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Vegetation Structure and Potential of Blue Carbon based on Hydromorphic Degraded Mangrove in the Northern Manokwari, West Papua

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Abstract. The mangrove forest in northern West Papua Province has important roles in both economic and ecological interests. This forest is facing various pressures so it is now degraded. The objective of this study was to ascertain the vegetation structure and potential for the blue carbon reserves. The bio-physical characteristic data were collected by establishing sampling plots at 2 locations representing coastal and estuarine mangrove forest. The results showed that the species diversity index in Saubeba Bay (estuarine mangrove) was low (H '= 1.26), while, the species diversity index in Saukori Bay (coastal mangrove) was very low (H '= 0.66). In Saubeba Bay,*Bruguiera cyclindrica* and *Avicenialanata*had the largest IVI, namely 87.47% and 80.55% respectively, while in Bay Saukori,*Aegiceras floridum*had the highest IVI (139.01%). The total carbon stocks of AGB and BGB of mangrove forest in Saubeba Bay were 224,77 MgC/ha and 77,57 MgC/ha respectively, while those in Saukori Baywere 174,90 MgC/ha and 59,98 MgC/ha, respectively.

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1. Introduction

Mangrove forests are the largest terrestrial carbon stores on earth. This is due to the accumulation of carbon sequestration for decades,or even hundreds of years from the development of succession stored on the ground in the form of plants, litter and soil organic matter [1]. The carbon stock in seaweed and mangrove in Indonesia reaches 3.4 Pg C, or about 17% of the world's blue carbon storage [2]. Meanwhile, [3] reported that the potential of carbon stocks ranged from 54.1 to 182.5 tons/ha.Since mangrove forests are closely linked to the economic functions especially as providers of wood, leaves, raw materials for medicines and food, they are now experiencing high rates of deforestation and degradation commensurate with the population growth and economic development,resulted in thedecrease in the distribution and size of mangrove forests. Many of the mangrove forest areas have been converted to farm, agriculture, industrial, residential, hydrological upstream and downstream sedimentation areas. As for the wetland sector in Indonesia, it is estimated that CO_2 emissions amount to 29,040 Gg CO_2 (eq), equivalent to about 3.2% of Indonesia's annual emissions is associated with conversion of forest and peat lands[2]. The deforestation and degradation of mangrove forests will continue to the extent that mangrove forests are viewed as valuable resources that should be sustainably managed.

In Indonesia mangrove ecosystems are found in many regions in Papua, Kalimantan and Sumatra [4]. In Papua,mangrove forest occupies an area of 1.3 million ha, or about one third of the mangrove forest area in Indonesia. Thus, the potential absorption of blue carbon from these mangrove forests is very high. However, studies and data related to blue carbon uptake are still very limited, especially when associated with hydromorphic factors.

A preliminary study to assess the potential of blue carbon by considering the hydromorphic structure of mangrove forest vegetation in northern coast of Manokwari, West Papua was done in the framework of ecological conservation and sustainable management.

2. Material and Methods

2.1.Study Area

The study was conducted in Saubeba Bay (Kampung Saubeba; 133°57'997" E and 00°43'843" S;estuarine mangrove) and Saukori Bay (Yom I village,-133°57'464" E and 00°43'622" S, coastal mangrove) located in North Manokwari District, West Papua Province (Figure 1).

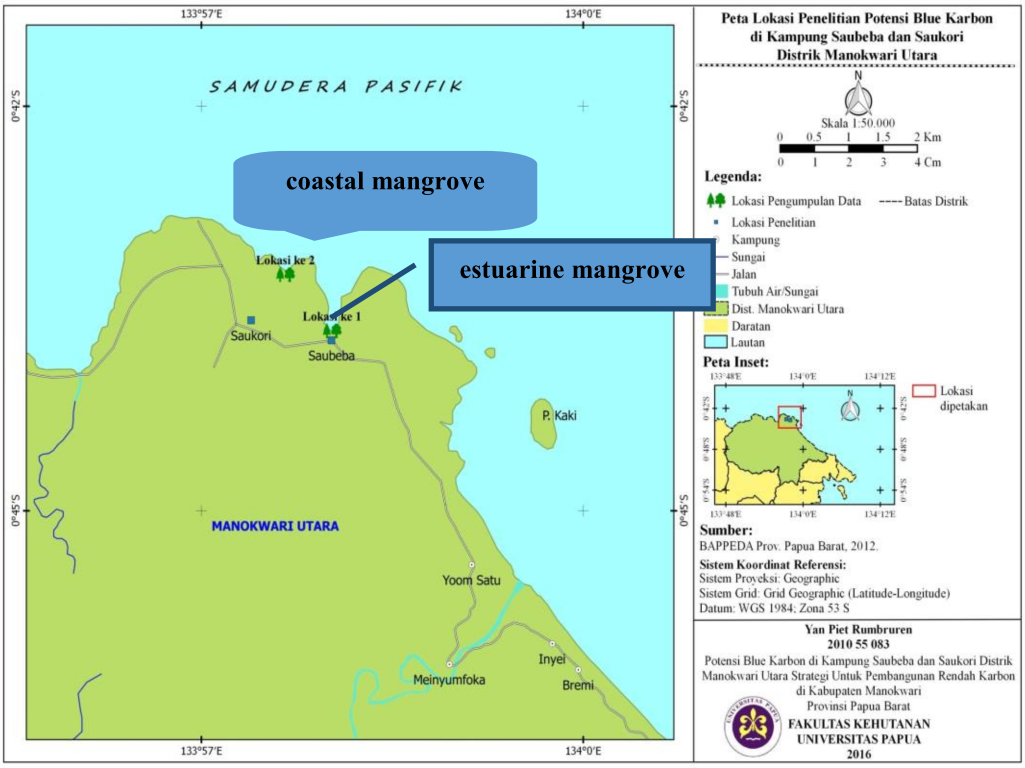


Figure 1. Map of research location

2.2.Bio-Physic and Carbon Stock Sampling

The data collection of bio-physical characteristics and carbon stock were carried out using sample plot as follows (Figure 2):

a. Seedling: 2 m x 2m.
b. Sapling: 5 m x 5 m.
c. Pole: 10 m x 10 m.
d. Tree: 20 m x 20 m.

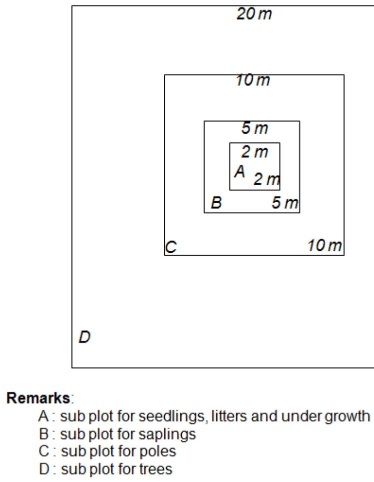


Figure 2. Design plot of observation

1. The component structure of the mangrove forest evaluation: it was classified based on its constituent components, complexity and canopy closure level.

2. Measurement of the carbon potential: it included above ground biomass, ground biomass, undergrowth, litters and soil carbon.

2.3.Bio-physical assessment

The bio-physical parameter expressed as index of species diversity (H value) was calculated using the distribution pattern of several abundance sizes among species [6] according to Shannon's formulation [7] as follows:

$$H' = -\sum_{i=1}^{S} Pi \ln Pi \quad \ldots \quad 1$$

where H is the species diversity index, S is the number of species that makes up the community and Pi is the ratio of the number of species i (in) to the total number of individual species in the community (N). The species diversity index was classified as follows: high (>2.0), moderate (2.0-1.6), low (1.6-1.0) and very low (<1.0) [8].

The evenness index (E')expresses how evenly the individuals in the community distributed across different species. Thiswas calculated according to Shannon's formulation [6] as follows:

$$E' = H / \ln S \quad \ldots \quad 2$$

where E' is the evenness index, and S is the number of speciesin the community. The evenness index was classified as follows: high (> 0.6), moderate (0.3 – 0.6) and low (< 0.3).

The vegetation data were quantitatively analyzed using relative density, relative frequency, and relative dominance. The Importance Value Index was determined as the sum of the relative density, relative frequency and relative dominance using the following formula:

$$\text{Density} = \frac{\text{number of individu of species}}{\text{the wide of observation plot}} \quad (3)$$

$$\text{Relative Density}(\%) = \frac{\text{density of a species}}{\text{density of all species}} \text{x}100\% \quad (4)$$

$$\text{Frequency} = \frac{\text{number of plots accupied by a species}}{\text{number of all observation plot}} \quad (5)$$

$$\text{Relative Frequency }(\%) = \frac{\text{frequency of a speceis}}{\text{frequency of all species}} \text{X}100\% \quad (6)$$

$$\text{Dominance} = \frac{\text{basal area of a species}}{\text{the wide of observation plot}} \quad (7)$$

$$\text{Relative Dominance }(\%) = \frac{\text{dominance of species}}{\text{dominance of all speceis}} \text{x}100\% \quad (8)$$

Importance Value Index =Rel. Density +Rel. Frequency + Rel. Dominance 9

2.4.Measurement of carbon potential

The carbon potential assessmentconsisting ofaboveground biomass (AGB) and subsurface (below ground biomass, BGB) was conducted using allometric equation formulas as follows[9]10]:

$$AGB \text{ or } N_t = \exp\left[-2.5570 + 0.9400\ln(\rho_w D^2 H)\right] \quad (10)$$

$$BGB = \exp\left[-1.0587 + 0.8836\ln(AGB)\right] \quad (11)$$

$$TB = AGB + BGB \quad (12)$$

where ρ_w is density of wood species (g cm-3), D is diameter (cm) and H isplant height (m), TB is total above ground biomass.

3.Results and Discussion

3.1. Species Diversity Index

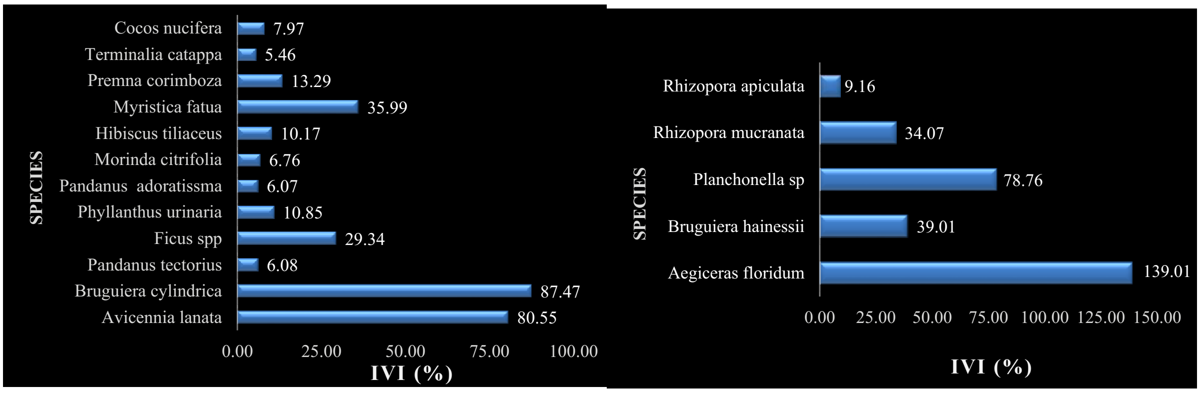
The diversity index of species found in both degraded mangrove forest areas can be seen in Appendix 1. The diversity index of species in Saubeba Bay (estuarine mangrove) was low (H '= 1.27), while that in Saukori Bay (coastal mangrove) was very low (H '= 0.66). These values were somewhat different from those reported bysimilar studies on natural mangrove forests in southern Papua namely coastal mangrove and estuarine mangrove withdiversity index (H’) of 1.79 and1.36, respectively[11].

The species diversity index (H') determines the stability level of a standing community. A community that has an H' value of <1 value is less stable and was found in mangrove forests in the Saukori Bay, while the value of H' between 1-2 indicates that the community is ina stable state [12]and this was found in mangrove forests in Saubeba Bay.

Further analysis of the distribution of the evenness index type (E ') showed that evenness types were moderate (E '= 0.3 - 0.6) with E' = 0.51 in Saubeba Bay and E '= 0.41 in Saukori Bay. This is because some species were represented from the sapling to tree level.

3.2. Important Value Index

Important Value Index (IVI) at Saubeba Bay - estuarine mangrove (Figure 3a) consisted oftwo types of plants with the largest IVI namely *Bruguiera cyclindrica* (87,47%) and *Avicenini lanata*(80,55%). The other types of plants with lower values of IVI were *Myristica fatua* (35.99%), *Ficus spp*. (29,34%), *Premna corimboza* (13,29%), *Phyllanthus urinaria* (10,85%) and *Hibiscus tiliacius* (10.17%). In general, the high value of the IVI was accounted for by *Relative Density* and *Relative Frequency* values. The highest value ofIVIvalue at Saukori Bay - coastal mangrove (Figure 3b) was contributed by *Aegiceras floridum* (139.01%) and followed by *Planchonella* sp. (78.76%), *Bruguiera hainesii* (39.01%) and *Rhizopora mucronata* (34.07%). The high value of IVI was also accounted for by those of *Relative Density* and *Relative Frequency*.



(a) (b)

Figure 3. IVI (%) at Saubeba Bay (a) and Saukori Bay (b)

3.3.Components Structure

Mangrove forests generally grow to form zonation starting from coast to inland with different widths. Mangrove zones can be either simple zonation (one zonation,mixed zonation) orcomplex zonation (several zonation), depending on the environmental conditions of the mangroves concerned [5].

Results of the study on degraded mangrove forest in Saubeba Village (Saubeba Bay) – estuarine mangrove and Yom I (Saukori Bay) - coastal mangrove revealed that some mangrove species that occurred in mixture with other types of beach vegetation had spreadto the mainland. The horizontal constituent structure of the Saubeba Bay - estuarine mangroves (Figure 4) indicated that the different species were found in the observation plot spreading from the coast to the land. The species found at the forefront of the first 10 mwas*Avicennia lanata*, then followed by *Avicennia lanata* and *Bruguiera cylindrica*at the next 10 m. At the third (10 m third) layer the following species were found:*Bruguiera cylindrica, Terminalia catappa* and *Avicennia lanata* while at the fourth layer (10 meters fourth) were *Hibiscus tiliaceus, Ficus spp., Phyllanthus urinaria, Premna corimboza, Myristica fatua, Cocos* *nucifera, Morinda citrifolia, Pandanus tectorius and Pandanus adoratissma*. The vertical constituent structure (Figure 5) composed of the following species from highest to lowest:*Avicennia lanata, Myristica fatua, Bruguiera cylindrica, Premna corimboza, Phyllanthus urinaria, Ficus spp., Hibiscus tiliaceus, Morinda citrifolia, Terminalia catappa, Cocos nucifera, Pandanus tectorius and Pandanus adoratissimus.*

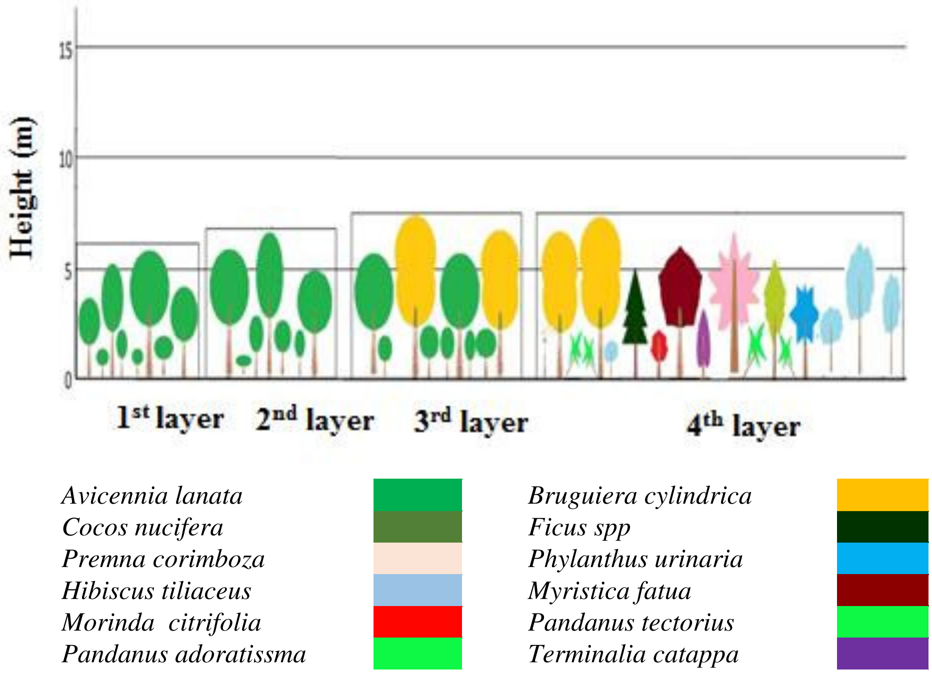


Figure 4. Horizontal structure components at Saubeba Bay

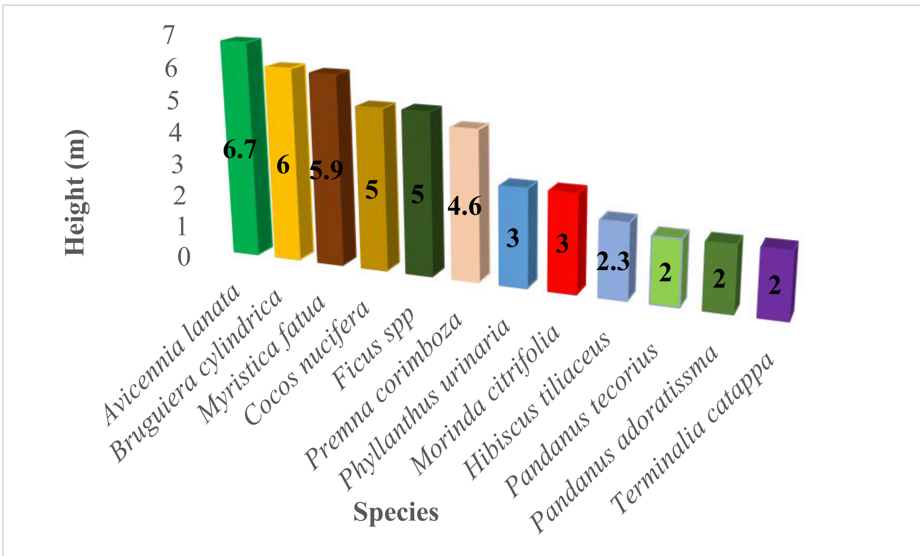


Figure 5. Vertical structure components at Saubeba Bay

The horizontal structure of constituents in the Saukori Bay - coastal mangroves (Figure 6) consisted of *Aegiceras floridum* at the first 10 m from the coast, while at the next 10 m (second layers) the following species were recorded: *Brugueira hainesii, Planchonella sp., Rhizopora mucronata and Rhizopora apiculata*. The vertical constituent structures (Figure 7) comprised of the following specices(from highest to lowest): *Bruguiera hainesii, Aegiceras floridum, Planchonella sp., Rhizopora mucronata and Rhizopora apiculata*.

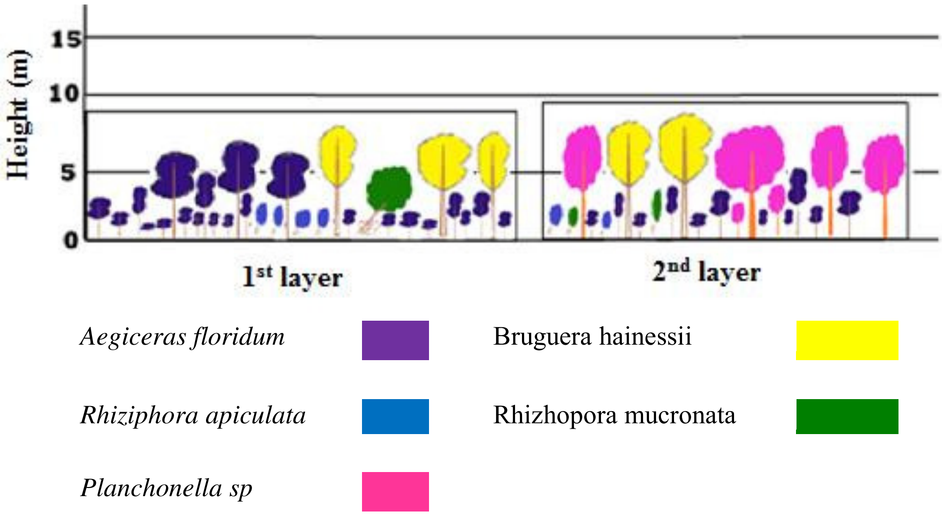


Figure 6. Horizontal structure components at Saukori Bay

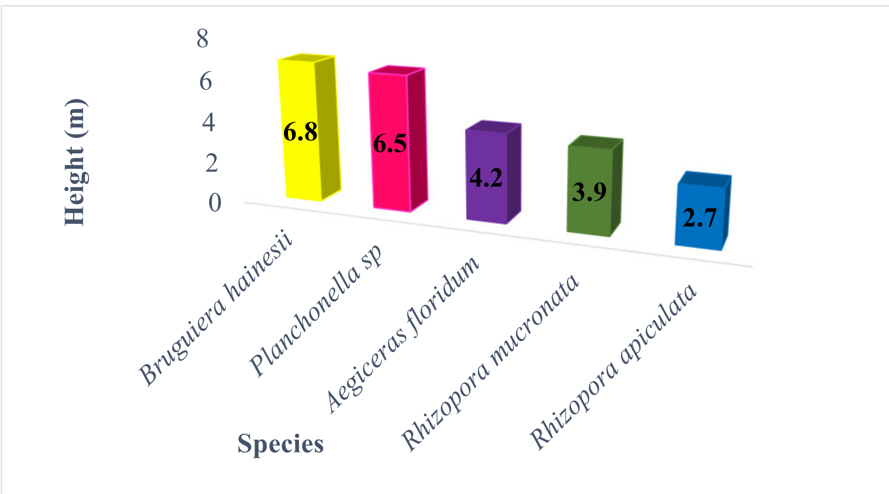


Figure 7. Vertical structure components at Saukori Bay

3.4.Potential Cabon Stock

Figure 8 shows that *Myristica fatua* (coastal forest) had the highest carbon stock with total biomass reaching 188.15 MgC/ha, followed by the type of mangrove plants, namely*Avicennia lanata* (35.13 MgC/ha) and *Brugueira cylindrica* (23.79 MgC/ha).If carbon stocks are only applied for mangrove forest, then the carbon stocks of AGB and BGB were42.80 MgC/ha and 16.12 MgC/ha respectively.

Thesevaluesare much lower compared to those of mangrove forests in some other places in Indonesia, with carbon stock values of 159.1 MgC/ha and 16.7 MgC/Ha for AGB and BGB respectively [2]. Results of a study conducted in mangrove forest in Banten revealed that the amount of carbon stored in *Avicennia lanata*is two-fold greater (182.5 MgC/ha) than found in northern Papua. The differencewasdue to the number, diameter and height of trees that were closely related to the soil fertility and local climate.

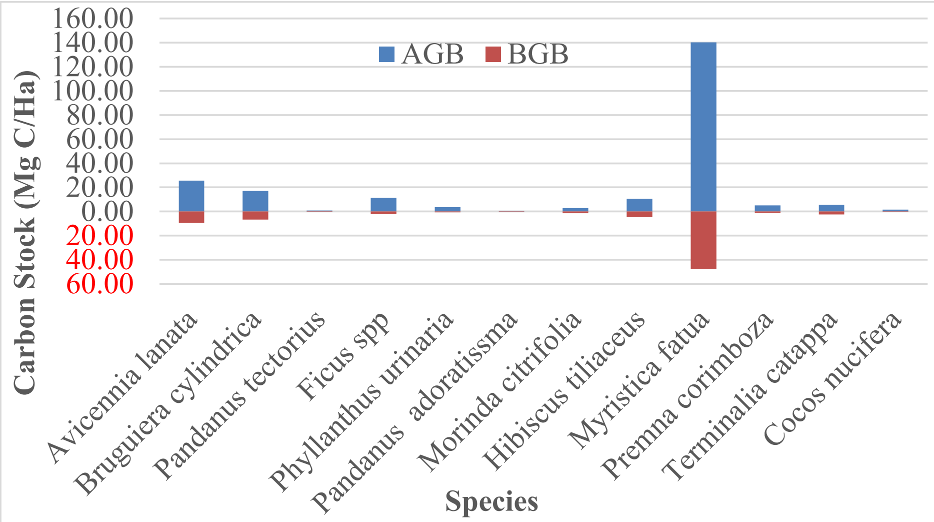


Figure 8. Carbon stock of mangrove forest at Saubeba Bay

The highest carbon stock of AGB and BGB in Saukori Bay was found in *Bruguiera hainesii* (196,63 MgC/ha), followed by *Rhizopora mucronata* (18.64 MgC/ha) and *Aegiceras floridium* (9.35 MgC/ha)(Figure 9). The total aggregate carbon stocks of AGB and BGB for mangrove species in the Saukori Bay were 174.90 MgC/ha and 59.98 MgC/ha. The value wasquite similar to the average value of carbon stock of mangrove forest in Indonesia[2].

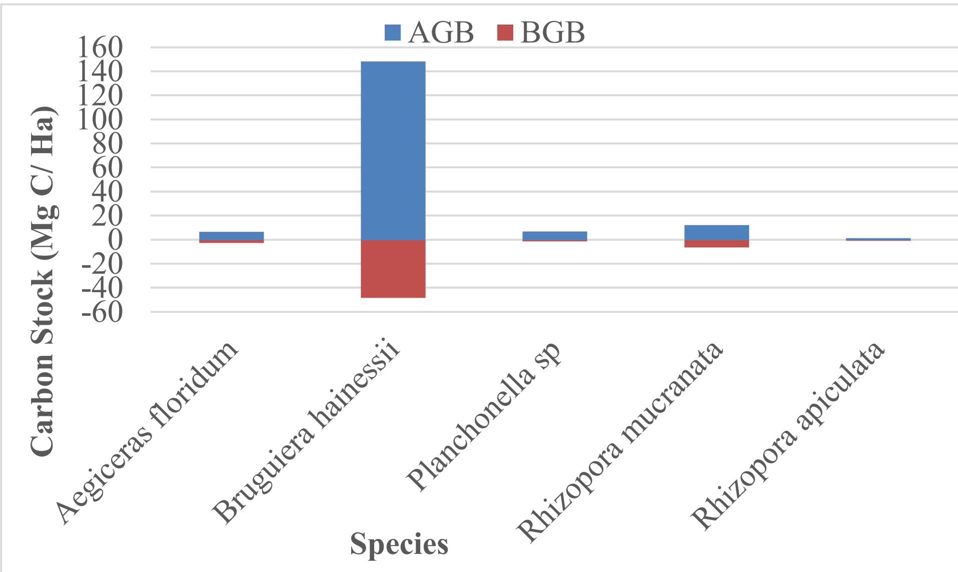


Figure 9. Carbon stock of mangrove forest at Saukori Bay

4.Conclusion

Biophysical descriptions of degraded mangrove forests expressed as species diversity index in Saubeba Bay (estuarine mangrove) was low (H'= 1.26), while that in Saukori Bay (coastal mangrove) was very low (H'= 0.66). The IVI mangrove in the Saubeba Bay was dominated by twospecies namely *Bruguiera cyclindrica* (87.47%) and *Avicenialanata* (80.55%), while the highest Bay Saukori IVIvalue was accounted for by *Aegiceras floridum* (139.01%).

The description of horizontal constituent structures at both bays had the same characteristics, namely the front to the third layer was dominated by the mangrove species and the last part (fourth layer) was a mixture typeof different beach plant species.

The total carbon stock of AGB and BGB of mangrove forest in Saubeba Bay (estuarine mangrove) was224.77 and 77.57 MgC/ha respectively, while that of AGB and BGB of mangrove forest in Saukori Bay (coastal mangrove) was 174.90 and 59.98 MgC/ha respectively.

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Appendix 1. IVI, H, and E'

Saubeba Bay

No	Species	Number of Individuls	Density	Rel. Density (%)	Frequency	Rel. Frequency (%)	Basal area	Dominance	Rel. Dominance (%)	IVI (%)	SDR (%)	Species Diversity Index	The Eveness Index
1	***Avicennia lanata***	105	0.04	45.85	0.46	27.08	2.67	0.001	7.61	80.55	**26.85**	-0.36	0.51
2	***Bruguiera cylindrica***	94	0.03	41.05	0.71	41.67	1.67	0.001	4.75	87.47	**29.16**	-0.37	
3	*Pandanus tectorius*	7	0.00	3.06	0.04	2.08	0.33	0.000	0.94	6.08	2.03	-0.11	
4	*Ficus spp*	6	0.00	2.62	0.11	6.25	7.18	0.003	20.47	29.34	9.78	-0.10	
5	*Phyllanthus urinaria*	4	0.00	1.75	0.04	2.08	2.46	0.001	7.02	10.85	3.62	-0.07	
6	*Pandanus adoratissma*	3	0.00	1.31	0.07	4.17	0.21	0.000	0.59	6.07	2.02	-0.06	
7	*Morinda citrifolia*	2	0.00	0.87	0.07	4.17	0.60	0.000	1.72	6.76	2.25	-0.04	
8	*Hibiscus tiliaceus*	2	0.00	0.87	0.07	4.17	1.80	0.001	5.13	10.17	3.39	-0.04	
9	***Myristica fatua***	2	0.00	0.87	0.04	2.08	11.59	0.004	33.04	35.99	**12.00**	-0.04	
10	*Premna corimboza*	2	0.00	0.87	0.04	2.08	3.63	0.001	10.34	13.29	4.43	-0.04	
11	*Terminalia catappa*	1	0.00	0.44	0.04	2.08	1.03	0.000	2.94	5.46	1.82	-0.02	
12	*Cocos nucifera*	1	0.00	0.44	0.04	2.08	1.91	0.001	5.45	7.97	2.66	-0.02	
	Total	229.00	0.08	100.00	1.71	100.00	35.07	0.013	100.00	300.00		1.27	

Saukori Bay

No	Species	Number of Individuls	Density	Rel. Density (%)	Frequency	Rel. Frequency (%)	Basal area	Dominance	Rel. Dominance (%)	IVI (%)	SDR (%)	Species Diversity Index	The Eveness Index
1	***Aegiceras floridum***	356	0.16	83.57	0.86	50.00	0.86	0.000	5.44	139.01	**46.34**	-0.15	0.41
2	***Bruguiera hainessii***	27	0.01	6.34	0.41	23.68	1.41	0.001	8.98	39.01	**13.00**	-0.17	
3	***Planchonella sp***	20	0.01	4.69	0.18	10.53	10.00	0.005	63.54	78.76	**26.25**	-0.14	
4	*Rhizopora mucranata*	15	0.01	3.52	0.18	10.53	3.15	0.001	20.02	34.07	11.36	-0.12	
5	*Rhizopora apiculata*	8	0.00	1.88	0.09	5.26	0.32	0.000	2.02	9.16	3.05	-0.07	
	Total	426.00	0.19	100.00	1.73	100.00	15.74	0.007	100.00	300.00		0.66	

Appendix 2. Total of Carbon Stock (MgC/Ha)

Saubeba Bay

No	Spesies	AGB	BGB	Total Carbon
1	***Avicennia lanata***	25.64	-9.48	35.13
2	***Bruguiera cylindrica***	17.15	-6.63	23.79
3	*Pandanus tectorius*	0.84	-0.47	1.31
4	*Ficus spp*	11.22	-2.09	13.31
5	*Phyllanthus urinaria*	3.58	-0.79	4.37
6	*Pandanus adoratissma*	0.47	-0.28	0.75
7	*Morinda citrifolia*	2.80	-1.37	4.18
8	*Hibiscus tiliaceus*	10.63	-4.61	15.24
9	***Myristica fatua***	140.37	-47.78	188.15
10	*Premna corimboza*	5.09	-1.12	6.20
11	*Terminalia catappa*	5.48	-2.57	8.05
12	*Cocos nucifera*	1.50	-0.38	1.88
	Total	**224.77**	**-77.57**	**302.35**

Saukori Bay

No	Spesies	AGB	BGB	Total Carbon
1	***Aegiceras floridum***	6.57	-2.78	9.35
2	***Bruguiera hainessii***	148.21	-48.43	196.63
3	***Planchonella sp***	6.81	-1.36	8.17
4	*Rhizopora mucranata*	12.17	-6.47	18.64
5	*Rhizopora apiculata*	1.15	-0.94	2.09
	Total	**174.90**	**-59.98**	**234.88**