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Carbon stocks of *Rhizhopora apiculata* and *Sonneratia alba* of mangrove forest in Ngurah Rai Forest Park, Bali Province, Indonesia

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Abstract

Mangrove forest is a typical tropical and subtropical forest, which is affected by sea tides. This study aimed to investigate the effect of pH, seawater salinity, and edaphic factors on carbon growth and stocks. The research plots were developed by employing transect method with a size of 20m x 50m for three plots along the beach. The pH value of plot A= 6.82, plot B= 6.90, and plot C= 7.26. The analysis of CEC elements found that plot A= 30.0, plot B= 25.2, and plot C= 25.4. The value of N-Total showed that plot A= 0.07, plot B= 0,07, and plot C= 0.04. The value of organic carbon was plot A= 2.1, plot B= 2.6, and plot C= 0.81. The results showed that the diameter of *Rhizophora apiculata* type in plot A, B, and C was 8.3±2.3cm, 8.4±2.8cm, and 8.9±3.3cm respectively, and that of *Sonnetaria alba* type in plot A, B, and C was 10.4±1.8cm, 9.0±3.8cm, and 8.5±1.5cm respectively. The biomass value of *R. apiculata* in plot A was 36.12ton ha^{-1}, B= 38.60ton ha^{-1}, and C= 45.94ton ha^{-1}, and the biomass value of *S. alba* in plot A, B, and C was 56.27ton ha^{-1}, 48.ton ha^{-1}, and 36.25ton ha^{-1} respectively. The value of carbon contents in *R. apiculata* in plot A, B, and C was 18.06ton ha^{-1}, 19.30ton ha^{-1}, and 22.97ton ha^{-1} successively. In addition, the value of carbon content in *S. alba* was 28.13ton ha^{-1} in plot A, 24.47ton ha^{-1} in plot B, and 18.12ton ha^{-1} in plot C.

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Introduction

Indonesia has the biggest mangrove ecosystems in the world, consisting of 27% (16.9 million ha) from the total mangrove forests in the world, and becomes the center of the distribution of species biodiversity and mangrove ecosystems (Spalding *et al*., 2014), however, it experienced rapid and dramatic destruction (Setyawan *et al*., 2003). Mangrove is a valuable treasure for Indonesian biodiversity with huge ecological and economical significances (Hema and Devi, 2015). Mangrove ecosystems also have a high economic value, either directly or indirectly, because the ecosystems have become one of meaningful income sources for the society and the country.

Mangrove forest is a typical tropical and subtropical forest type, growing along the beach and estuary affected by sea tides. Mangroves are generally found around coastal areas protected from the onslaught of waves and gently sloping terrain. Mangroves optimally grow in coastal areas with large estuary and in deltas whose water flow contains a lot of mud. On the contrary, mangroves do not optimally grow in coastal areas with no estuary. Mangrove is a valuable treasure for its biodiversity, ecologically and economically (Hema and Devi, 2015). Thus, services, approaches, and improvements to nearby society needs to be done in order to understand the mangrove ecosystems (Mukherjee *et al*., 2014; Nguyen *et al*., 2019). The role of mangroves the natural hazards and it is difficult for mangroves to grow in steep, choppy coasts with strong tidal currents because it does not allow the deposition of mud that is needed as a substrate for its growth (Spalding *et al*., 2014). Reduced-impact logging method can directly decrease emissions becaused using mono-cable winch on forest floors induced by logs skidding on top soil and injured with bark broken intensity for remaining stands (Ruslim 2011; Ruslim *et al*., 2016; Chien, 2019).

The land of mangrove forests in terms of the habitat and the ecosystems is a diffused environment that is formed by the encounter between marine environment and land environment which have a big impact on human life or even for their ecosystem balance. Since mangrove forest is always affected by excessive water throughout the year and is sometimes interspersed with drying in some parts in a short time, it may involve a chemical reaction of soil oxidation radicals Since mangrove forest growing in inhospitable environment in tropics and sub-tropics are equipped with very efficient free radical foraging system to withstand the variation of stress conditions (Thathoi *et al*., 2013). Mangrove plants may grow in different types of soil; therefore, their vegetation, species composition and structure may vary considerably at the global, regional, local region (Sherman *et al*., 2003)

The height and time of seawater flooding in particular locations during the high tide can also determine the salinity. The salinity is of factors determining the spread of mangroves. In addition, the salinity also becomes the limiting factor for particular spesies. Even though some mangrove species have a high mechanism adaptation towards salinity, however, if fresh water supply is not available, this will make soil and water salinity reach an extreme condition which is potential to threaten its life (Chen and Ye, 2014; Nyangon *et al*., 2019).

Mangrove forests as any other forests have a significant role as a carbon dioxide (CO_2) sink in the air. Carbon dioxide sink has a significant relation to tree biomass. Trees during photosynthesis process absorb CO_2 and convert it into organic carbon (carbohydrate) which is merged into the body of the trees. Mangrove can also provide food and shelter for various organisms, either in land or in water (Ekka and Pandit, 2012).

Essentially, the atmosphere receives more carbon than it ejects, as a result of burning fossil fuels, motor vehicles, and industrial machines which make carbon accumulated (IPCC, 2003). On the other hand, tropical forest deforestation also contributes in supplying carbon to the atmosphere (Defries *et al.,* 2002). This function is a part of ecosystem service which is not traded in the market but highly contributes to the human welfares (Barbier *et al*., 2011; Liquete *et al*., 2013; Ezebilo, 2016). Carbon stock was estimated from mangrove biomass referred as 50% of the value of biomass (Komiyama *et al*., 2005). Measurement of biomass was done in a non-destructive way. It was determined based on data from measurements of tree volume Bismark, 2008).

On the other hand, the amount of CO_2 absorption decreases as a result of deforestation, the change of land use, and residential development. The carbon accumulation in the atmosphere provokes greenhouse effects as sunlight shortwave trapped in the atmosphere that increases the temperature of the earth atmosphere. One of the forest ecosystems that is able to reduce the greenhouse effect and functions as climate change mitigation is mangrove forest (Komiyama *et al*., 2008). For the sake of human beings, the result of our observation showed that the stretch of mangroves and corals is the ecosystem that is most often rated, meanwhile the stretch of seaweed is not really taken into account (Mehvar *et al*., 2018).

During the high tide, the seawater often goes further to the inland. At this time the soil absorbs various nutrients from underground water. Enrichment of the soil on the surface can also occur through the movement of water. Therefore, the nature of the soil under the mangrove vegetation is also related to the chemical components under the groundwater. On the other hand, mangrove roots are essential for the coastal environment due to its function that can retain the soil under the mangrove forest from the seawater, so it can strengthen the coastline and maintain the land around the roots as an environment that is suitable for marine life breed.

The height and time of seawater-flooding in Ngurah Rai Forest Park during the high tide can determine salinity. The salinity is one of the determining factors of the mangroves spread. In addition, the salinity also becomes the limiting factor for particular species. Even though some mangrove species have a high mechanism adaptation towards salinity, however, if freshwater supply is not available, this will make soil and water salinity reach an extreme condition which is potential to threaten its life.

Based on the above descriptions, it can be stated that the spread of mangrove species is mainly affected by the condition of the waters where it grows while the growth of mangrove stands is influenced by edaphic conditions which cover physical characteristics and soil fertility where it grows. Mangrove forests like any other forests have a significant role including absorbing carbon dioxide (CO_2) in the air so that its existence contributes to controlling climate change.

The ability of mangrove forests in absorbing CO_2 is depending on the amount of stands biomass and carbon content of the soil where the forest grows. In order to support the function of Ngurah Rai Forest Park, especially as a means of developing science and educational facilities supporting cultivation, tourism and recreation, a study that can reveal the relationship between mangrove stands and their habitats is important to be conducted. From the above background this study aims to: (i) How is the physical condition and soil fertility of the mangrove forests in Ngurah Rai Forest Park and how many edaphic factors that affect the growth of mangrove stands. (ii) To measure the physical characteristics, chemical characteristics (pH, cation exchange capacity (CEC) and soil fertility (organic material components, total Nitrogen) of the mangrove forest habitat in Ngurah Rai Forest Park (iii) To evaluate the growth conditions of the mangrove forest habitat in Ngurah Rai Forest Park, including the number of trees, tree height, tree diameter, basal area, stand volume, stand biomass, and the content of carbon stands.

Materials and methods

Time and Location

The present study was conducted in mangrove forest located in the area of Kuta Municipality forest park, Bali Province (Fig 1).

Procedures

As adjusted to the research goals and objectives, this study consisted of 1) the making of transect lines from the seashore to the shore for the zoning of mangrove forest; 2) the making of sample plots along the transect lines; 3) the determination of tree species in the sample plots 4) measuring the tree diameter and height in the sample plots 5) testing the edaphic nature (soil physic/chemistery) in the sample plots and 6) testing the parameters of mangrove forest water such as subtracts, salinity, water pH, and carbon stock estimation. The sample plots were made by employing transect method with a size of 20m x 50m for three plots along the beach. The measurement was conducted based on commonly used criteria, which was the diameter of chest-tall tree trunks (130cm) or the topmost roots of the soil surface.

Fig. 1. Research location (■), Kuta Municipality forest park, Bali Province, Indonesia.

Data analysis

Productivity of mangrove stand

Data of mangrove species identification results were tabulated in Microsoft Excel to calculate the potentials of mangrove species at the studied area. Analysis of mangrove wood was done by calculating the total volume of standing stock (including height, diameter, basal area, and volume).

Basal area calculation

The conversion of the diameter obtained by using a diameter measuring tool was done by applying the following formula:

$$g = \frac{1}{4} \pi d^2$$

With g = basal area (m^2); and d = diameter breast height (cm);

Volume calculation

The tree volume was measured by using Ruchaemi formula (2006) as follow:

$$V = \frac{1}{4} \pi d^2 \times h \times f$$

With V = Tree volume (m^3); d = diameter breast height (cm); h = tree height (m) and f = form factor

Physical and chemical testing of the soil

The method used for parameter analysis of physical and chemical properties of the soil was based on Bogor soil research center and Wenworth scale. The place for soil analysis was in the soil laboratory of the Forest Rehabilitation Center Mulawarman University, Samarinda East Kalimantan.

Result and discussions

Soil Reaction (pH H_2O)

The pH value of particular water and soil reflects the balance between acid and base concentration in the water. The pH value of water is affected by some factors, such as photosynthesis activity, biology activity, temperature, oxygen content, and the existence of cations and anions in the water (Aksornkoae, 1993). The results of soil pH measurement in sample plots are presented on the Table 1.

Table 1. Test result data pH H_2O and of the soil in sample plots.

No	Parameter	Methods	Unit	Data Analysis								
				Plot A			Plot B			Plot C		
				0-30	30-60	Average	0-30	30-60	Average	0-30	30-60	Average
1	pH H_2O	Electrode	-	6.74	7.32	7.03	5.38	4.59	4.99	7.57	7.40	7.49
2	Ca^{++}	AAS	meq100gr^{-1}	8.59	9.93	9.26	2.22	2.35	2.29	10.80	1.89	6.35
3	Mg^{++}	AAS	meq100gr^{-1}	4.56	4.28	4.42	4.49	4.56	4.53	8.13	5.83	6.98
4	Na^{+}	AAS	meq100gr^{-1}	13.38	13.23	13.305	13.44	13.44	13.44	10.18	9.39	9.79
5	K^{+}	AAS	meq100gr^{-1}	2.89	2.24	2.565	3.70	4.12	3.91	1.89	1.66	1.78
6	KTK	Hitung	meq100gr^{-1}	30.00	30.10	30.05	24.51	25.97	25.24	31.58	19.27	25.43
9	Total N	Kjeldahl	%	0.10	0.04	0.07	0.08	0.06	0.07	0.04	0.04	0.04
10	C. Organic	Walkley and Black	%	2.29	1.92	2.105	2.71	2.49	2.60	0.84	0.77	0.81

The Table 1 shows that the mangrove forest soil inspected had a varying pH value. Plot C which was located closest to the beach had a neutral pH with highest average (7.49), while plot B which was located between plot A and plot C had an acidic pH with much lower value (4.99). On the other hand, plot A which was located furthest from the beach also had a neutral pH with average value of 7.03. The low pH value of the soil in plot B was because the mangrove stands in that plot produced more litter than in plot A and C. Through the decomposition process, besides producing minerals, the litter also secreted organic acid that made the soil pH become sour. The more litter produced in plot C than in the other plots was also indicated by the more organic carbon contents available (plot B= 2.60%; plot A= 2.10%; plot C= 0.81%).

The influence of frequency and time and the duration of water logging towards the pH value of mangrove forest soil was also reported by Nursin *et al.* (2014) through their study in Balinggi sub-district, Parigi Moutong region, Central Sulawesi. The other studies that revealed the same phenomenon were Ragil *et al.* (2017) through their study in mangrove forest in Mempawah Region, West Kalimantan. The result of this study about mangrove soil pH was compared to the other related studies such as 7) found that the mangrove soil pH in Muara Resort, Selangor, was 7.7, whereas Kamariah (2014) found that the mangrove forest in Mamuju Region, West Sulawesi had a pH value of 5.98-6.12. Onrizal and Kusmana (2008) informed soil and water quality take effect on mangrove growth in mangrove rehabilitation activities at east coast of North Sumatera. Regarding soil pH values in mangrove forests, Hasrun *et al.* (2013) stated that the water with pH value of < 4 is categorized as highly sour and potentially threaten the life of organisms. On the other hand, the water with pH value of > 9.5 is classified as highly alkaline and could also result in death for organisms and reduce productivity. On the contrary, plants can easily absorb carbon when the soil has a neutral pH (Setiawan *et al.*, 2013).

The correlation of seawater pH and total volume is shown in details through the following Fig 2 and Fig 3.

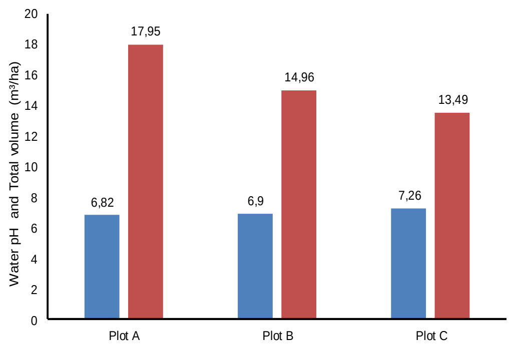

Fig. 2. The correlation of seawater pH and total volume of *Rhizophora alba* tree.

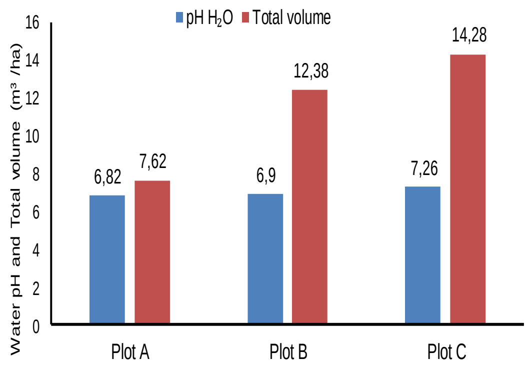

Fig. 3. The correlation of seawater pH and total volume of *R. apiculata* tree.

As shown on Fig. 2, the seawater pH was increasing from the direction of plot A (closest to land) to plot c (closest to sea), and it affected the decreasing of the tree total volume. From this phenomena, it can concluded that *S. alba* mangrove had a less tolerant nature towards seawater pH on particular limits. On the contrary, Fig. 3 shows that the volume of *R apiculata* tree increased as the seawater pH increased. It proved that this type of mangrove was tolerant to the seawater pH.

Organic Carbon (C)

Soil organic matter is of soil components derived from the rest of dead animals and plants, both in the form of original and weathered tissues. The main resources of soil organic matter in the sample plots were the litters of mangrove stands such as the components of leaves, twigs, branches, stems and roots. According to Lee *et al.* (2014), organic matter has a productive function to support plant biomass production and a protective function to keep the soil fertility and soil biotic stability.

Generally, the soil C concentration of the sample plots had a status of very low to moderate with values between 0.81 to 2.60%. the lowest C concentration was found in plot C which was located closest to the beach. The higher frequency and duration of the waterlogging in plot C do not only limit the chance of piles of dropping organic matter on the forest floor, but also limit the rate of decomposition of organic matter on the forest floor. Ferreira *et al.* (2007) stated that the decomposition of soil organic matter under mangrove stands is highly affected by frequency, duration of waterlogging, and distribution of its subtract particle size. The estimation of soil carbon concentration in mangrove forests in the study areas was in line with that reported by Handoko *et al.* (2017) who conducted a study in Balinggi sub-district, Parigi Region, Central Sulawesi. She found that soil carbon concentration in that area was 0.34-2.34%. A higher figure was reported from a study by Ragil *et al.* (2017) stating that the soil C concentration was 3.99-5.05% (high to very high), based on their study conducted in mangrove forest in Mempawah Region, West Kalimantan.

Total Nitrogen

Nitrogen is an essential element for plants, functioning to improve vegetative growth. The main resource of N in forest mangrove soil is the litters produced by mangrove stands as well as other dead organic material components that have been accumulated on the forest floor. The decomposition of the organic matter to be minerals, including N, is highly affected by inundation periodization. The anaerobic conditions when the floor flooded causes litter decomposing microorganisms restricted, otherwise, in aerobic conditions when the floor is not flooded, the microorganism activity increases. The total N concentration in mangrove forest soil in the sample plots is presented on Table 1.

Table 1 shows that soil N concentration in the depth of 0-60cm in the sample plots was very low, only about 0.04-0.10%. In plot A and B, the soil N concentration in the depth of 0-30cm was higher than that in the depth of 30-60cm. However, in plot C, the soil N concentration in both layers was similar. The impact of the flood on organic material mineralization process to be N could be seen from the lower N concentration in the depth of 0-30cm in plot C which was bordering with the beach compared to plot A and B respectively. Plot was located the furthest from the beach, whereas plot C was located in between plot C and A.

The estimations of soil N concentration value as reported by the researchers are as follows: 0.27-0.45% (status: moderate) in mangrove forest in Mangunharjo, Semarang Region (Chrisyariati *et al.*, 2014); and 0.29-0.43% (status: moderate) in mangrove forest in Mamuju Region, West Sulawesi (Malik *et al.*, 2019).

Cation Exchange Capacity (CEC)

Overall, the average value of CEC for the mangrove soil studied in the depth of 0-60cm, categorized as high, was 25.2 – 30.0 me $100g^{-1}$. In plot A and B, the CEC value of topsoil and subsoil was relatively similar, while in plot C there was a significant difference. As mentioned before, there are two factors affecting the high and low of soil CEC, namely organic matter content and its mineral clay content.

The result shows that the highest CEC value for mangrove forest soil in this study was in the depth of 0-30cm in plot C (31,6 me $100g^{-1}$). Since the soil organic matter content was lower than that in the other plots (see Table 4), the factor causing the high CEC value of the soil in the depth of 0-30cm was the clay content which was higher than in plot B or plot A (Table 1).

In the layer of 30-60cm, the CEC value of the soil in plot C significantly decreased to 19.3 me $100g^{-1}$ even though the clay content was not really different from that in the layer of 0-30cm (11.5%). This is interesting because despite its lower clay content, 10.6%, the soil in the depth of 30-60cm in plot A had a higher CEC value (30.1 me $100g^{-1}$) than in plot C. I may be because the soil in plot A had higher organic matter content (2.10%) than in plot C (0.77%).

Cation Exchange Capacity (CEC) is the soil chemical nature highly related to the soil fertility. The soil with higher CEC is able to absorb and provide nutrients better than the soil with lower CEC. The soils with organic matter content or with higher clay content consisted of higher CEC compared to the soils with lower or sandy organic matter content (Soewandita, 2008). The CEC value of soil is influenced by the soil weathering level, organic matter content and the number of alkali cations in the soil. The soil with higher organic matter content had higher CEC, so did young soil with newly started weathering level, and soils with further weathering levels had low CEC value.

The Condition of Mangrove Forest Stands In Ngurah Rai Forest Park

The mangrove in plot A (Distal zone or the furthest zone from sea), plot B (Midle zone or middle zone), and plot C (Proximal zone, the closest zone from sea) was carried out an inventory covering number of trees, diameter at breast height (DBH), the height of free trunk (TBC), the total height (TTL), the width of basal area (LBD), and the total volume (VT). Besides, the calculation was also done towards the amount of biomass and the content of carbon stands in each of those researches. The types of mangrove available in the research plots only consisted of *R. apiculata* and *S. alba*.

The Density and Types of Tree Stands

The number of trees in a research plot was not the same. Plot B had the most number of trees, including 272 trees, each of 162 trees of *R. apiculata* type and 110 trees of *S. alba*. Plot C had 220 trees, each of 110 trees of *R. apiculata* and *S. alba*. In the hectare unit, the numbers of trees in each plot were: plot A 1.950trees, plot C 2.200 trees and plot B 2.720trees, the total of trees $438ha^{-1}$ and $517ha^{-1}$ reached the study result in Mentawir Village Balikpapan, Kalimantan Timur of $2{,}300ha^{-1}$, Lahjie *et al.*, 2019; Kristiningrum *et al.* (2019). The stand density of mangrove forests in eastern coast of North Sumatera varied from 1,692ind ha^{-1} to 2,990ind ha^{-1} (Onrizal *et al.*, 2019a).

The density of mangrove tree stands in each plot tended to be influenced by each clay content. Plot B with the highest tree density (2720 trees ha^{-1}), also had the highest clay content (11,40-14,30%). Followed by plot C with the number of 2.200 trees ha^{-1} and clay content 11, 50-12,70%, and plot A with the number of 1950 trees ha^{-1} and clay content 6,50-10,60%. As described by Hossain and Nuruddin (2016), clay fragment is a supporting factor of the regeneration process, where the clay particle in the form of mud will catch the mangrove fruit that falls when it is ripe. This process determined whether a zone was dense or not.

Comparing the study results from Tolangara and Ahmad (2017) in Bacan mangrove forest, Halmahera Selatan Regency which resulted in the density of the tree of 1.500 ha^{-1} so the number of trees per hectare in Mangrove Forest in Tahura Ngurah Rai for the three observing plots were considered denser. But if compare with the study result of Handoko *et al.* (2017) at 12 research plots of mangrove forest in the area of South Rupat Island, Pekanbaru, with the density value ranges between 2.592 trees ha^{-1} until 8.148 trees ha^{-1}, therefore the tree stands of mangrove forest in Tahura Ngurah Rai was much lower.

The types of R. apliculata and *S. alba* were the two types of mangroves that were available in all research plots lying from the seashore (plot C) to the land (plot B and plot A). Generally outermost zone of mangrove with high salinity occupied by Avicennia associated with Sonneratia spp., while Rhizophora was located in the middle zone and Bruguiera grew in the furthest zone of the beach with much lower salinity. Onrizal *et al.* (2019b) said in muddy areas with high salinity levels which can grow *R. apliculata* species. The phenomenon of Rhizopora domination in the research area was suspected to be related to the low salinity of its water ecosystem. The typical water salinity in the research area of 14,8 -19,6% in reality was much lower than those reported by other researcher. The factors that influence high and low water salinity were evaporation and rainfall. The higher the level of evaporation of seawater, the higher the salinity would be. The higher rainfall, then the lower salinity would be.

Trunk Diameter

Based on attachment 1-6, it was known that trunk diameter of tree type *R. apiculata* in each research plot was : plot A = 8,3 ± 3,8cm, plot B = 8,4 ± 2,8cm and plot C 8,9 ± 3,3cm then the average value of trunk diameter for the whole plots was 8,56cm. in terms of the diversity of trunk diameter of each plot, it can be concluded that the growth of trunk diameter in plot A stands was more identical than other plots. Meanwhile, in plot C the growth of trunk diameter was largely diverse.

S. alba type tended to have a bigger trunk diameter. In plot A, its value was = 10,4 ± 1,8cm, plot b = 9,0 ± 3,8cm, plot C = 8,5 ± 1,5cm so the average value for all plots was 9,3cm. Trunk diameter of *R. apiculata* was bigger in plot A and even smaller in plot B and plot C which located further from the beach. Meanwhile, type *S. alba* showed the opposite. The closer to the land, the bigger the diameter was. Due to that matter, it was suspected that the growth of *R.apiculata* was better that the salinity in higher waters.

Climate affected the development of mangrove and the physical factor of its growing place was substrate and waters. Further, Alwikado (2014) reported that climate also affected the growth of mangrove through the light element, rainfall, temperature, and wind. The diameter growth and mangrove diameter increment growth were also influenced by many factors of its growing place including the substrate. The substrate in this study referred to a substrate containing soft mud. Furthermoe, Hastuti and Budhihastuti (2016) added that growth was the result of the interaction of various physiological processes. The physiological process referred to as photosynthesis, respiration, and transpiration. While the results that were reported by Kusmana *et al.* (2003) in mangrove Center Lampung were obtained from the diameter value of 7,5 – 9,7cm. Moreover, Pattipeilohy (2014) in Minahasa Utara Sub-district obtained the diameter value of 11cm.

Tree Height

As shown by its diameter growth, the average of total height growth of trees type *S. alba* (15,99m) was bigger than tree type *R. apiculata* (12, 19m). Hence, it can be concluded that as a whole that the condition of mangrove habitats in the research area is more suitable for *S. alba* than for *R. apiculata*. The results of the total height growth of trees type *R. apiculata* in each plot was: plot A = 13,08 ± 2,34m, plot B =10,57 ± 2,91m, plot C = 12,91 ± 2,68m while for type *R. alba* plot A= 15, 58 ± 5,99m, plot B = 16,28 ± 5,88m, plot C -16,11 ± 1,9m. For type *R. apiculata*, plot A resulted in a bigger height growth with a smaller coefficient of variation than those grew in other plots. The height growth and diameter of tree is not only depending on the space and surface canopy, relative humidity as well as root system, but also influenced by climate and soil fertility. Cuenca *et al.* (2015) stated the factors were complex and affected towards the distribution and mangrove growth including salinity, tidal drying, disturbance, warming, and predation. Meanwhile, Toknok (2006) in Donggala obtained the value of 13-20m.

The Width of Basal Area

According to the estimation conducted in the research location, Ngurah Rai Forest Park, Denpasar, it was revealed that the widths of the basal area of *A. apiculata* in plot A, B, and C were 0.006m^2 tree^{-1}, 0.006m^2 tree^{-1}, and 0.007m^2 tree^{-1} respectively. The average width of the basal area was 0.006m^2 tree^{-1}.

On the other hand, the widths of the basal area of *S. alba* were 0.009m² tree⁻¹ in plot A, 0.008m² tree⁻¹ in plot B, 0.006m² tree⁻¹ in plot C, and 0.008m² tree⁻¹ on average. Meanwhile, Aswita and Syahputra (2012) on their study in Seuruway sub-district, Aceh Taming Region, Aceh Province, reported that the width of the basal area of mangrove stands was 0.004m² tree⁻¹.

Stand Biomass and Carbon Content

The result showed that the average biomass of mangrove forest stands in the research location was 87.38ton ha⁻¹, consisting of *R. apiculata* biomass of 40.22ton ha⁻¹ (46%) and *S. alba* biomass of 47.16ton ha⁻¹ (54%). *S. alba* in plot A (located the furthest from the beach) and plot B (located in the middle) were higher than in plot C (located closest to the beach). The accumulation of the three plots was higher (12.7ton ha⁻¹) compared to the finding of the research conducted by Bindu *et al.* (2018). As shown on Table 2, in terms of the average number of trees in the three plots, actually, *S. alba* had a fewer number (107 trees) than *R. apiculata* (131 trees), however, in terms of tree average diameter and height (D=9.30cm; T=15.99 m), *S. alba* had a bigger size than *R. apiculata* (D=8.56cm; T= 12.19 m).

Table 2. Biomass and carbon content of each species of mangrove at Plot A, Plot B and Plot C.

No	Plot	Biomass (ton ha⁻¹)		Carbon (ton ha⁻¹)	
		R. apiculata	*S. alba*	*R. apiculata*	*S. alba*
1	Plot A	36.12	56.27	18.06	28.13
2	Plot B	38.60	48.95	19.30	24.47
3	Plot C	45.94	36.25	22.97	18.12
Total		120.66	141.47	60.33	70.72
Average		40.22	47.16	20.11	23.57
Average total		87.38		43.68	

Biomass is defined as the total number of organisms on the surface of a tree and is measured by using the ton unit of dry weight per area (Brown, 2004). The amount of biomass in particular mangrove forest is obtained from measuring the diameter, height, and wood density of each type of mangroves (Rachmawati *et al.,* 2014). Mangrove ecosystem has an ecological function to absorb and store carbon. Mangroves absorb CO_2 during the photosynthesis process and then change it into carbohydrate by storing it in form of biomass in roots, stems, branches, and leaves. According to Kauffman *et al.* (2012), carbon stocks in mangrove forests are higher than that in any other forests, where the biggest carbon stocks are contained in mangrove sediments. When compared to the biomass estimation from other studies the biomass of mangrove forest stands in research location was much lower. It may be affected by the difference of the number of trees ha⁻¹, the size of stem diameter, height as well as the wood density of types of mangroves making up of stands. Rachmawati *et al.* (2014) revealed that the biomass of mangrove stands in Wilayah Pesisir Muara Gembong, Bekasi Region was 108.6ton ha⁻¹. Meanwhile according to Kristiningrum *et al.* (2019) the average value of mangrove forest carbon at the studied area in Mentawir Village is 50.73tons C ha⁻¹. In addition, Bachmid *et al.* (2018) found that the biomass of mangrove stands in Kuburaya Region, West Kalimantan, was 189.2ton ha⁻¹. Kristiningrum *et al.*, 2019 informed the biomass of mangrove forests in Mentawir which is part of the Balikpapan Bay Area is one and a half times higher than that in Siberut Island, West Sumatra, which is 49.13tons ha⁻¹ (Bismark 2008). Kusmana *et al.* (2003) stated that muddy sediments are generally richer in organic matter compared to sandy sediments.

The relation between organic carbon and total volume of *R. apiculata* and *S. alba* can be seen at Fig 4 and Fig. 5.

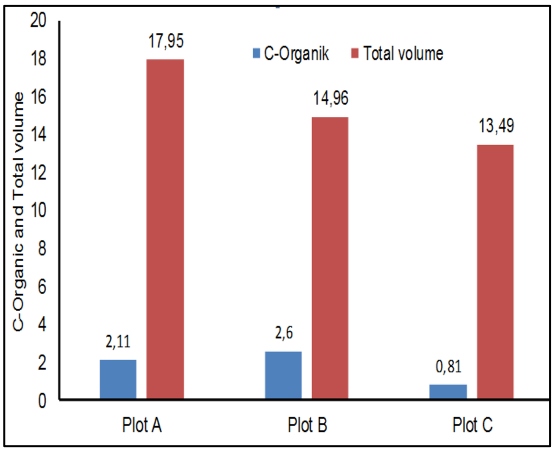

Fig. 4. The relation between organic C and total volume of *S. Alba*.

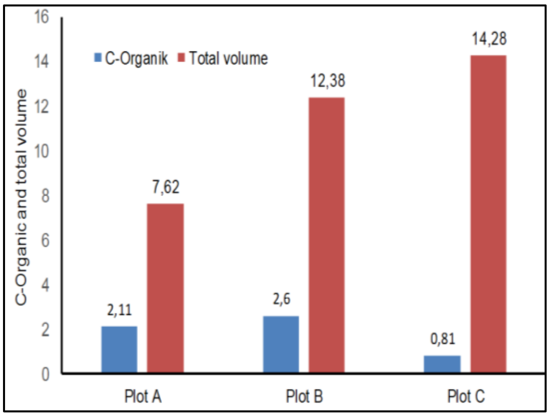

Fig. 5. The relation between organic C and total volume of *R. apiculata*.

Fig. 4 shows that in *S. alba* the organic C content was decreasing from plot A (closest to land) to plot C (closest to sea), and so did the total volume of the trees. It can be concluded that *S. alba* really needs organic C to increase its total volume. On the contrary, Fig. 5 shows that in *R. apiculata* the organic C value decreased, however, the tree total volume was increasing. It proves that *R. apiculata* is able survive in the areas with lower organic C.

The average value of water pH was 7.03% in plot A, 4.99% in plot B, and 7.49% in plot C. Furthermore, the organic C value was 2.1% in plot A, 2.6% in plot B, and 0.81% in plot C. On the other hand, the total N value was 0.07% in plot A, 0.07% in plot B, and 0.04% in plot C. The CEC value was 30.0 me $100g^{-1}$ in plot A, 25 me $100g^{-1}$ in plot B, and 25.4 me $100g^{-1}$ in plot C. The basal area of *R. apiculata* was 0.006 m^2 $tree^{-1}$ in plot A, 0.006 m^2 $tree^{-1}$ in plot B, and 0.007 m^2 $tree^{-1}$, whereas the basal area of *S. alba* was 0.009 m^2 $tree^{-1}$ in plot A, 0.008 m^2 $tree^{-1}$ in plot B, and 0.006 m^2 $tree^{-1}$ in plot C. The biomass value per ha for *R. apiculata* was 36.12ton ha^{-1} in plot A, 38.60ton ha^{-1} in plot B, and 36.25ton ha^{-1} in plot C, meanwhile the biomass value of *S. alba* was 56.27ton ha^{-1} in plot A, 38.60ton ha^{-1} in plot B, and 36.25ton ha^{-1} in plot C.

The value of carbon stock per ha for *R. apiculata* was 18.06ton ha^{-1} in plot A, 19.20ton ha^{-1} in plot B, and 22.97ton ha^{-1} in plot C. On the other hand, the value carbon stock per ha for *S. alba* was 28.13ton ha^{-1} in plot A, 24.47ton ha^{-1} in plot B, and 22.97ton ha^{-1} in plot C.

Conclusions

The results showed that the diameter of *R. apiculata* type in plot A, B, and C was 8.3±2.3cm, 8.4±2.8cm, and 8.9±3.3cm respectively, and that of *Rhizophora alba* type in plot A, B, and C was 10.4±1.8cm, 9.0±3.8cm, and 8.5±1.5cm respectively.

The biomass value of *R. apiculata* in plot A was 36.12ton ha^{-1}, B= 38.60ton ha^{-1}, and C= 45.94ton ha^{-1}, and the biomass value of *S. alba* in plot A, B, and C was 56.27ton ha^{-1}, 48.ton ha^{-1}, and 36.25ton ha^{-1} respectively. The value of carbon contents in *R. apiculata* in plot A, B, and C was 18.06ton ha^{-1}, 19.30ton ha^{-1}, and 22.97ton ha $^{-1}$ successively. In addition, the value of carbon content in *S. alba* was 28.13ton ha^{-1} in plot A, 24.47ton ha^{-1} in plot B, and 18.12ton ha^{-1} in plot C.

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