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ANALYSIS OF BIOMASS AND STORED CARBON STOCK IN MANGROVE FOREST AREA, TAMAN HUTAN RAYA NGURAH RAI BALI

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ABSTRACT

Mangrove forests are transitional ecosystems between land and sea that occur mainly along tropical and subtropical coastlines. Ecologically, mangroves function as carbon sinks and stores, with most of them being allocated below the soil surface. It is possible that the increase in atmospheric CO2 that contributes to global warming can be reduced through the process of sequestration of carbon into the soil. The more carbon stored in the soil as soil organic carbon, it can reduce the amount of carbon in the atmosphere so that it can reduce global warming and climate change. SOC (Soil Organic Carbon) is distributed into various layers of soil, and its stability is also very diverse. The objectives of this research are:(1) Knowing the organic carbon storage below the soil surface in the mangrove forests of the Taman Hutan Raya Ngurah Rai and (2) Knowing the vertical variation of organic carbon stored in the soil in the mangrove forests of Taman Hutan Raya Ngurah Rai. The estimation of biomass using the method without harvesting by measuring diameter at breast height (DBH, 1.3 m) mangrove. Carbon deposits are estimated from 46% of biomass. The method used in this research is loss on ignition (LOI). The average distribution of soil organic carbon storage at a layer of 0 cm - 15 cm, 15 cm - 30 cm, 30 cm -50 cm, 50 cm -100 cm and > 100 cm respectively is 84.18 ton C / ha, 90 , 43 ton C / ha, 93.39 ton C / ha, 115.70 ton C / ha and 80.75 ton C / ha.

Keywords: Mangrove; Biomass; Carbon Stock

INTRODUCTION

Mangrove is an ecosystem that uses carbon in the air for photosynthesis. The mangrove ecosystem has a role as an absorber of CO_2 from the air. Mangrove forests store more carbon than most tropical rainforests. This is in accordance with Donato et al. (2011), which states that mangroves have the ability to assimilate and have a high carbon absorption rate. By measuring the amount of carbon stored in the body of living plants in a land, it can describe the amount of CO_2 in the atmosphere that is absorbed by plants.

Mangrove is one of the parameters of blue carbon because of its role in utilize CO_2 for photosynthesis and store it in the form of biomass and in sediments (Atiet al., 2014). Amount of biomass in an area is assumed to be obtained from measurement diameter, height and wood density of each type of mangroves (Rachmawati et al., 2014). According to Kauffman et al., (2012) carbon storage in forests mangroves is higher than savings carbon in other forest types, where it stores The largest carbon is found in mangrove sediments. Fallen leaves and branches of mangrove trees decomposed by microorganisms, and become a source of organic matter in sediments mangroves (Susiana, 2011).

Mangrove forests have several functions both physically, biologically and ecologically. Ecologically, mangrove forests have an important function for coastal areas, namely as a carbon sink and storage in efforts to mitigate global warming (Rachmawati et al., 2014). This function makes mangrove forests store large amounts of carbon both in vegetation (biomass) and other organic material found in mangrove forests (Cahyaningrum et al., 2014). Mangrove forests store aboveground and belowground carbon, with most of it being allocated below ground level (Alongi, 2012). The photosynthetic carbon results will be stored in the plant body and then stored in the soil.

The difference in the diversity of soil organic carbon content at soil depth occurs because each type of vegetation is different in its vertical root distribution and leaves a different trail in the depth distribution (Lal, 2005). At a depth of 30 cm or more, it is rich in organic soils, where this depth accounts for 49 - 98% of carbon storage (Daniel et al., 2011).

RESEARCH METHODS

Time and Location of Research

This research was conducted in August - October 2019 in the mangrove forest area of Taman Hutan Raya, Bali. Field data taken in this study were mangrove vegetation, sediment (soil organic matter), and environmental parameters.

Tree biomass analysis was carried out by measuring all the diameter at breast height (DBH 1.3 m) of mangroves; then calculations were carried out using an allometric model to estimate the potential for biomass and carbon storage (Sutaryo, 2009). Meanwhile, to assess sediment organic carbon is carried out by taking sediment samples at a depth of 0-100 cm (Kauffman et al., 2012). Processing and analysis of samples were carried out by the Soil Laboratory of the Faculty of Agriculture, Udayana University.

Data Analysis

Mangrove Density

Density shows the individual value of the unity of the area (Ariani et al., 2016). The density value can be calculated by the following formula:

$$K = \frac{i}{L\ plot} \quad \ldots (1)$$

Where is:K = density of a variety (individual/m^2); i =the number of individuals of a variety; L plot = the area of the entire sample plot

Mangrove Biomass

Mangrove biomass determination uses allometric equations for each type. Allometric equations are used to determine the relationship between tree size (diameter or height) and overall tree weight (dryness) (Sutaryo, 2009). The allometric equation for determining the biomass value of mangrove trees is presented in Table 1.

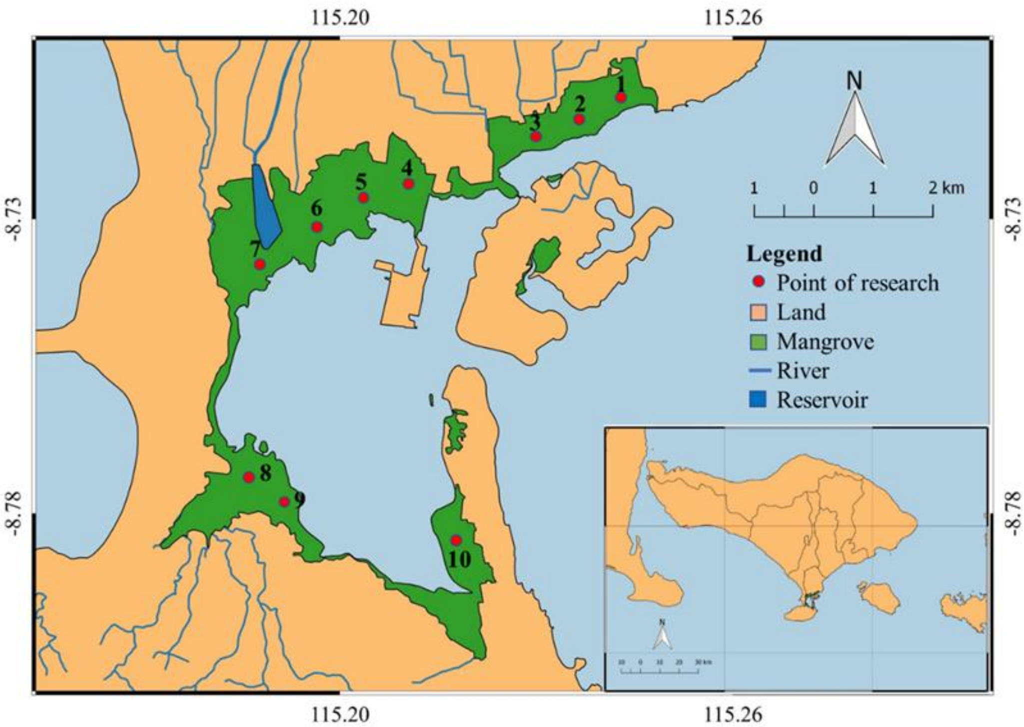

Figure 1. Map of Research Location

Table 1. Allometric Equations for Calculating Mangrove Tree Biomass

Species	Allometric Model	References
Avicennia alba	$B = 0{,}079211{*}D^{2{,}470895}$	Tue et al., 2014
Avicennia marina	$B = 0.1848{*}D^{2.3524}$	BalitbangKehutanan, 2013
Bruguieragymnorrhiza	$B = \rho{*}0.0754{*}D^{2.505}$	Kuffman et al., 2012
Rhizophoraapiculata	$B = 0{,}048{*}D^{2{,}614}$	BalitbangKehutanan, 2013
Rhizophoramucronata	$B = 0{,}1466{*}D^{2{,}3136}$	Dharmawan, 2013
Sonneratia alba	$B = 0.3841{*}\rho{*}D^{2.101}$	Kauffman and Donato, 2012
Xylocarpusgranatum	$B = 0.1832{*}D^{2.21}$	Tarlan, 2008

Where is: B = Biomass (kg); D = Diameter of Tree Trunk (cm); ρ = *wood density* (gr/cm^2)

Carbon of Biomass

The calculation of carbon from biomass uses a formula that refers to the National Standardization Agency for Indonesia (2011), namely:

$$Cb = B \times \%C\ organic \quad \ldots (2)$$

Where is:Cb =carbon content of biomass (kg); B = total of biomass (kg); % C organic = percentage value of organic carbon content (0,47)

Soil Organic Carbon

Calculation of soil organic carbon content uses a formula that refers to the National Standardization Agency for Indonesia (2011), namely:

$$Ct = Kd \times \rho \times \%C\ organic \quad \ldots (3)$$

Where is:Ct = soil organic carbon content (g/cm^2); Kd = soil sample depth / soil depth (cm); ρ = bulk density (g/cm^3); % C organic = the percentage value of organic carbon content obtained from the results of measurements in the laboratory

Biomass Carbon Stocks per Hectare

The equation for calculating carbon from biomass per hectare, according to the National Standardization Agency for Indonesia (2011) is as follows:

$$Cn = \frac{Cx}{1000} \times \frac{10000}{L\ transek} \quad \ldots (4)$$

Where is:Cn = carbon stock per hectare in each carbon pool on each transect (ton/ha); Cx = carbon content in each carbon pool on each transect (kg); L transect = transect area in each carbon pool (m^2)

Soil Organic Carbon per Hectare

The equation for calculating soil organic carbon content per hectare according to the National Standardization Agency for Indonesia (2011) is as follows:

$$Ct = C\ soil \times 100 \qquad (5)$$

Where is: C soil = soil organic carbon content per hectare (ton/ha); Ct = soil carbon content (g/cm^2); 100 = conversion factor from g/cm^2ke ton/ha

Total Carbon Deposits

Calculation of total carbon storage according to the National Standardization Agency for Indonesia (2011), namely:

$$Ctotal = Cn + C\ org\ soil \qquad (6)$$

Where is:Ctotal = total carbon deposits (ton/ha); Cn = carbon content per hectare on each carbon pool (ton/ha); C org soil = soil organic carbon content per hectare (ton/ha)

RESULTS AND DISCUSSION

General Conditions and Environmental Parameters at the Research Site

Taman Hutan Raya Ngurah Rai is the only major forest park in Bali, which is a brackish forest type area that is always inundated by brackish water and is affected by tides. The natural environment of the Mangrove Forest Area Ngurah Rai has the potential for biodiversity in the form of mangrove forests, land animals (bird species, creeping animals, etc.) and aquatic animals (fish, molluscs and shrimp species), so this area is essential to be preserved ecologically and can be used as recreational nature tourism, educational tourism and research which is very meaningful in economic development.

Environmental parameters are one of the important factors for each organism, including in this case the mangrove forest in the area that is influenced by land and sea. Environmental parameters were measured in situ at the study site. Environmental parameters measured include temperature, degree of acidity / pH, and salinity levels. The results of measurement of environmental parameters are compared with seawater quality standards based on the Minister of Environment Decree No. 51 of 2004. The results of environmental parameters measurement can be seen in Table 2.

Table 2. Environmental Parameters at the Research Site

Station	Temperature (°C)	pH	Salinitas ($^0/_{00}$)
1	29,20	7,30	30
2	28,00	6,41	29
3	29,60	8,09	20
4	30,10	7,15	29
5	29,90	7,03	28
6	30,00	8,67	29
7	29,40	7,28	20
8	31,00	8,59	31
9	28,40	8,40	31
10	29,00	8,70	30
Quality Standard	**28-32**	**7-8,5**	**≤ 34**

References: Minister of Environment Decree No. 51 of 2004 about Seawater Quality Standards

Based on the environmental parameter values at stations 1 to 10, the values are relatively the same or not much different in temperature, degree of acidity / pH and salinity. All parameters measured are still within the range that can be tolerated by aquatic organisms to live, including mangroves

Temperature is one of the most determining factors in the metabolic processes of organisms in waters. The measured temperature measurements at the study sites showed varying results between 28°C to 31°C. This temperature value range is following the applicable quality standards and in accordance with the opinion of Ayu Lestari (2018), where mangroves found along the coast of subtropical and tropical areas have temperature values ranging from 26°C to 31°C.

PH measurements at the study sites showed varied results, where the pH value ranged from 6.41–8.70. The results of this pH measurement are supported by Ayu Lestari (2018) that the pH value of water in the range of 6 to 8.5 is a pH value that is very suitable for mangrove growth..

Salinity is one of the oceanographic factors that can affect mangrove growth. Most of the mangroves can live at a salinity of 15-30 $^0/_{00}$, and there are several types of mangrove plants that can grow well in high salinity conditions, and there are several types of mangroves that can grow at salinity lower than 15 $^0/_{00}$.

Mangrove Density

Tree stand density is an indicator in determining the size of the biomass value. Mangrove vegetation in the Mangrove Forest of Taman Hutan Raya Ngurah Rai has the lowest density value, namely 1674 ind / ha, and the highest is 4167 ind / ha. The mangrove density values found were in a good category. This is in accordance with the Decree of the Minister of Environment (2004), which states that a good density level has a density value of more than 1500 ind / ha.

In general, the composition of vegetation in the Mangrove Forest Area of Ngurah Rai Forest Park is dominated by Rhizophora sp. According to Rachmawati et al., (2014) mangrove Rhizophora sp has higher adaptability than other types.

Mangrove Biomass

Biomass consists mainly of carbon. The main constituent of biomass is carbohydrate building blocks consisting of the elements carbon (C), hydrogen (H), and oxygen (O) which are produced through the process of plant photosynthesis. Based on research that has been conducted in the Mangrove Forest of Taman Hutan Raya Ngurah Rai, it shows that the average mangrove biomass at Station 7 has the highest value compared to other stations with average biomass worth 451.55 kg / m2. The station with the lowest average biomass is at Station 4, with an average biomass value of 79.56 kg / m2 (Figure 2).

Based on the graph bellow, it can be said that the more the number / quantity of trees has the potential to contain a higher amount of biomass. The biomass content of a stand is determined based on the tree diameter. This is confirmed by Suwardi et al., (2013) that the biomass value is calculated using two parameters, namely specific gravity and stem diameter. The trunk diameter can affect the amount of tree biomass, and it can be illustrated that the larger the diameter of the stem, the higher the biomass value.

Mangrove Carbon

The value of carbon content in mangrove vegetation is obtained by multiplying the biomass content of mangrove trees by the percentage value of organic carbon content, which is 0.47 according to the National Standardization Agency (2011). The following is the value of the carbon content stored in the mangrove vegetation at the research location as shown in Figure 3.

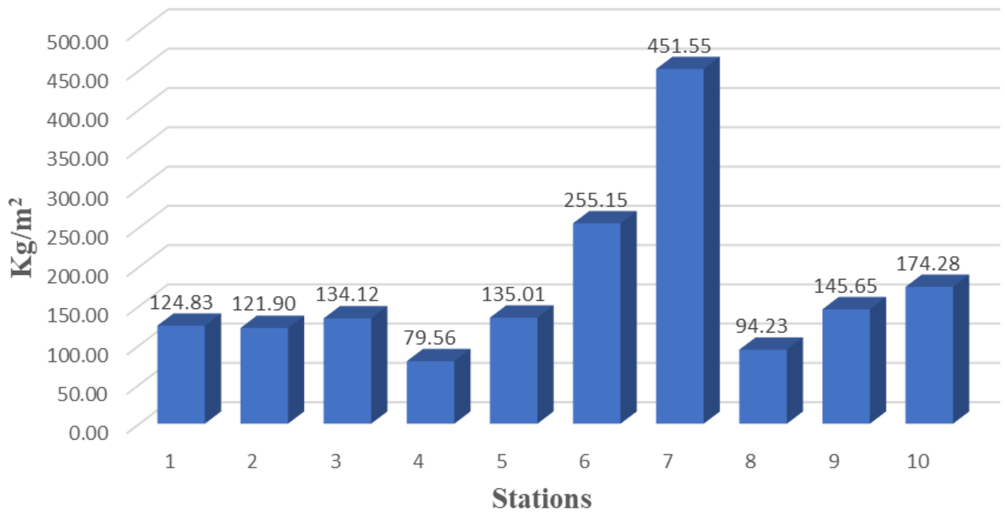

Figure 2. Graph of Average Mangrove Biomass at Each Station

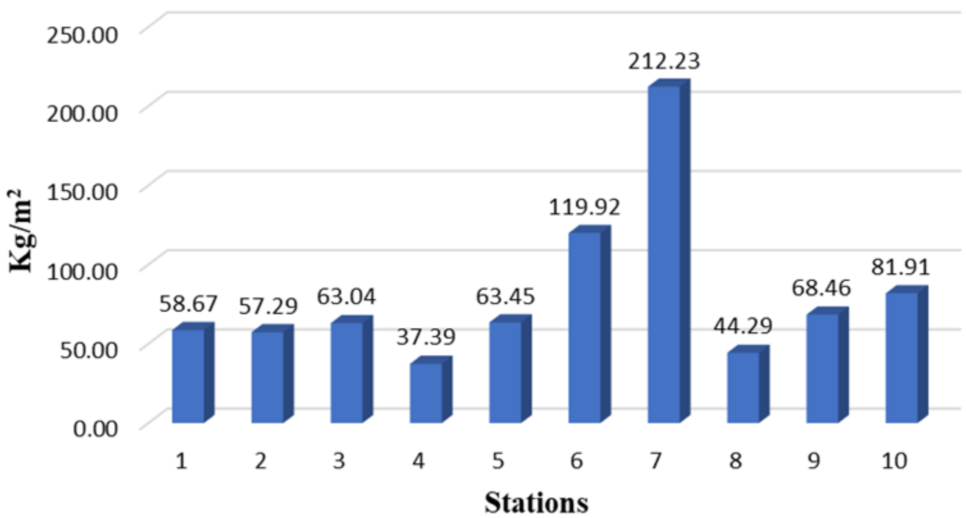

Figure3. Graph of Average Mangrove Carbon Content at Each Station

Based on the research that has been done, the average mangrove carbon content at Station 7 is greater than the other stations, with a value of 212.23 kg / m2. The station with the lowest average carbon content is Station 4, with a value of 37.39 kg / m2. The value of tree biomass is directly proportional to its carbon value, where the higher the biomass value, the higher the carbon value. This is because the value of the carbon content of organic material is 47% of the total biomass (National Standardization Agency for Indonesia, 2011).

The high carbon content at Station 6 and Station 7 compared to other stations is thought to be because the area is still well at this location has not experienced logging or high land clearing activities by the community, even though this area is close to the port. Meanwhile, at Station 4, part of the area has experienced logging and land clearing. Purnobasuki (2012) states that if forests are converted into agricultural lands or plantations, or ponds, the stored carbon will continue to decrease.

Soil Organic Carbon

Soil organic carbon is all soil organic matter at a certain depth, including fine litter with a diameter of less than 2 mm because it is difficult to distinguish. According to Supriyadi (2008), organic carbon is a priority for improving soil quality and for carbon storage.

The percentage value of sedimentary organic carbon in this study was obtained from data processing, different for each research station. The percentage value of organic carbon is obtained from the LOI (Loss on Ignition) ashes method to determine the organic matter and convert it to organic carbon. According to Dewanti et al., (2016), the primary source of soil organic matter comes from organic plant tissue, which can be in the form of leaves, twigs, stems, fruits and roots. Weathering results from fallen leaves of plants and organisms associated with plants that die and are degraded in sediment deposits. The carbon storage in the sediment shows how much the mangrove has the absorption capacity. Carbon products can come from weathering results from fallen leaves and organisms associated with mangroves.

Table 3. Average of Soil Organic Carbon per Depth

	Depth (cm)				
Station	**0-15**	**15-30**	**30-50**	**50-100**	**>100**
1	22.41	26.10	36.24	38.70	27.60
2	48.25	35.77	48.90	49.22	32.92
3	51.79	79.58	76.50	82.38	51.37
4	62.80	59.01	59.75	60.39	50.11
5	66.17	61.58	64.77	64.47	52.08
6	212.60	245.79	246.47	410.96	236.19
7	189.34	186.04	208.17	216.62	177.52
8	77.53	65.12	70.23	78.98	71.40
9	61.34	87.93	78.88	103.07	68.19
10	49.53	57.37	44.02	52.17	40.10
Average	**84.18**	**90.43**	**93.39**	**115.70**	**80.75**

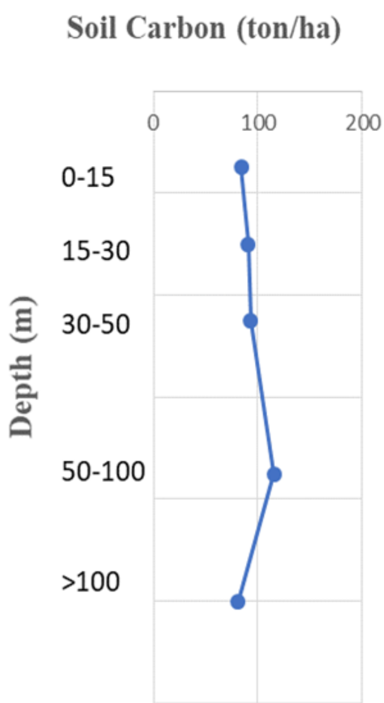

Figure 4. Graph of Average Soil Organic Carbon at Each Station per Depth

Graphical distribution of the average soil organic carbon storage per depth layer can be seen in Figure 4. The distribution of average soil organic carbon storage at a layer of 0 cm - 15 cm, 15 cm - 30 cm, 30 cm -50 cm, 50 cm -100 cm and> cm, respectively 84,18 ton C/ha, 90,43 ton C/ha, 93,39 ton C / ha, 115.70 tonnes C / ha and 80.75 tonnes C / ha (Figure 4). The soil layer at a depth of 50-100 cm is significantly different from the soil layer with a depth of 0-15 cm, 15-30 cm, 30-50 cm and> 100 cm. This is because the samples at this depth were taken more than the other depth samples. Siringoringo (2015) states, in this layer, the carbon value is more influenced by root density. Plant roots will release a number of organic compounds into the surrounding environment—these compounds such as lignin, suberin and rhizodeposition. In addition to organic compounds, the subsoil layer also contains microzoan fungi, and illuviation occurs through the mixing of sediment or soil by organisms. Soil organic carbon content has an important role in suppressing climate change; the increasing soil organic carbon content, the greater the soil can store CO_2 from the air in the form of organic matter in the soil (Mahasani et al., 2016).

CONCLUSION

Based on the results of this study, it can be concluded that the highest supplier of biomass is at location 7, and the lowest is location 4. The average distribution of soil organic carbon storage at a layer of 0 cm - 15 cm, 15 cm - 30 cm, 30 cm -50 cm, 50 cm -100 cm and> cm respectively is 84.18 ton C / ha, 90 , 43 ton C / ha, 93.39 ton C / ha, 115.70 ton C / ha and 80.75 ton C / ha.

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