CARBON STOCK ASSESSMENT OF SEAGRASS ECOSYSTEM IN KEMA, NORTH SULAWESI REGARDING THE CLIMATE CHANGE MITIGATION

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Abstract

Seagrass is one of the blue carbon ecosystems capable of utilizing CO_2 in organic carbon and mostly stored in the biomass and sediments. This research was carried out on April 27 - May 3, 2015, in Kema waters, North Minahasa Regency, North Sulawesi Province. This research aimed to assess the carbon stock of seagrass beds in Kema District and its correlation to the climate change mitigation in the region. Purposive sampling methods which combined with carbon analysis in the biomass and sediments was used to represent all study sites and observation stations. The result showed that nine species of seagrass were found in the study sites, where Enhalus acoroides has an enormous value of carbon stock around 1.88 Mg C/ha. The average value of carbon stock in biomass about 1.05 ± 0.55 Mg C/ha, while the highest percentage of carbon stock lies in the below-ground approximately 57% of total carbon biomass. The average value of carbon stock in the seagrass sediment was 423.59± 273.78 Mg C/ha to one-meter depth. The seagrass ecosystem's role in Kema coastal region in both the biomass and sediments was 424.64 Mg C/ha, equivalent to CO_2 utilization of 1557.01 Mg CO_2e /ha, which significant for climate change mitigation action.

Keywords: Carbon Stock, Climate Change, Kema Waters, Seagrass Ecosystem

INTRODUCTION

Seagrass has several ecosystem services for the adjacent environment not only as a producer, and biota habitat (spawning grounds, nursery grounds, and foraging areas) but also as a sediment catcher, and a nutrient recycler. According to Phillips and Menez [1], the seagrass ecosystem known as a productive marine ecosystems in shallow waters which has functions as following:
1). Stabilizing and trapping sediments carried by currents and waves pressure (sediment trap); 2). Reducing currents and waves through it leaves, which also increasing sedimentation; 3). Providing protection for animals and adults near the seagrass beds; 4). Helpful for the epiphytes organism; 5) High in productivity and growth; 6). Fixing CO_2 in the water column, which partly enters the food chain recycling system, while others stored in biomass and sediment.

The ability of seagrass to do the CO_2 fixation in the water body, which is used for photosynthesis process will reduce CO_2 in the water column and be stored in biomass and sediment. The amount of seagrass ability to store carbon in biomass varies, where large seagrass species has the ability to store CO_2 in biomass longer than the small one caused by its leaf turnover rate, which associated with the amount of carbon stored (carbon sink) in the epiphytes attached to the seagrass leaves. Seagrass sediments stored the biggest portion of carbon pool, which divided into two types namely allochthonous carbon that comes from other ecosystem (based on seagrass function as a sediment trap) and autochthonous carbon which deposited in the seagrass ecosystem by natural decomposition [2].

Several research activities regarding carbon stock in seagrass biomass and sediment showed a contrast carbon content based on its location, such as in Miskam Bay, Tanjung Lesung with 1.32 Mg C/ha equivalent to 4.85 Mg CO_2e/ha in biomass, while in the sediment about 475.21 Mg C/ha equivalent to 1,742.43 Mg CO_2e/ha [3] compared to Spermonde Island, where the carbon stored in seagrass biomass was 0.57 Mg C/ha equivalent to 2.07 Mg CO_2e/ha and in sediment was 186.15 Mg C/ha equivalent to 682.54 Mg CO_2e/ha [4].

The coastal region defines a meeting point between land and sea, where land encompassed terrestrial areas towards land, both wet, submerged, and dry region, which are still influenced by the sea characteristics such as tides, sea wind, and salwater seepage. In contrast, the sea covers parts of the sea that are still affected by the natural processes on lands such as sedimentation and freshwater flows and those caused by human activities on land such as deforestation and pollution [5].

Kema waters is an area located in the northern part of Sulawesi Island, facing Tomini Bay, which known as the second-largest bay's in Indonesia. Kema waters have five well-known tourism destinations such as Batu Nona and Firdaus Beach situated in Kema Satu Sub-district, also Kema Tiga, Lilang and Makalisung [6]. Kema coastal waters have a huge and dense seagrass beds cover [7], which also potential in storing carbon, both in the biomass and sediment, and potential due to its role in climate change mitigation as the focus of this study. This study aimed to obtain and examine the existing conditions of the seagrass presence in Kema waters in correlation to the climate change mitigation action mandated by the government of Republic of Indonesia.

METHODOLOGY

The study site located in Kema District, administratively under the authority of North Minahasa Regency and geographically lies between 124^0 40' 24"- 125^0 15' 53" E and 1^0 08' 19"- 0^0 50' 46" N. Seagrass ecosystem in the study site stretched along 13 km from up north to down south, where there were eight site named as L1–L8 as shown in figure 1.

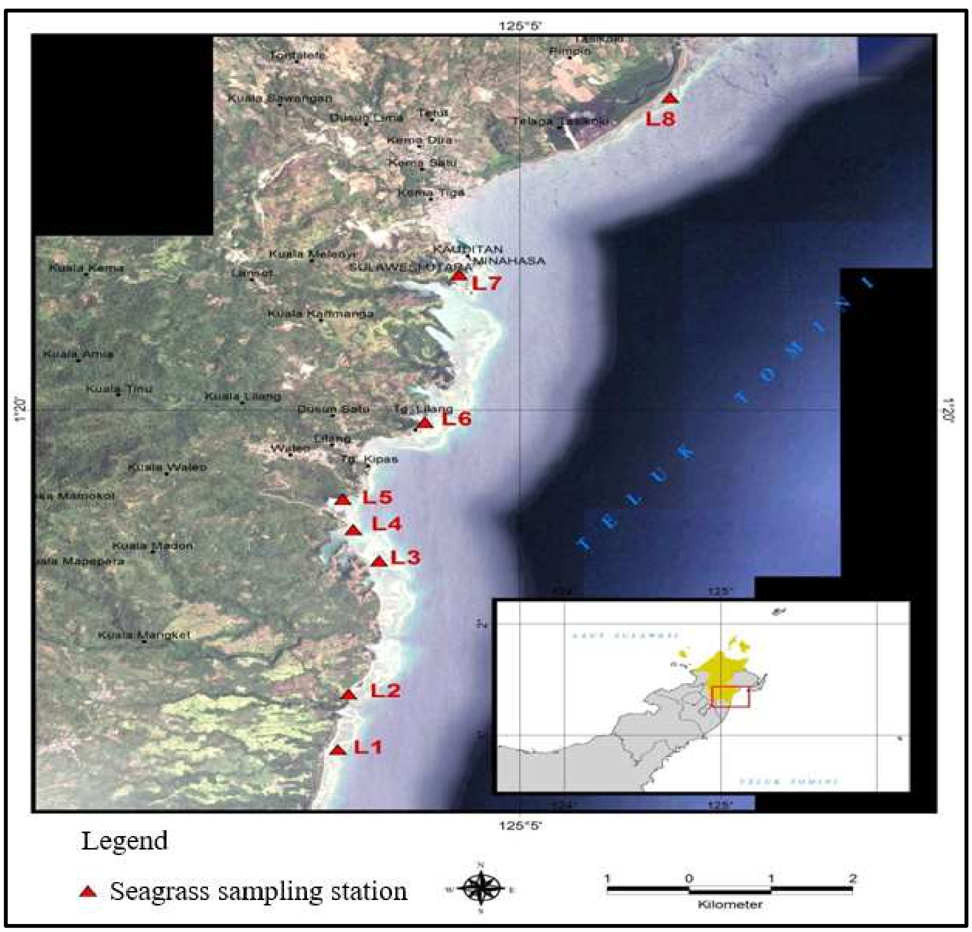


Figure 1. Study site, Kema Waters, North Minahasa, North Sulawesi (April 2015)

The research method was carried out by purposive sampling, which expected to represent the coastal region based on seagrass presence, whether by boat or walk. SeagrassWatch method was used to collect seagrass information using line-transect and modified following the seagrass bed [8]. The transect line drawned perpendicular to the coastline, and then a square measuring 50 x 50 cm² placed systematically with a distance between squares of 10 meters, depending on the length of the seagrass bed. The distance between transects ranging from 50 - 100 meters depending on the width of the seagrass bed.

Parameters taken from each station were the percentage of seagrass canopy cover in 50 x 50 cm² squared frame visually based on the SeagrassWatch method [8], encompassing the total percentage coverage and from each species. The number of seagrass shoots for large seagrass species such as *Enhalus acoroides* were counted inside the 50 X 50 cm2 frame, while for other species and specimens were collected in a smaller frame 25 x 25 cm2. The specimens were placed in labeled plastics for further treatment. Each type of seagrass found in the site was also taken as a specimen for re-identification.

The obtained seagrass biomass was cleaned from epiphytes and the attached substrate, separating the upper part (above ground) and the lower part (below ground) of seagrass, followed by wet weighing and storage. The dry weight was obtained in the laboratory by putting the biomass sample into the oven at 60ºC for about three days until the sample dry and the weight stable. Furthermore, the sample refined and analyzed using Carbon Hydrogen Nitrogen Sulfur Analyzer (CHNS analyzer) to get the carbon content. The same treatment applied for sediment sample, which divided the samples per layer depth from 0-30 cm, 30-50 cm and 50-100 cm as shown in Figure 2.

Several types of seagrass analysis:

a. Coverage by species: To examine the species coverage C(Pi) by comparing the number of individuals of each species with the total sampling area using methods from English et al. [10].

$$C(Pi) = \frac{\Sigma(Mi \; x \; fi)}{\Sigma f} \tag{1}$$

C (Pi) = Coverage of the-i species (%)
Mi = Median class -i
f = Frequency (total sub-quadrat with the same median)

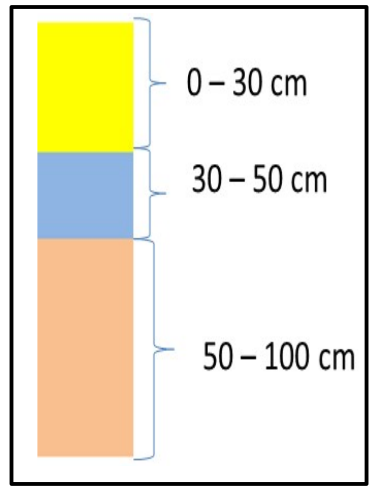


Figure 2. Sediment layer separation based on depth (modified from Forqurean et al. [9])

b. Density: Specific density (Ki), which is the total number of species in a measured of unit area. The species density of seagrass calculated based on methods from Fachrul [11], as follows:

$$Ki = \frac{Ni}{A} \tag{2}$$

Ki = density of the-i species
Ni = Total number of individuals of type i
A = Total sampling area (m^2)

c. Carbon Biomass: The carbon content on biomass calculated based on the formula from Fourqurean *et al.* [9]:

Carbon biomass = Dry weight (kg)/area (m^2)*C%
Conversion in Mg C/ha = Carbon biomass (kg C/m^2)*(Mg/1,000kg)*(10,000m^2/ha)

The total biomass carbon stock equals the summary of all species found in the sampling plot.

d. Sediment carbon stock: Carbon content assessment in sediment carried out right after bulk density analysis, which obtained using the formula from Kauffman and Donato [12]:

$$\text{Bulk density} = \frac{dry\ weig\quad sample\ (g)}{volume\ sample(cm^3)} \tag{3}$$

Furthermore, the calculation of carbon content in sediments carried out with the formula from Kauffman and Donato [12]:

Sediment carbon (Mg/ha) = bulk density (g/cm^3) x depth interval (cm) *% C

Sifleet et al., (2011) stated that the carbon content obtained under units of gC/cm^3 with a depth of up to the first 1 m (top soil) can be considered as the amount of CO_2 used or stored by calculating the following formula:

$$\frac{gC}{cm^3}\ x\ \frac{10^6 cm^3}{1m^3}\ x\ \frac{10^4 m^2}{1ha}\ x\ \frac{44gCO_2e}{12gC}\ x\ \frac{1Mg}{10^6 g} = \frac{MgCO_2e}{ha*m} \tag{4}$$

RESULTS AND DISCUSSION

The condition of Kema Waters, North Minahasa visually still in a good condition, where most of the activities in this coastal region well known by its beautiful beaches, and natural scenery waters, which became a tourist destination with its infrastructures and supporting facilities such as Batu Nona Resort, Firdaus Beach, Mangket Beach, Maleokoki Beach, Black Sand Beach and traditional capture fisheries activities by fishers.

Several research activities in Kema Coastal Region found nine seagrass species consisted of two families namely *Hydrocharitaceae* and *Cymodceaceae*. Four seagrass species of *Hydrocharitaceae* namely *Enhalus acoroides, Thalassia hemprichii, Halophila decipiens* and *Halophila ovalis*, while five other seagrass species encompassed *Cymodocea serrulata, Cymodocea rotundata, Halodule uninervis, Halodule pinifolia* and *Syringodium isoetifolium*.

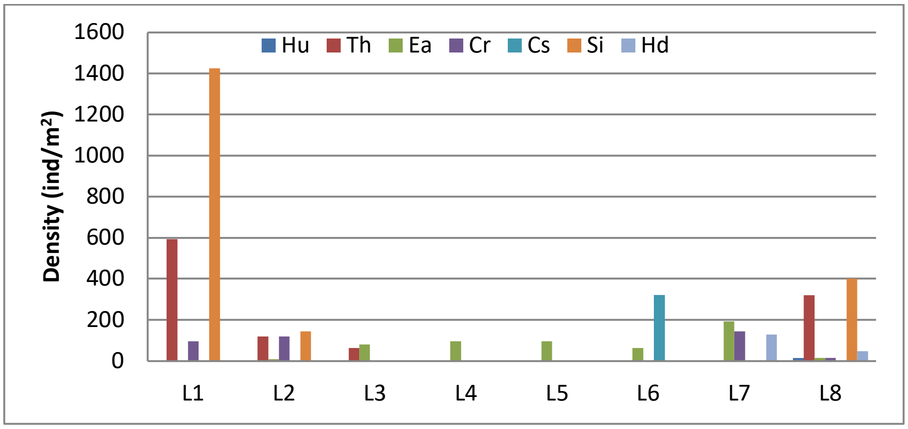
Total cover percentage of seagrass in Kema Coastal Region ranging from 10-100%, where two stations forming a monospecies seagrass bed, which generally located in the inner-side of small bay, and in front of mangrove ecosystem as shown in figure 3 and Table 1.

Tabel 1. Seagrass substrate, coverage, and species found in Kema Coastal Region (April 2015)

Station	Substrate	Total Coverage (%)	Average Coverage (%)	Seagrass types
L1	Sand	80 - 100	92,17	Ea, Cr, Si, and Th
L2	Rubble, sand	70 - 80	78,33	Ea, Cs, Cr, Si, Th, and Hp
L3	Sand	50 - 100	65,83	Ea, Cs, and Th
L4	Sandy mud	10 – 40	25,83	Ea
L5	Sandy mud	0 - 40	18,33	Ea
L6	Sand	0 - 50	30	Ea
L7	Sand	30 - 60	46,67	Ea, Hd, Cr, and Th
L8	Sand	65 - 80	72,5	Ea, Ho, Hd, Cs, Cr, Si, and Th

Ea = *Enhalus acoroides* Th = *Thalassia hemprichii*
Cs = *Cymodocea serrulata* Cr = *Cymodocea rotundata*
Hp = *Halodule pinifolia* Hd = *Halophila decipiens*
Si = *Syringodium isoetifolium* Ho = *H. Ovalis*

The density of seagrass species in the study site based on its shoots or individual in seagrass extent (individuals/m^2) were shown in figure 3. Seagrass density assessed using a frame with an area of 0.0625 m^2. There were three seagrass species with high density, namely *Syringidium isoetifolium* (1,424 individual/m^2), *Thalassia hemprichii* (592 individual/m^2) and *Cymodocea serrulata* (320 individual/m^2). Low density of *Enhalus* *acoroides* species was found in all observation stations, ranged from 8-192 individual/m^2, where the highest density situated at L7 station. This condition occurred due to the characteristics of *Enhalus acoroides* as a large seagrass species, which is different from other seagrass species as shown in figure 3.



Ea = *Enhalus acoroides*
Th = *Thalassia hemprichii*
Hd = *Halophila decipiens*
Cr = *Cymodocea rotundata*
Cs = *Cymodocea serrulata*
Si = *Syringodium isoetifolium*
Hu = *Halodule uninervis*

Figure 3. Seagrass density in Kema Coastal Region

Seagrass biomass measured in wet weight, dry weight, and then assessed in carbon weight. The highest wet weight measurement of seagrass biomass generally occurred in a large seagrass and the top part (above ground = Ag). The amount of biomass stock in terms of wet weight, dry weight, and carbon can be seen in the figures below.

The amount of biomass in the Kema coastal region shows that based on type and species, the most extensive carbon biomass content is in *Enhalus acoroides* and *Thalassia hemprichii* species, which considered as a large seagrass with a long life span. However, although small seagrasses have lower biomass than the large one, it depends on the density and the coverage of seagrass beds formed. If seagrass beds formed on a large scale, the complex and interrelated seagrass root systems (rhizomes and roots) will be able to store more carbon both allochthonous with the function of seagrass as a sediment trap and autochthonous where carbon derived from the seagrass itself, both fresh biomass, litter, and that is decomposed.

It can also be seen based on the wet weight that is generally large in the upper part of seagrass. The dry weight and the bottom part of seagrass's carbon weight are more significant than the upper part. The wet and dry weight is related to the water content in the upper part of the seagrass compared to the lower part, which is higher (the average water content of the upper seagrass is 61.65% of the total seagrass weight, while the bottom part is 38.35%). The bottom part of seagrass, especially rhizomes, has a denser structure than the upper part (leaves). Besides, the carbon content of the lower part has a more significant value than the upper part, which shown by the bellow part carbon biomass (ranging from 30.16 - 35.54% with an average of 33.33%) more significant than the upper part (ranging between 26.77 - 33.4% with an average of 30.05%).

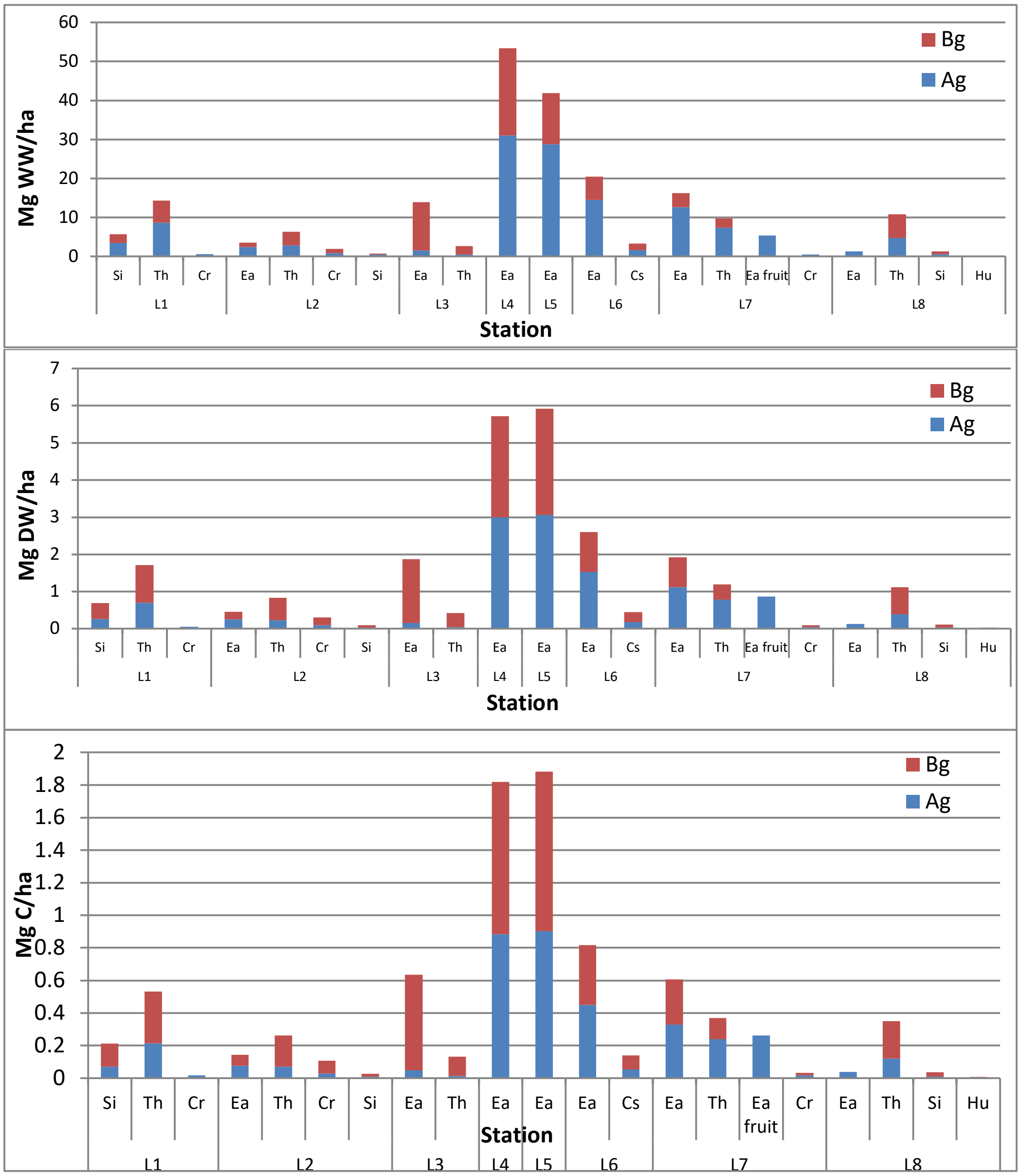


Figure 4. Seagrass biomass stock (Mg), wet weight (top), dry weight (middle) and carbon weight (bottom) in all stations in Kema coastal region

The biomass value per station shows the carbon content at the bottom of the seagrass for dry weight and carbon weight (Figure 5). The highest biomass stock is located at stations L4 and L5, where the *Enhalus acoroides* beds existed and considered a monospecies seagrass bed in a protected area, adjacent to the mangrove ecosystem and towards the mainland. Protected areas rich in nutrients are one of the main factors in forming monospecies seagrass beds with an extensive seagrass species existence. The seagrass size indicates the ability and capacity to store more carbon from its biomass, especially in wet conditions and the upper part, where the leaves may reach more than one meter long.

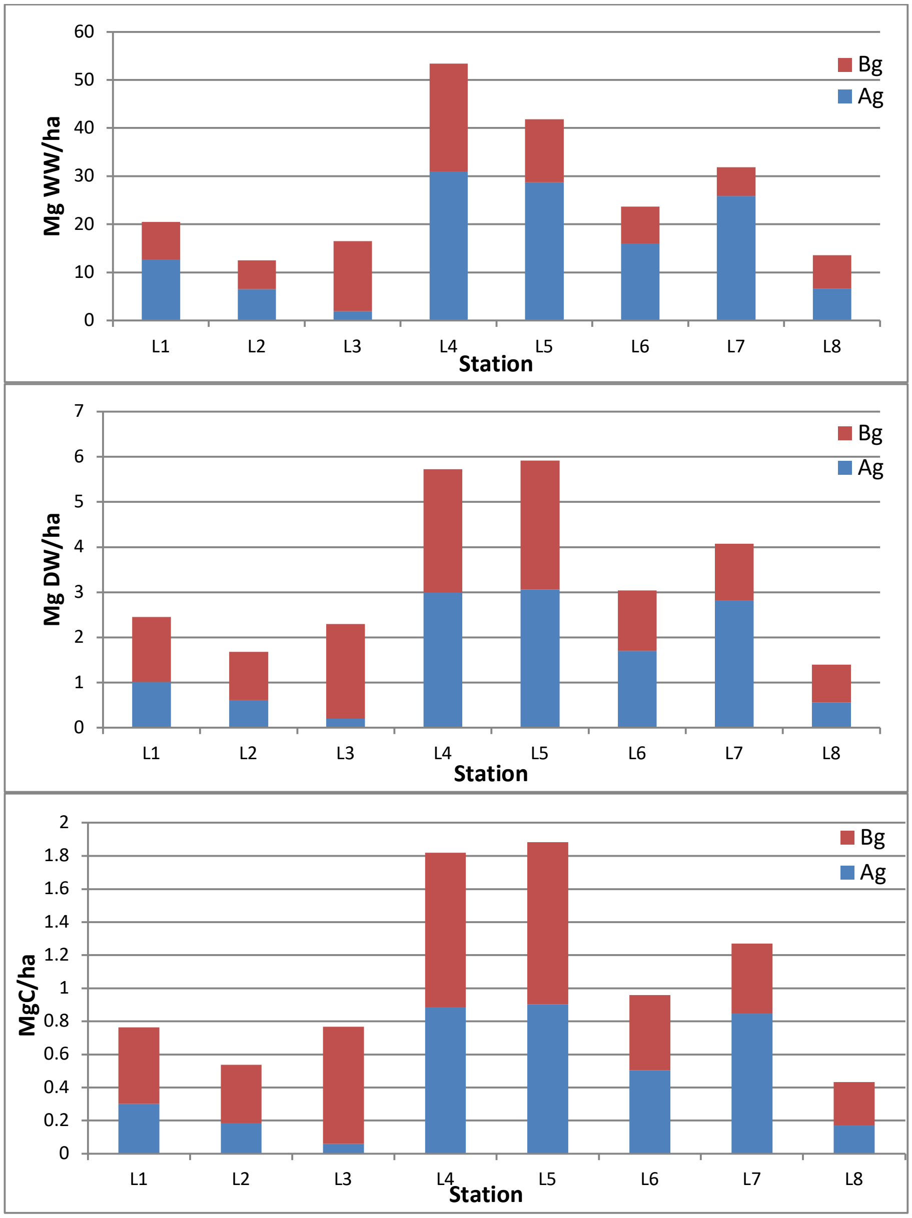


Figure 5. Seagrass biomass stock (Mg), wet weight (top), dry weight (middle) and carbon weight (bottom) in all stations in Kema coastal region

The value of carbon biomass in Kema waters is 1.05 ± 0.55 Mg C/ha, which is smaller than Tanjung Lesung, Banten [3], but greater than in Ratatotok Bay [14] and Lembeh Island [15]. The biomass carbon stock is generally more significant at the bottom (below ground) than the upper part, strengthened by the high carbon allocation in the below-ground area, about 57.42% of the total biomass carbon. Different results were found in stations L5 and L6, where the carbon biomass in the upper part is higher than the bellow ground due to the difficulties in rhizomes and roots collection hard substrate sand coral that bind the rhizomes and root tightly.

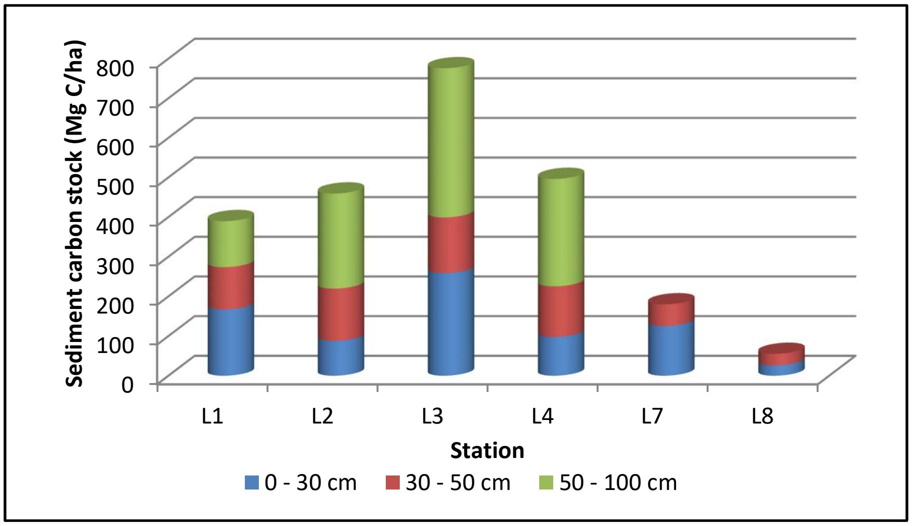


Figure 6. Sediment carbon content of seagrass ecosystem in Kema coastal region

Carbon sediment in the seagrass ecosystem tends to increase in-line with the depth such as at stations L2, L3, L4 and L8, except stations L1 and L7, higher at the surface layer. As in station L4, it's the location for healthy *Enhalus acoroides* and adjacent to the mangrove ecosystem, which estimated to contain high carbon in the sediment derived from the seagrass ecosystem (autochthonous), but also from the mangrove litter carried and trapped in the seagrass ecosystem.

The highest carbon sediment located at L3 station is about 775.67 Mg C/ha, measured to one-meter depth, where the lowest carbon sediment was 54.98 Mg C/ha located at L8 station wth only reach 50 cm depth. Based on the seagrass ecosystem's average ability in storing carbon in the sediment, approximately 423.59 Mg C/ha, which is equivalent to 1553.16 Mg CO_2e/ha. The mean total carbon stored in biomass and sediment is 424.64 Mg C/ha, equivalent to GHG utilization of 1557.01 Mg CO_2e/ha, which has a higher value than in Tanjung Lesung, Ratatotok bay, and Lembeh Island [3], [14], [15].

The highest carbon sediment was the combination between the dominant Enhalus acoroides and Thalassia hemprichii, due to seagrass's role as a sediment trap, especially Enhalus acoroides with large ribbon-like leaves in trapping sediment during the high-tide and a place for epiphytes which also contribute to carbon sequestration. In general, seagrass thrives in carbonate sediments that contain high carbon, so the carbon in the sediment will continue to increase, be stored and locked tightly with a complex root system.

Overall, seagrass's function as a dissolved CO_2 absorber in the water for photosynthesis will reduce the dissolved CO_2 content, which will cause the CO_2 flow from the atmosphere to the water due to the difference in partial pressure between both. This function will work well if the seagrass ecosystem is healthy by forming a large seagrass bed. The seagrass plants that are smaller than mangroves stores less organic carbon than the mangrove's ecosystem. However, another function as a sediment trap is to store autochthonous carbon and store allochthonous carbon from other ecosystems such as from the sea and mangroves or estuaries more and longer.

Besides, the benefits of the seagrass ecosystem as blue carbon in mitigating climate change and reducing and storing CO_2, which is one of the greenhouse gases (GHG), will also help avoid the vulnerability of sea-level rise, also can reduce sea surface temperature. Healthy and wide seagrass will prevent the rise in sea level and the increase in sea surface temperature. The role of blue carbon coastal ecosystems will reduce CO_2 in the atmosphere, reducing the temperature on the earth's surface, increasng the coastal resilience to the natural disaster such as rob flood, high waves, and tsunamis, which considered as coastal ecosystem services (seagrass ecosystem) apart from fisheries. Therefore, coastal ecosystem restoration, rehabilitation and conservation from stakeholders in Kema District urgently needed, not only to maintain the remaining natural resource, but also to increase and upgrade the natural resources both in quality and quantity [16]

CONCLUSION

Water quality in Kema coastal region considered as good and natural, based on its clarity and visual observation in the field, where there were nine seagrass types from two families found, with the presence of *Enhalus acoroides* in all stations. The Enhalus acoroides existence indicates the importance and significant role of seagrass ecosystem in adapting to the climate change as evidenced by the potential carbon stock of seagrass biomass around 1.05 ± 0.55 Mg C/ha, while potential carbon stock in seagrass sediment approximately 423.59 MgC/ha, both contribution equal to the greenhouse gasses utilization as 1,557.01 $MgCO_{2e}$/ha. The presence of seagrass ecosystems in a coastal region is essential in adapting the climate change, sea-level rise issue, and in reducing sea surface temperatures as part of global warming issue. Integrated management in the coastal region urgently needed for the community's welfare and supporting sustainable development goals, particularly in life below water.

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