive sampling method was undertaken to ensure a spatially representative research site and analyzed the amount of carbon contained in biomass and sediment. The results show that there were eight species of seagrass across the islands with the highest carbon stock derived from Enhalus acoroides species at Kapoposang island constituting 1.64 MgCha^{-1}. The average carbon stock of the total biomass (above-and below ground) in the largest island (Bauluang island) was 1.89 ± 0.92 MgC ha^{-1} with 77% of carbon was derived from below ground component. The average of total sediment carbon stock in this study was 531.87 ± 74.08 MgC ha^{-1}. The role of seagrass ecosystem in Spermonde islands in climate change mitigation was equivalent to the sequesteration of CO_2 for 1955.26 MgCO$_{2e}$ ha^{-1}.

Keywords: Seagrass, Spermonde Islands, blue carbon, mitigation.

INTRODUCTION

Seagrass is one of the angiosperm plants that has the ability to adapt with seawater, forming a mono or mixture species which is called seagrass beds/ meadows and becomes one of the key ecosystems in the coastal area (Duarte *et al*., 2013; Duarte *et al*., 2010; Duarte, 2002; Duarte, 1999). Seagrass meadow is considered to be one of the coastal blue carbon ecosystems (such as saltmarsh, mangrove, and seagrass) that has ecological functions as a carbon storage both in its biomass and sediments (Chmura *et al*., 2003; Fourqurean *et al*., 2012b; Brown *et al*., 2016).

Seagrass is divided into two parts, including above and below ground which performs as carbon pool in the ocean. The largest potential function of seagrass as blue carbon is found in the below ground parts. The ratios of the above and below ground biomass of Zostera capensis and Halodule wrightii species are 1:11 and 1:1.13, respectively, where 16% of the organic carbon is stored in the sediments. The burial rate of Posidonia oceanica is 58 gCm^{-2}year^{-1} (Mateo *et al*., 1997; de Boer, 2007). sediment carbon of seagrass is divided into two types, including allotochonous and autochonous carbon (Howard *et al*, 2014). Allotochonous carbon is defined as carbon originating from other ecosystems and deposited on seagrass beds, while autochonous carbon is specified as carbon that is produced and deposited from seagrass biomass mainly from derived rhizomes and leaf decomposition (Howard *et al*., 2014). Carbon stock potential of seagrasses in Indonesia amounted to 119.5 MgCha^{-1} (Alongi *et al*., 2016). Seagrass meadow can be found in the coastal spread out in all over the world, and generally exists in the small islands (Short *et al*., 2007; Duarte, 2000; De Iongh *et al*., 2007). Small island is an island which has an area of less than or

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equal to 10,000 km^2, with a population of less than or equal to 200,000 (UNCLOS, 1982; KMKP, 2000a; KMKP, 2000), while based on in the revision of Law No. 27 of 2007 jo of Law No 1 of 2014 small island is an island with an area of less than or equal to 2,000 km^2 and including the unity of the surrounding ecosystems (UU No 27, 2007; UU No 1, 2014). Coastal ecosystems surrounding the small islands are generally well developed by coral reef and seagrass ecosystems.

Spermonde islands are located in the high biodiversity Coral Triangle Initiative (CTI) region which has a strong linkage with the Indonesian Through Flow (ITF) as it delivers about 75% of the Indian Ocean water mass to the Pacific Ocean (Gordon *et al*., 2008). Research about seagrass in Spermonde Islands has been conducted mainly in the Barranglompo Island (research station of Hasanuddin University, Makassar). The ranges of carbon stocks in seagrass (*Enhalus acoroides*) at Barranglompo and Bonebatang island were 0.49 to 1.05 MgCha^{-1} and 0.08 to 0.34 MgCha^{-1} respectively (Amri, 2012). These values are higher than that in Tanjung Lesung (0.35 MgCha-1) (Rustam *et al*., 2014) and lower than that in Pari Island (2.66 MgCha^{-1}) (Rustam, 2014).

Many activities on both Sulawesi and Spermonde islands are leading to a degradation of seagrass ecosystems. This study aims to calculate carbon stock and to update seagrass status in four zones of Spermonde islands and its relation to climate change mitigation.

METHODOLOGY

The research location is administratively located in Spermonde Islands and is geographically positioned between 119° 6’50”- 119° 32’31” E and 4° 52’33” - 5° 22’41” LU (Figure 1). The research was focused on four seperated islands including Bauluang and Baranglompo Island in the inner middle zone; Saroppokeke island in the outer middle zone, and Kapoposang Island in the outer zone. Overall, there are 11 sampling points across the islands including two sampling points at Bauluang Island, and three sampling points each in Barranglompo, Saropokeke and Kapoposang Islands.

The method used in this research was using survey method, in which the data collection in the field was focused on specific the characteristic of the research objects, following guideline described by Effendi. (2003). The purposive sampling method was used to obtain a spatially representative distribution as well as verification of the seagrass existence. Percentage of canopy cover in each 50 x 50 cm² quadrant was taken by visual estimation based on Seagrass Watch visual standards guide (Mc Kenzie *et*

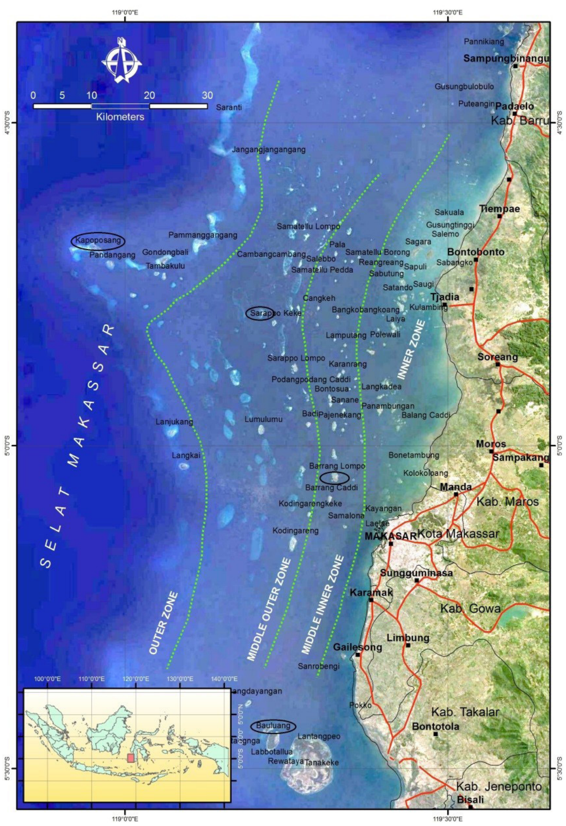


Figure 1. Location of the study Spermonde Islands (Source map modification from Candra, 2013).

al., 2003). Numbers of shoots were calculated at each quadrant for *E. acoroides*, while for other species calculations were done using specimen retrieved in a 25x25 cm^2 frame. The specimen was put in a plastic label and the number of all individual specimens within the squares were counted in the base camp. Each species was also collected as a speciment that was further identified and analyzed in the laboratory.

The above and below ground seagrass biomass were weighed after clearing the epiphytes and substrates that were still attached to the leaves or roots. The dry weight of biomass was obtained in the laboratory by heating up the sample at 60°C until a stable weight for approximately three days. Samples were grounded into powder and analyzed by elemental Carbon Hydrogen Nitrogen Sulfur (CHNS) analyzer to obtain carbon contents.

Sediment samples were collected by a stainless steel auger sediment core. The depths of the sediments were less thn 50 cm. At each core, a 5-cm-interval sediment from the base to the top of the core was sampled and stored in the sample container and labeled. Sediment samples from each core were subsequently measured for bulk density, total carbon, and total nitrogen content.

The seagrass percent cover analysis was carried out using the method of Saito and Atobe (English *et al*., 1994), while the density of seagrass species was calculated with reference according to Fachrul (2007). Biomass and sediment carbon stocks were analyzed based on the formula from Fourqurean *et al*. (2014). Sediment bulk density was obtained by calculation using the formula from Kauffman & Donato. (2012) and the carbon contents were converted into the amount of CO2 that were used or stored, by multiplying the value with the conversion factor of 3.67 (Sifleet *et al*., 2011; Howard *et al*., 2014).

RESULTS AND DISCUSSION

The results of this study found that there were eight species of seagrasses in the four Islands of the Spermonde Waters that derived from two families (*Hydrocharitaceae* and *Cymodoceaceae*). Four species from the family *Hydrocharitaceae* were *Enhalus acoroides*, *Thalassia hemprichii*, *Halophila decipiens* and *Halophila ovalis*. While the other four species from the family *Cymodoceaceae* were *Cymodocea rotundata*, *Halodule uninervis*, *Halodule pinifolia* and *Syringodium isoetifolium*.

The total percentage of seagrass cover in the Spermonde Waters was ranging between 0-90 percent, where at all sampling points, the species are generally mixed. In Kapoposang Island and Saropokeke Island for instance, seagrass meadows can be a mixture of several species, such as *Cymodocea rotundata*, *Thalassia hemprichii*, *Thalassia hemprichii* and *Enhalus acoroides* (Table 1).

Figure 2 shows the density of seagrass species in the studied sites based on shoot/individual seagrass expansion (individuals/m^2). Seagrass density was measured by using a frame with an area of 0.0625 m^2. There are three species of seagrasses which have high density, namely *S. isoetifolium* (1424 ind/m^2), *T. hemprichii* (592 ind/m^2) and *C. serrulata* (320 ind/m^2), while species *E. acoroides* although was found at all stations, has a lower density, ranged between 8-192 ind/m^2, with the highest density was observed in Kapoposang Island. This is because *E. acoroides* usually has a large size, so that the density of this species in the same area will be different from the other seagrass species (Figure 2).

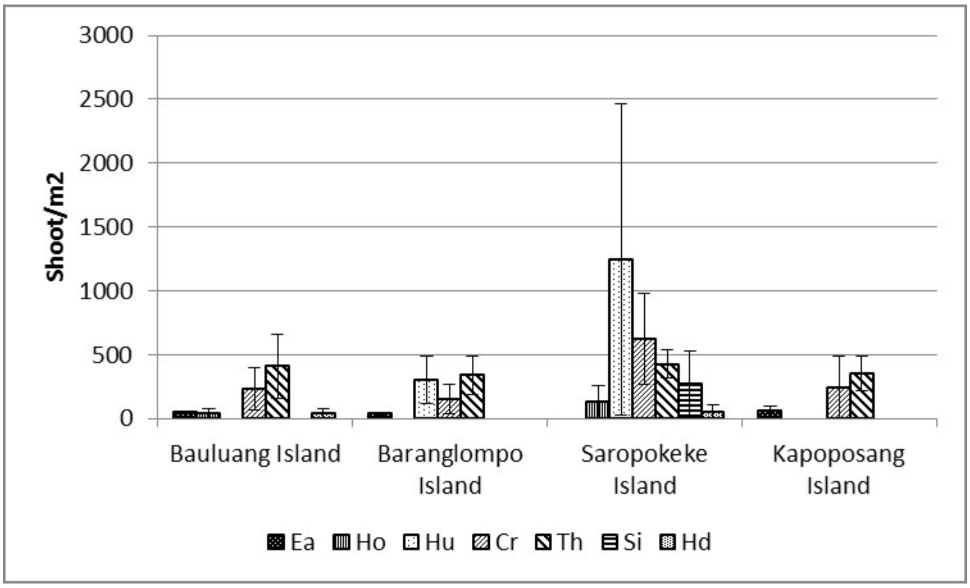
Biomass Carbon Stock

Seagrass biomass was measured for its wet weight and dry weight, and also its carbon weight. For

Table 1. Percentage of total seagrass cover, substrate and type of seagrass found in Spermonde Islands

Location	Range of Percent Cover (%)	Average ± Standard Error	Types of seagrass
Bauluang Island	6 -70	41.75±2.25	Ea, Ho, Cr, Hu dan Th
Baranglompo Island	10 - 80	48.06±6.74	Ea, Hu, Cr, Th, Hp dan Si
Saropokeke Islans	0 - 90	50.56±4.82	Hu, Hd, Cr, Si, Ho dan Th
Kapoposang Island	0 - 90	44.06±4.85	Ea, Ho, Cr dan Th

Description: Ea = *Enhalus acoroides* Th = *Thalassia hemprichii*
Hu = *Haludule uninervis* Cr = *Cymodocea rotundata*
Hp = *Halodule pinifolia* Hd = *Halophila decipiens*
Si = *Syringodium isoetifolium* Ho = *H. ovalis*



Description: Ea = Enhalus acoroides; Th = Thalassia hemprichii; Hu = Haludule uninervis; Cr = Cymodocea rotundata; Hp = Halodule pinifolia; Hd = Halophila decipiens; Si = Syringodium isoetifolium; Ho = H. ovalis

Figure 2. The density of seagrass in the Spermonde islands.

all species particulary in the above ground biomass usually has higher wet weight than below ground part. However, for the dry weight/carbon weight (biomass carbon) the above ground biomass is lower than compared to below ground biomass (Figure 3).

Biomass carbon is generally high in the belowground, with the highest value was observed in the Bauluang Island (1.89 MgC ha^{-1}), followed by Barranglompo Island (1.55 MgC ha^{-1}), Kapoposang Island (1.31 MgC ha^{-1}), and the lowest was observed in the Saropokeke Island (0.77 MgC ha^{-1}) (Figure 3). The higher amount of biomass carbon stock measured in the Bauluang Island was likely because the type of seagrass that were found in this area are mostly the large-sized seagrass species such as *E. acoroides* and *T. hemprichii*. In the Saropokeke Island, there are many types of seagrasses found but generally small in size, and usually are pioneer seagrass species. Large-sized seagrass such as *E. acoroides* was not found in seagrass meadows in this area.

Based on the species, the highest amount of biomass carbon was measured in *E. acoroides* and *T. hemprichii* which have a large size with a long life span (Figure 4). However, the small size seagrasses which have a lower biomass carbon may also contain high carbon stocks, depends on the density and seagrass

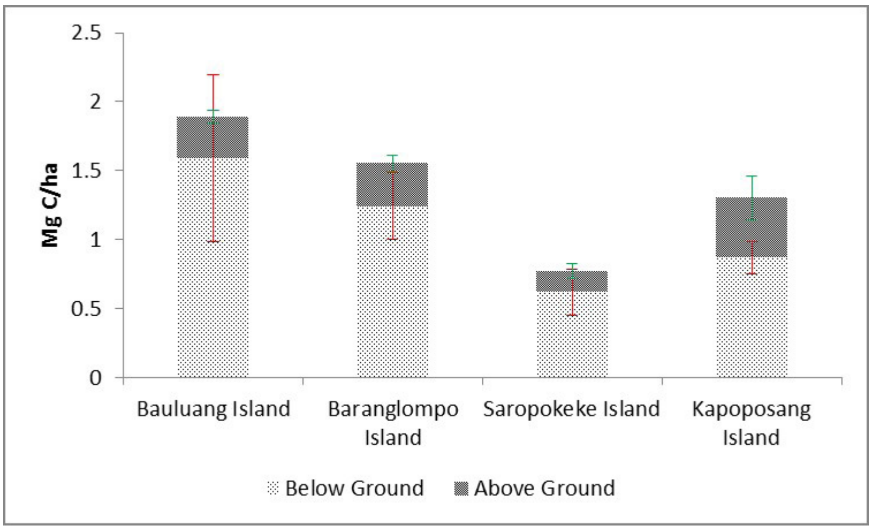


Figure 3. Stock biomass seagrass Spermonde Islands.

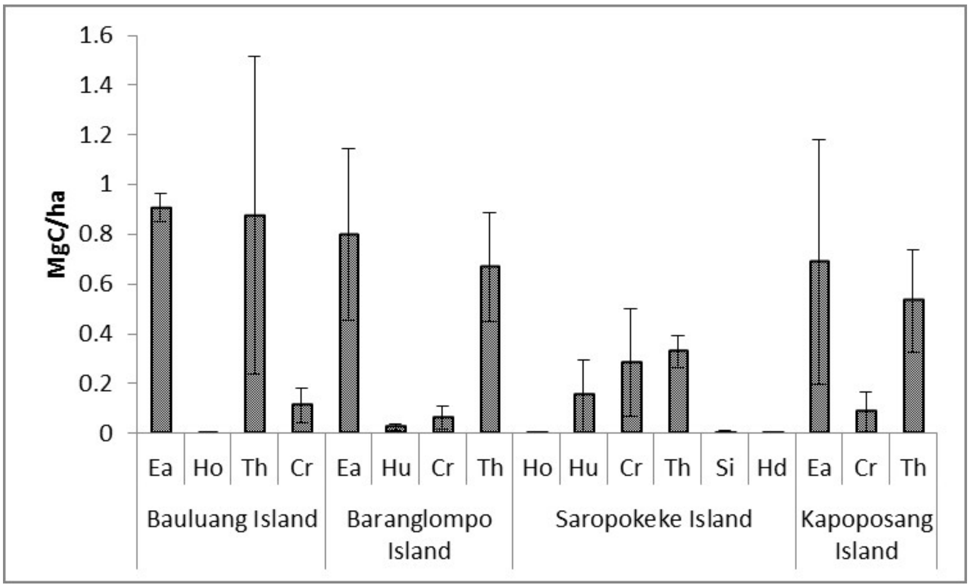


Figure 4. Seagrass biomass carbon stocks per type at the study site.

forms. Seagrasses that form a vast meadow with an interconnected complex root systems (*rhizomes* and *roots*) are able to store carbon, both allochthonous carbon that is derived from adjacent areas and trapped by seagrass roots, and autochthonous carbon that is derived from seagrass biomass either fresh, litter and decomposed biomass. Supriadi (2012) reported that the production of seagrass litter the species *E. acoroides* from the Barranglompo Island are 100% during the wet season and 124.9% during the transition season between east and the west season which was deived from seagrass leaves itself.

Wet weight is generally greater in the above ground of seagrass biomass than in the below ground, while dry weight is usually greater in the below than in the above grounds. This is related to the higher water content in the above ground of seagrass biomass than in the below ground (the average water content of seagrass biomass in the above ground is accounted for 77% of the total weight of seagrass, and 23% in the the below ground). The below ground of seagrass biomass, particularly the rhizomes, have a denser structure than the above ground (leaves). The carbon content is also found greater in the below ground biomass that is ranging between 25.03 to 37.03% with an average of 34.29%, compared to the above ground which is ranging between 30.34 to 35.11% with an average of 32.86%.

The amount of biomass carbon stocks of seagrasses in the Bauluang Island and in the Barranglompo Island observed in this study (1.89 MgC ha^{-1} and 1.55 MgC ha^{-1}, respectively) are greater than those in Tanjung Lesung water, Banten and Kema coastal water (Rustam *et al.*, 2014; Rustam *et al.*, 2016). Carbon stock in Barranglompo Island tends to increase, in which the amount is higher compared to the previous research, where the highest production was contributed from species *E. acoroides*, *T. hemprichii* and *C. rotundata* (Amri *et al.*, 2011; Supriadi *et al.*, 2012). Carbon stocks in Kapoposang Island is greater than that in Kema (Rustam *et al.*, 2016). The amount of biomass is generally greater at the below ground. This is reinforced by the large allocation of carbon on the below ground (77% of total carbon biomass).

Sediment Carbon Stock

Sampling of seagrass sediment was done by using sediment core at the depth down to 50 cm. Carbon that is stored in seagrass sediment generally contains high carbonate, which can be derived from coral rubble, shell and others. The value of sediment carbon stocks from the studied sites between 378,17 - 685.89 MgC ha^{-1} (Figure 5). Sediment carbon stock in the Bauluang Island is lower than that of other islands. This can be attributed to a lower seagrass cover and density in the Bualang Island compared to other islands (Table 1 and Figure 2).

Based on the calculation at each sampling point, carbon stock in the Kapoposang island tends to increase with depth (Figure 5). The Kapoposang Island is located in the outer zone of the four existing zones, where seagrass meadows are usually formed by a large seagrass species such as *T. hemprichii* and *E. acoroides*. In the Barranglompo Island, the highest sediment carbon stock was measured at the intermediate depths of 15-30 cm. Large amount of

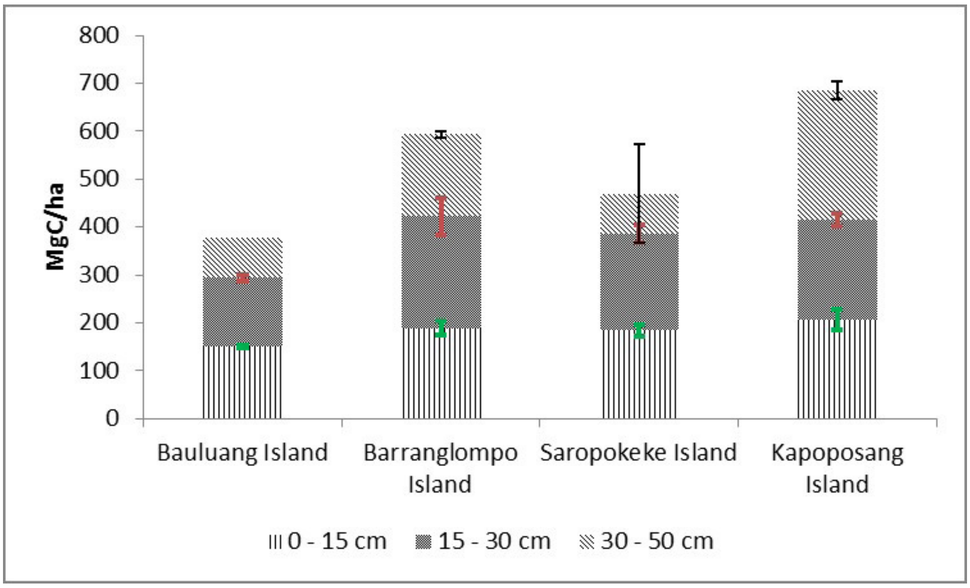


Figure 5. Stock carbon sediments in seagrass Spermonde Islands.

sediment carbon stock observed in the Kapoposang Island was likely derived from the accumulation of carbonate and seagrass litter (autochthonous).

For more details, figure 6 displays sediment carbon stocks profiles in 5 cm depth intervals. Sediment sample was devided by 5 cm interval prior to analyses to see the vertical profile of carbon stocks. The amount of carbon stocks tend to increase with depth, except in the Bauluang Island, where the carbon stock is higher in the surface than in lower layers. The increase of sediment carbon stocks with depth was clearly visible in the Barranglompo Island with R2 value of 0.701 (70%).

Carbon stocks of seagrass ecosystems and climate change

Among the three carbon pools of seagrass ecosystems in the studied sites, the highest carbon stock was measured in the sediment. The highest mean of total carbon stock was measured in the Kapoposang Island for 687.19 MgC ha^{-1}, in which 99.81 % of the total carbon stock is stored in the sediment.

Carbon stock in seagrass ecosystems derives from the sequestration of CO_2 which is used for plant growth thus is stored in plant biomass and sediment. This is one of the roles of seagrass for climate change mitigation. The total amount of carbon stock in the Bauluang Island was 380.06 MgC ha^{-1}, which is

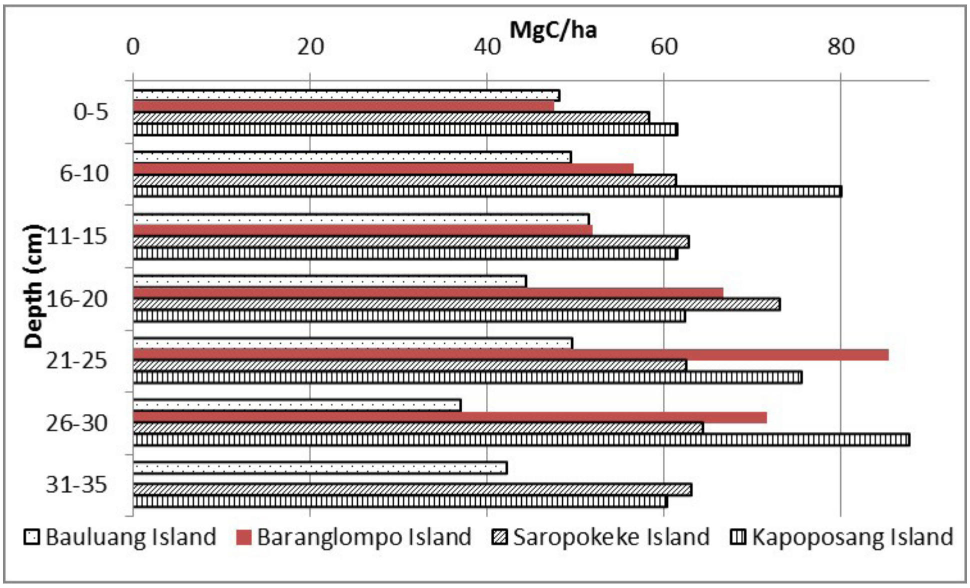


Figure 6. The profile of carbon stocks sediment to a depth of 35 cm for seagrass ecosystem in Spermonde island.

equivalent to the absorption of 1393.57 $MgCO_2$ eq ha^{-1}, carbon stocks in the Barranglompo Island amounted for 595.37 MgC ha^{-1} is equivalent to 2,183.03 $MgCO_2$ $eqha^{-1}$, carbon stocks in the Saropokeke Island amounted for 470.38 MgC ha^{-1} is equivalent to 1,724.74 $MgCO_2$ $eqha^{-1}$, and the highest carbon stock in the Kapoposang Island amounted for 687.19 MgC ha^{-1} is equivalent to the absorption of 2,519.71 $MgCO_2$ $eqha^{-1}$. These values are higher than those measured in Tanjung Lesung, Banten and Kema coastal water, North Sulawesi (Rustam *et al*., 2014; Rustam *et al*., 2016).

Seagrass function as a natural carbon sink is associated with the utilization of dissolved CO_2 in the water for photosynthesis, which cause reduction of CO_2 availability in the water and cause the flow of CO_2 from the atmosphere into the water. This function will work properly when seagrass ecosystems are in a healthy condition by forming a vast seagrass bed. Due to their smaller size compared to mangrove plants, seagrasses store a lower aboveground organic carbon. However, seagrasses also function as a sediment trap, which deposit not only autochthonous carbon, but also allochthonous carbon that originates from other ecosystems such as estuaries and mangroves in a long period of time.

Apart from their role as a natural blue carbon sink, which is important in climate change mitigation by reducing and storing CO_2, seagrasses also have an important role in preventing coastal vulnerability to the rising of sea level, and an ability to lower sea surface temperature. (Greiner *et al*., 2013; Marbà *et al*., 2015; Duarte *et al*., 2013; Fourqurean *et al*., 2012; McLeod *et al*., 2011; Duarte *et al*., 2013b). The role of blue carbon ecosystems in reducing CO_2 in the atmosphere will give an impact on the reduction of the earth's surface temperature. All together, these roles are part of the coastal ecosystem services from seagrass, in addition to fisheries.

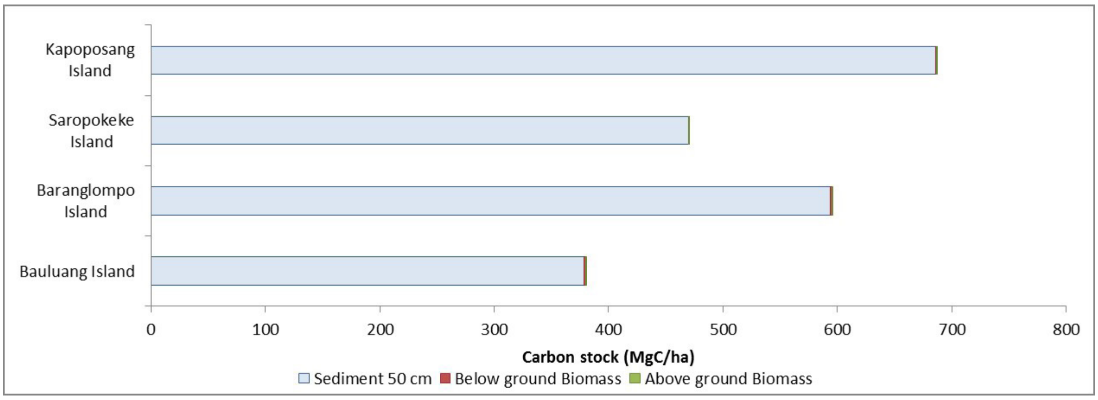


Figure 7. Stock carbon seagrass in Spermonde Island.

Figure 8. The seagrass meadow of mix *T hemprichii* and *C rotundata* in Saropokeke island.

CONCLUSION

The highest percentage of seagrass cover was measured in the Saropokeke Island, where the meadow was formed by a mixture of six different seagrass species. However, the highest biomass carbon stock was measured in the Bauluang Island, where the meadow was dominated by a large size species such as *E. acoroides* and *T. hemprichii*. The highest total carbon stock was measured in the Kapoposang Island, which is located far from the mainland. The low percentage cover suggests that there was a degradation of seagrass ecosystem in the Spermonde Islands, which may reduce the ability of seagrass ecosystem to sequester the anthropogenic carbon as one of the important services of seagrasses in climate change mitigation.

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