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The potential of seagrass beds on the coast of Putri Menjangan as a carbon sequestration ecosystem on Bali Island

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Abstract. Seagrass beds are one of the coastal ecosystems with high productivity. Seagrass beds have also an ability to absorb carbon then store it as carbon stock. One of the potential seagrass beds located on the coast of Putri Menjangan, Regency of Buleleng, Province of Bali. This research aims to assess 1) the value of carbon sequestration, 2) the potential of carbon stock, and 3) carbon stocks value differences between below ground (Blg) and above ground (Abg). Collecting data includes measuring seagrass density, leaves productivity, dry biomass, and carbon content. There were 5 species of seagrasses, i.e., Thalassia hemprichii, Cymodocea rotundata, Halodule pinifolia, Halodule uninervis, Halophila ovalis, which exists in the area. Species of Cymodocea rotundata and Thalassia hemprichii dominate the seagrass beds on the field. Carbon sequestration by seagrass on the coast of Putri Menjangan was 1.45 gC/m2/day. Total carbon stocks (Abg+Blg) was 52.06 gC/m2 which the Blg carbon stocks was twice greater (67%) than the Abg carbon stocks (33%). These results suggested that the potential of seagrass beds in absorbing and storing carbon on the coast of Putri Menjangan was quite vast; therefore it is necessary to protect and preserve seagrass vegetation following the land use change and local development.

1. Introduction

Seagrass has important roles in the environment and also human life. One of the important roles of seagrass as a climate change mitigation [10]; [2]. Nowadays, climate change becomes a global problem, which is caused the global warming by increasing the greenhouse gases (GHG) that released into the atmosphere. One of the GHG that has a big deal to the global warming is CO_2. This problem has led the earth became hotter and more extreme weather happened [1].

CO_2 in the atmosphere will diffuse into the sea through the carbon cycle [6]. Later on, the CO_2 will be used by marine vegetation (e.g.: seagrass and mangrove) to processed on photosynthesis then converted to biomass and stored it to the tissues of seagrass in below ground (Blg) or even on above ground (Abg) [8]; [7]; [11]; [12]. Seagrass had become the most abundant carbon-absorber of marine vegetation with high productivity [4].

Seagrass distribution on tropical coastal areas, especially in the Indo-Pacific tropics, maintained to be very high and becomes an area with the highest level of seagrass species diversity [4]; [2]. Indonesia has 12 of 52 species of seagrasses that were identified in the whole world [1].

[1] IPCC (2015).

Bali is one of the most extensive seagrass distributions in Indonesia. The distribution of seagrass on Bali found on the coast of Tanjung Benoa, Sanur, Ungasan, Nusa Lembongan and Nusa Ceningan, Serangan, Gilimanuk, Candidasa, Semaya, Padangbai, Gilimanuk, Goris (Putri Menjangan) and Pengulon [15]. However, information about the carbon stocks potential on Bali is still limited. The research that has been carried out was in the south of the island of Bali precisely on Sanur beach which was considered to have high carbon stocks that equel to 20.68 gC/m^2 [8]. Therefore it is necessary to conduct research in other locations to be able to estimate the size of the carbon stocks potential on Bali. This research took place on the coast of Putri Menjangan which is in the north of Bali; this place is also a conservation area. The purpose of this study was to determine the seagrass carbon sequestration, seagrass carbon stocks value and find out the carbon stocks value differences between below ground (Blg) and above ground (Abg). The results of this study are expected to be complement information on the potential of seagrass on Bali. Hopefully, this could be beneficial for coastal ecosystem management.

2. Material and Methods

This research was conducted on March 2018 on the coast of Putri Menjangan located in Pejarakan Village, Gerokgak District, Buleleng Regency, Bali. Determination of the research station is based on zoning management at Putri Menjangan, namely ST1 Station that located in the exclusive zone, ST2 Station in the intensive use zone, and ST3 Station in the rehabilitation zone (Figure 1).

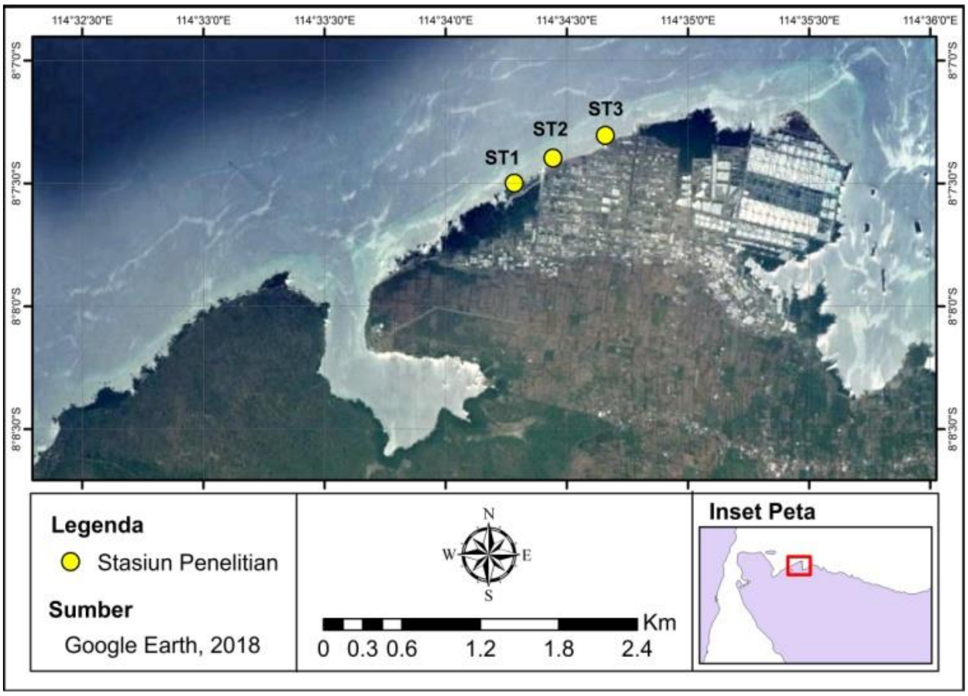

Figure 1. Putri Mejangan beach.

2.1. Seagrass density

Seagrass density was calculated using a 50 x 50 cm squared transect which was given a 10 x 10 cm grid [5]. The calculation of seagrass density was carried out by repeating at each station to get accurate results and approach the actual condition.

2.2. Seagrass leaves productivity

The productivity of seagrass leaves could be found out by measuring the addition of new parts of leaves using the leaves marking method [17] (Figure 2) then followed by analysis of dry weight biomass. The number of stands that marked was 5–10 stands in the dominant species with a period of observation was 5 days.

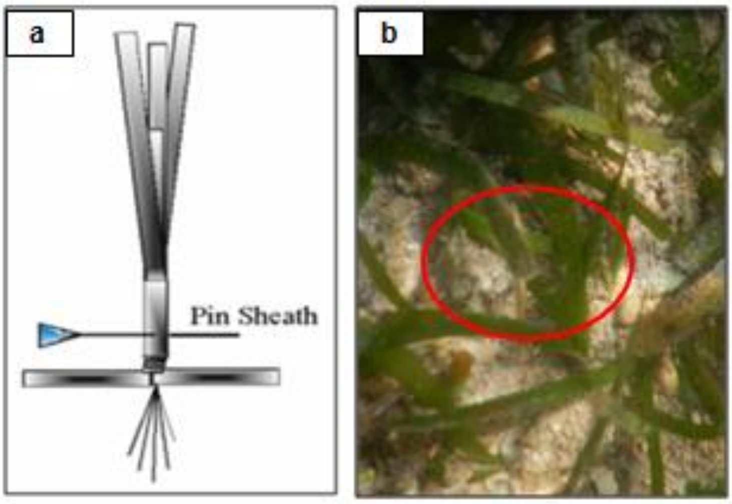

Figure 2. Seagrass marking method (a) and seagrass marking in the field (b).

2.3. Biomass

Seagrass samples used in this study were divided into two, which are carbon stocks samples and carbon sequestration samples. Samples of carbon stocks obtained by sampling whole seagrass (leaves, rhizome, and root) as many as 10 stands in large morphological seagrasses and 10-20 stands in small morphological seagrasses. The sample of carbon sequestration was taken from the new part of the seagrass leaves that had been marked.

Analysis of seagrass biomass was carried out in the Central Laboratory of Living Sciences (LSIH), University of Brawijaya. This research conducted by drying the sample in an oven at 60^{o}C for 24 hours then measured the dry weight (DW). The value of biomass per seagrass stand was obtained by multiplying DW per stand with seagrass density.

2.4. Carbon content

Analysis of carbon content was carried out on dried seagrass samples by Loss on Ignition method using a muffle furnace for 3 hours at a temperature of 500oC until the sample became ash [8]. After that, the value of carbon stocks can be known by converting biomass with carbon content. Likewise, the value of seagrass carbon sequestration can be known by converting leaves productivity with the carbon content obtained.

3. Results and Discussion

3.1. Cymodocea rotundata and Thalassia hemprichii dominated over seagrass density

Seagrass species found on the coast of Putri Menjangan were *Thalassia hemprichii*, *Cymodocea rotundata*, *Halodule pinifolia*, *Halodule uninervis*, and *Halophila ovalis*. Based on the results of the seagrass density calculation, different values were obtained at each research station (Table 1), which were *Cymodocea rotundata* and *Thalassia hemprichii* become the dominant species on the field. The *Cymodocea rotundata* has the highest density value of 706.67 ± 479.04 stands/m^2 at ST1 Station while *Thalassia hemprichii* was 302.00 ± 407.43 stands/m^2 which is also found at ST1 Station. The results of the seagrass density calculation of *Halodule pinifolia*, *Halodule univervis*, and *Halophila ovalis* showed significantly different values with *Cymodocea rotundata* and *Thalassia hemprichii*.

The high and low value of seagrass density is affected by several factors such as water conditions and substrate type [11]. The explained that the type of substrate is the main factor that affects seagrass density because the substrate has significance as a stabilizer so that the seagrass is not carried away by currents or waves. In addition, the substrate also has a role as a provider of nutrients that are needed by seagrasses [7].

Table 1. Seagrass density.

Species	Density (stands/m^2)		
	ST1 Station	ST2 Station	ST3 Station
Thalassia hemprichii	302,00 ± 407,43	177,33 ± 190,89	78,00 ± 143,50
Cymodocea rotundata	706,67 ± 479,04	502,67 ± 172,49	640,00 ± 326,35
Halodule pinifolia	76,00 ± 131,33	58,00 ± 76,05	176,67 ± 190,16
Halodule uninervis	0	0	62,67 ± 68,85
Halophila ovalis	0	13,33 ± 21,27	94,67 ± 160,81

3.2. Seagrass density and environmental conditions affect the carbon sequestration

The measurement of seagrass productivity was found that the highest value at ST1 Station, by *Cymodocea rotundata* at 2.18 gDW/m^2/day and *Thalassia hemprichii* at 2.11 gDW/m^2/day (Figure 3) while at ST2 Station the rate of productivity of *Thalassia hemprichii* was 1.70 gDW/m^2/day and *Cymodocea rotundata* was 1.21 gDW/m^2/day. The productivity rate of seagrass at ST3 Station cannot be calculated because the marker that has already made cannot be found.

The rate of leaves productivity carried out by seagrass is closely related to the growth and seagrass density [3]. The value of the seagrass leaves productivity will be higher if the density value is high. Therefore, environmental factors such as water substrate, nutrient, temperature, salinity, water turbidity, current velocity, and seagrass depth were also found to affect the rate of seagrass productivity. That seagrass morphology will affect the seagrass productivity [18]. In addition, organic materials such as nitrate and phosphate (N and P) could also affect the growth, which is much contributed by mangrove ecosystems. Therefore, seagrass beds that are close to mangrove ecosystems have a higher productivity value [7].

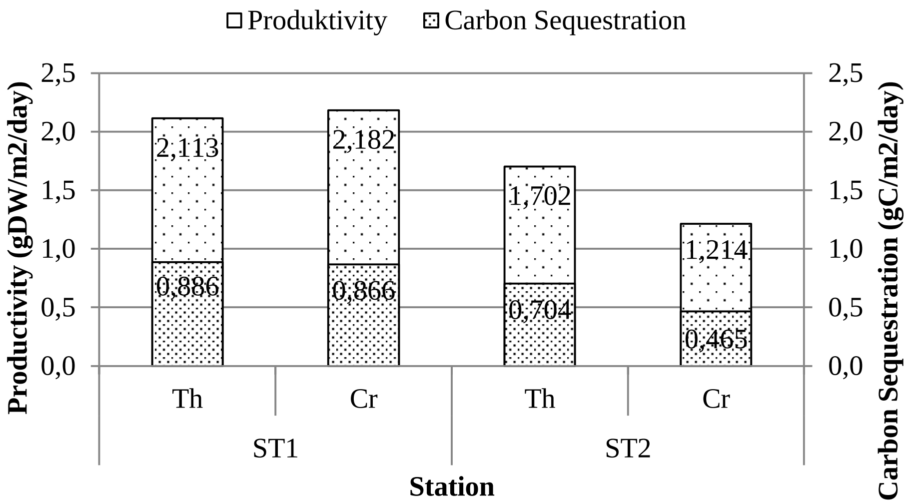

Figure 3. Seagrass productivity and carbon sequestration.

Notes:
Th = *Thalassia hemprichii*; Cr = *Cymodocea rotundata*

The carbon sequestration could reform the conversion of seagrass productivity with carbon content. Figure 4 shows the highest value of carbon sequestration were by *Thalassia hemprichii* and *Cymodocea rotundata* at ST1 Station. At ST1 Station and ST2 Station, species of *Thalassia hemprichii* absorbs carbon higher than *Cymodocea rotundata*.

The average of carbon sequestration on the coast of Putri Menjangan was 1.45 gC/m^2/day. This value didn’t have significance distinction from the carbon sequestration by seagrass on Pari island which ranges from 0.20 to 1.83 gC/m^2/day [14], but the result was quite higher compared to carbon sequestration that occurs on Bintan Island which equal to 0.10 – 0.41 gC/m^2/h [12].

The different value of carbon sequestration in each location can be caused by chlorophyll content in each seagrass species found, and also the presence of epiphytes that attached to seagrass leaves [3]. Chlorophyll that contained in seagrass leaves will affect the photosynthesis process that occurs in seagrass leaves. Likewise, the presence of epiphytes in the leaves of seagrass can lead a competition between seagrasses and the epiphytes during photosynthesis.

3.3. Carbon stocks depend on biomass and seagrass carbon content

Biomass is an organic material that has the main compound in form of carbohydrates consisting of elements of carbon, hydrogen, and oxygen [2]. The results of biomass measurements showed the highest biomass value of seagrass (Abg + Blg) was found at ST1 Station and the lowest was at ST3 Station (Figure 4). The highest biomass species was *Thalassia hemprichii* followed by *Cymodocea rotundata*.

The high value of biomass in a seagrass can be influenced by its high-density value, but in this study, it can be inferred that the size of seagrass morphology more influenced the value of biomass in a seagrass. The high value of *Thalassia hemprichii* biomass was caused by its greater morphology even though this species has a lower density compared to the *Cymodocea rotundata* species [3]. This was similar to some result of others research [9]; [12], which said the greater size of seagrass will have a higher biomass than the small seagrass.

Based on the results of converting the biomass with the carbon content of seagrass found on the coast of Putri Menjangan, the highest value of total stocks carbon (Abg + Blg) carbon stocks was found in ST1 Station which was 76.98 gC/m^2 followed by ST2 Station as much as 41.59 gC/m^2 and the lowest at ST3 Station was 37.60 gC/m^2 (Figure 5). The average carbon stocks of the three research stations was 52.06 gC/m^2. These results indicate that the value of seagrass carbon stocks was higher than the results of seagrass carbon stocks on Sanur Beach which have an average of 20.68 gC/m^2 [8], but the carbon stocks were much lower than carbon stocks obtained in Bakau Bay and Pengudang on Bintan Island which has carbon reserves of 133.71 gC/m^2 and 133.24 gC/m^2 [13].

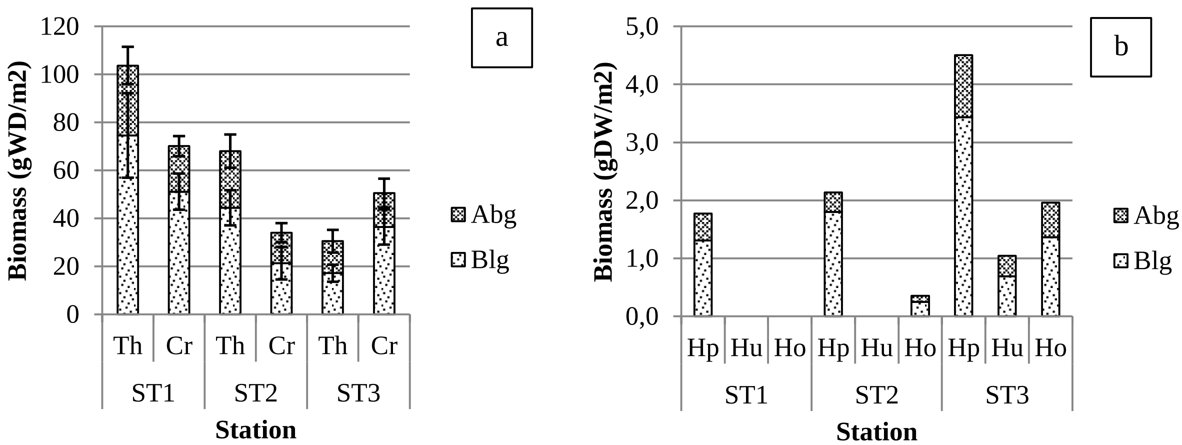

Figure 4. Grafik of Average biomass in each station a. Seagrass with big morphology, b. Seagrass with small morphology.

3.4. Carbon stocks on below Ground (Blg) was twice higher than above ground (Abg)

Based on Figure 6, it can be inferred that seagrass carbon stocks on Blg was higher than carbon stocks in Abg. The highest carbon stocks on Blg was found in *Cymodocea rotundata* at ST1 Station (27.34 gC/m^2) while the lowest one was in *Halophila ovalis* at ST2 Station (0.11 gC/m^2). The highest carbon

[2] Purwanto *et al*. (2012).

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stock in Abg was found in *Thalassia hemprichii* (13.26 gC/m^2) at ST1 Station and the lowest value was in *Halophila ovalis* (0.05 g/m^2) at ST2 Station.

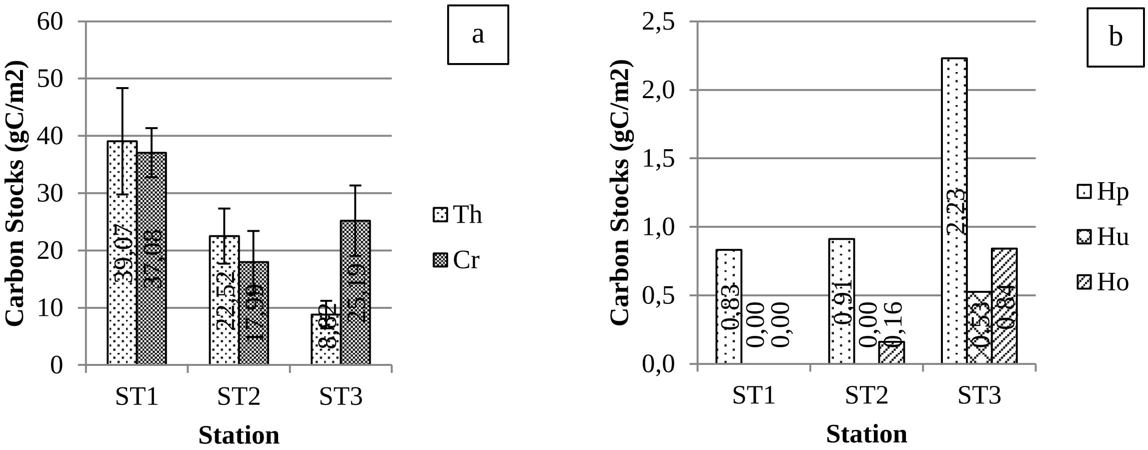

Figure 5. Carbon Stock in each research station.

Notes:
Th = *Thalassia hemprichii*; Cr = *Cymodocea rotundata*; Hp = *Halodule pinifolia*; Hu = *Halodule uninervis*; Ho = *Halophila ovalis*

Overall, the percentage of carbon stocks stored in seagrass beds on the coast of Putri Menjangan was 67% on the Blg part or twice greater than the Abg 33% (Figure 7). These results are similar to the results found who conducted research in Tanjung Lesung, Banten where the value of seagrass carbon stocks on Blg was almost twice as great as that the carbon stock in Abg part [3]. The high value of carbon stocks can be caused by environmental effects such as waves or currents that are not too large [19]. That the high value of carbon stocks is related to one of the functions of seagrass roots, that is as a supporter that strengthens seagrass on the substrate [8].

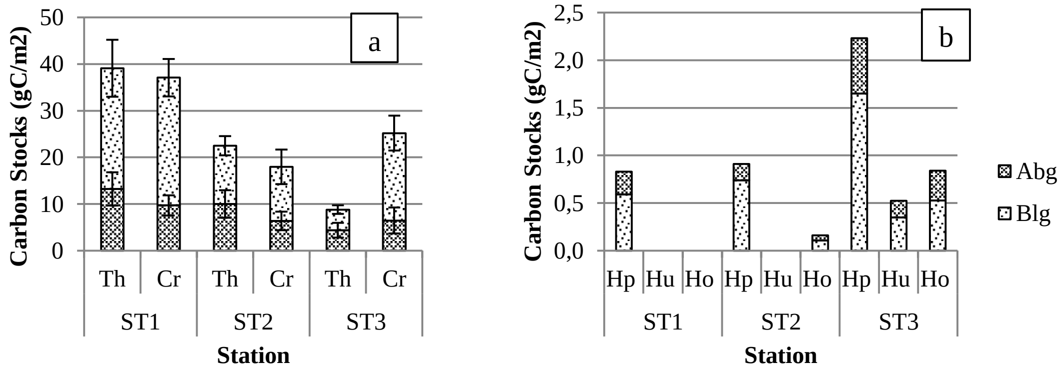

Figure 6. Grafik of carbon stock in each station a. Big morphology seagrass and b. Small morphology seagrass.

3.5. Seagrass in Putri Menjangan beach potential to absorb anthropogenic CO_2

The potential of seagrass beds by storing and absorbing carbon on the coast of Putri Menjangan can be discovered by converting the value of carbon stocks or carbon sequestration that has been obtained with the total area of seagrass beds in that location. The area of seagrass beds on the coast of Putri Menjangan

[3] Rustam *et al*. (2014).

was 6.5 Ha [15]. Based on these data, the potential of carbon stocks contained on Putri Menjangan Beach was 3.38 tons of carbon. While the amount of carbon uptake was 5.29 tonC/Ha/year was equivalent to 0.0006 tonC/Ha/day. If further calculations are carried out by linking the results of the potential carbon uptake with CO_2 emission factors resulting from electricity usage, where every 1 MWh of electricity usage (megawatt hour) will produce CO_2 of 0.741 tons [16] then the carbon absorption potential which was carried out every 1 Ha of seagrass in the location of this study was 0.082%.

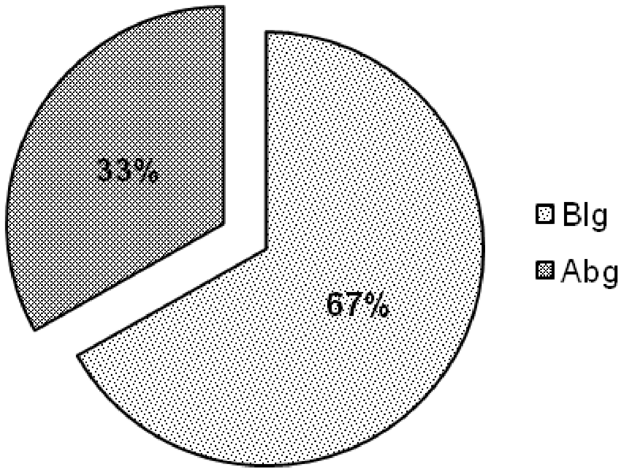

Figure 7. Percentage of seagrass carbon stocks.

Overall, seagrass beds found on Bali island were not only at Putri Menjangan but also widely spread in several other areas, such as Tanjung Benoa, Sanur, Ungasan, Nusa Lembongan and Nusa Ceningan, Serangan, Gilimanuk, Candidasa, Semaya, Padangbai, Gilimanuk and also Pengulon with a total area of seagrass beds of 1323.5 Ha [15]. From the results of this study and research in Sanur Beach [8], it can be seen that the estimation of carbon stocks on the island of Bali was 481.36 tons with an average value of carbon reserves of 0.36 tons/ha.

Based on the calculation of estimated carbon stocks on Bali, it can be inferred that seagrass beds at Putri Menjangan Beach contribute as much as 0.70% with an area of 0.49% of the total area of seagrass beds on the island of Bali. Nevertheless, these results have shown the potential of seagrasses to absorb and store carbon in their body tissues and provide evidence that seagrasses play an important role in climate change mitigation. The ability of seagrass will reduce the amount of anthropogenic CO_2 released into the atmosphere which is one of the substances that trigger global warming which will cause climate change.

4. Conclusion

The results of this study showed the capability of seagrass on the coast of Putri Menjangan which can be used as an effort in mitigating climate change. This can be seen from the seagrass density which was dominated by *Cymodocea rotundata* and *Thalassia hemprichii* species with density 20-1248 stands/m^2 and 24 - 980 stands/m^2, respectively. The carbon stocks were 52.06 gC/m^2, where carbon stocks stored on the below ground (Blg) was twice as high as carbon stocks in above substrate (Abg). The value of carbon sequestration by the dominant species at the study location was 1.45 gC/m^2/h.

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