Estimation of mangrove biomass and carbon absorption of *Rhizophora apiculata* and *Rhizophora mucronata* in Banda Aceh, Aceh Province

I Dewiyanti¹²*, M martunis¹, S Agustina³

¹Marine Biology Laboratory, Faculty of Marine and Fisheries, Universitas Syiah Kuala, 23111, Indonesia
²Marine and Fisheries Research Center, Universitas Syiah Kuala, Indonesia
³Marine Chemistry and Biotechnology, Faculty of Marine and Fisheries, Universitas Syiah Kuala, 23111, Indonesia

*E-mail: irmadewiyanti@unsyiah.ac.id

**Abstract.** Mangrove ecosystems can reduce CO₂ through a mechanism of sequestration which is absorption of carbon from the atmosphere and its storage in several compartments such as plants, litter and soil organic matter. The purpose of this study was to determine carbon uptake in the mangrove vegetation of *Rhizophora apiculata* and *Rhizophora mucronata* in Banda Aceh. The research was carried out in two sampling sites, those were Gampong Jawa and Lambaro Skep Banda Aceh on January to March, 2018. This research was conducted at Marine Chemistry and marine Biology Laboratory, Faculty of Marine and Fisheries, Syiah Kuala University. The method used in this study was destructive sampling method. The results of the study showed that the amount of carbon absorption by *Rhizophora apiculata* and *Rhizophora mucronata* were 4033.33 g CO₂/tree and 3888.36 g CO₂/tree, respectively. The results of statistical calculations using the t-test showed that the carbon absorption of *Rhizophora apiculata* and *Rhizophora mucronata* did not different significantly, where the value of p > 0.05 (p = 0.33). Furthermore, the differences between sites also showed that the two stations were not significantly different, with a value of p > 0.05 (p = 0.47).

1. Introduction

Mangroves are one of the green plant ecosystems that can live in salty waters and tidal areas along the coastal area. Ati et al. [1] stated mangrove could be one of the blue carbon parameters, because of its role in utilizing CO₂ for photosynthesis and storing it not only in the form of biomass but also in sediments. Moreover, mangrove ecosystems have a function as coastal protectors, microclimate balancing, preventing seawater intrusion, habitat, foraging places, nurturing and enlargement, spawning sites, and as carbon sinks [2]. The amount of biomass in an area is thought to be obtained from measurements of diameter, height and wood density of each type of mangrove [3]. According to Kauffman et al [4] carbon deposits in mangrove forests are higher than carbon deposits in other forest types. Furthermore, mangroves vegetation are considered as an important component in climate change mitigation and reducing emissions from deforestation and degradation (REDD+) schemes [5].

According to research conducted by Donato et al. [6] in 25 mangrove forest areas throughout the Asia-Pacific region recorded that the mangrove forest contains 1023 Mg C / ha. This is equivalent to
10% of global emissions even though it is only 0.7% of all tropical forest areas. Based on the results of the previous study conducted in the island of Cawan, Indragiri Hilir Regency, Riau found that *Rhizophora* sp. is the most dominant species that has carbon quite larger than other mangrove species which was 45.51 tons/ha [7]. Mangrove vegetation in Banda Aceh initially had a very large area. The mangrove vegetation in Banda Aceh and Aceh Besar has undergone a change an area, where since 2000 there has been a shift in function into fishpond and residential housing. Rehabilitation program has been carried out since 2005 after tsunami with rehabilitation activities. The tremendous amount of total carbon sequestered and stored in the biomass and mangrove sediment [8]. The importance of measuring carbon absorption because by knowing the amount of mangrove carbon absorbed, it will better understand the ecological benefits of mangroves as carbon sinks and efforts to conserve mangrove in order to reduce global warming [9]. Therefore, the purposes of the present study were to determine biomass and carbon absorption in the mangrove vegetation of *Rhizophora apiculata* and *Rhizophora mucronata* in Banda Aceh City, Aceh Province.

2. Materials and Methods

2.1 Study Area

The present study was carried out in the mangrove ecosystem located in Gampong Jawa and Lambaro Skep, Banda Aceh (Figure 1) which began in January to March 2018. Species identification and chemical preparation i.e. oven drying of mangrove component, and measurement of mangrove biomass were conducted at the Marine Biology and Marine Chemistry Laboratory of the Faculty of Marine and Fisheries, Syiah Kuala University.

![Research Map](image)

**Figure 1.** The map of study sites located at Banda Aceh city.

2.2 Data Collection Procedure

The process of collecting data in this study was carried out in two stages, the first step was data collection in the mangrove field and the second was laboratory data collection. The method used to estimate biomass of vegetation was destructive sampling method. The destructive sampling method is a method that requires a considerable amount to produce more accurate results and the vegetation must pull it out to determine its biomass [10]. Sampling in mangrove area consisted of mangrove species, tree height,
tree diameter and wet weight of each part of the tree such as stems, fruit, branches, branches, and roots. The mangrove vegetation taken in the study was vegetation with a standing height of 100-120 cm, where samples were taken at two stations (Gampong Jawa and Lambaro Skep) with 3 repetitions at each station, totally there were six sampling locations. One vegetation was taken from *Rhizophora apiculata* and *Rhizophora mucronata* in each sampling location. After measuring tree height at each sampling location, the mangrove was extracted. The selected mangrove plants will be divided into several parts, namely the stem, fruit, branches, leaves and roots and then weighed to determine the wet weight of each part of the plant. Furthermore, the mangrove components were oven dried in the laboratory to obtain data on the amount of dry weight and moisture content of mangrove vegetation.

2.3 Collection of laboratory data
Mangrove samples were separated based on components including roots, stems, leaves, branches, twigs and reproductive organs (flowers and fruits). The litter sample was oven dried at 70°C for 48 hours and weighed until the constant and final dry weight was recorded with a precision of 0.01 g. Before oven dried, all parts of the sample had been cut into small pieces to make drying time will be the same. Oven dried was used to get the dry weight and biomass of each part of the plant [11].

2.4 Data Analysis
Carbon content in vegetation is calculated using formula as below [12, 13]:

\[ \text{Carbon content (g)} = \text{Plant dry weight} \times 50\% \]  

(1)

Calculation of carbon dioxide (CO$_2$) uptake is carried out using electricity as below [11]:

\[ \text{CO}_2 (g) = \frac{\text{Mr CO}_2}{\text{Ar C}} \times \text{Carbon content} \]  

(2)

or \[ \text{CO}_2 (g) = 3.67 \times \text{Carbon content} \]  

(3)

Where CO$_2$ is Carbon Dioxide Uptake, Mr is Relative Molecule, and Ar is Relative Atom

In addition, statistical t-test were used to determine the difference of carbon absorption between *Rhizophora apiculata* and *Rhizophora mucronata*, and the difference between two stations as sampling location.

3. Results and Discussion
3.1 Composition of Mangrove species in sampling location
There were two mangrove species were dominated found in study area namely *Rhizophora apiculata* and *Rhizophora mucronata*. Number of individual of *R. apiculata* and *R. mucronata* was higher than other mangrove species because the *Rhizophora* sp. which species could live in various types of substrate and cosmopolitan mangrove species [14, 15]. The substrate in the study area was categorized as very fine substrate and mixed with sand and clay. Based on the research conducted by Rahman [16] in the Tallo Makassar river region, mangroves commonly found in the subtle or muddy substrate are *Rhizophora* sp. In addition to the appropriate substrate, the mangrove species of *Rhizophora* sp. is also dominant because the research location was rehabilitation area and homogeneity mangrove plantation. *Rhizophora* sp. is the common species planted in rehabilitation areas and this species is a dominant type of mangrove that grows on the coast of Banda Aceh and Aceh Besar, Aceh Province [17]. *Rhizophora* sp. is true mangrove species and it has exclusively restricted to tropical intertidal habitat and does
not extend into terrestrial plant community. Furthermore, these species are morphological, physiologically and reproductively adapted to saline, waterlogged and anaerobic condition [18].

3.2 Plant biomass and carbon absorption
Biomass is a basic calculation in forest management, this is because forests are the largest area of carbon storage and absorption [19]. Biomass is the amount of living material contained in trees and is expressed in units of tons of dry weight per unit area [20]. The amount of biomass in a plant can illustrate how much plants can bind carbon dioxide (CO$_2$) from the air. Every carbon dioxide absorbed from the air is not entirely oxygen, but some carbon dioxide will become energy for plant physiology and some will enter into plant structures and become part of plants for example, cellulose stored in stems, roots, twigs, and leaves [21]. The results of the calculation of biomass and absorption of carbon dioxide (CO$_2$) mangroves of the $R$. apiculata and $R$. mucronata species in the study area were listed in the following table 1 and table 2.

Table 1. Biomass of $R$hizophora apiculata and $R$hizophora mucronata in study area

| Species             | Height (cm) | Biomass (g/tree) | Total |
|---------------------|-------------|------------------|-------|
|                     |             | Leaf  | Branch | Twig | Stem | Root |       |
| $R$. apiculata      | 120         | 535   | 125    | 101  | 960  | 477  | 2198  |
| $R$. mucronata      | 120         | 604   | 120    | 79   | 843  | 473  | 2119  |

Table 2. Carbon Absorption of $R$hizophora apiculata and $R$hizophora mucronata in study area

| Species             | Height (cm) | Carbon Absorption (g/tree) | Total |
|---------------------|-------------|----------------------------|-------|
|                     |             | Leaf  | Branch | Twig | Stem | Root |       |
| $R$. apiculata      | 120         | 981.73| 229.37 | 185.33| 1761.60| 875.29| 4033.33|
| $R$. mucronata      | 120         | 1108.34| 220.20 | 144.96| 1546.90| 867.95| 3888.36|

Table 1 and 2 showed that in each part and species of trees have different amounts of biomass and carbon uptake. The stem components of mangrove plants were the highest biomass and carbon dioxide (CO$_2$) absorption. The data shows that the two types of samples have the highest biomass and carbon uptake in the stem component. $R$. apiculata had a biomass of 960 g / tree with absorbed carbon of 1761.6 g CO$_2$ / tree. Moreover, $R$. mucronata had a biomass of 843 g / tree and carbon absorption was 1546.9 g CO$_2$ / tree. Mangrove forests can store more than three times the average carbon storage per hectare by terrestrial tropical forests [22], the optimal function of carbon sequestration by mangroves reaches 77.9%, where the carbon absorbed is stored in mangrove biomass parts such as stems, leaves, and roots and the biggest carbon store is in the stem [23]. Aminudin [24] mentioned that the mangrove absorbs carbon dioxide (CO$_2$) and then releases it in the form of O$_2$, so that carbon (C) which is absorbed by plants becomes a linear sugar molecule which is a constituent of cellulose, where cellulose is the main constituent of wood which is most stored in the stem. This is also reinforced by the results of previous research conducted by Hapsari [25] where the stem was the highest part of biomass is found in the study area. On the contrary, Nurruhwati [26] stated that the highest carbon content was found in the $R$. mucronata root at 40.69 % which is equal to 129 grams and in the stem was 35.37 % which is equal to 95.5 grams. Additionally, the value of the carbon content of the roots did not vary with the stem because the characteristics of its constituent substances are almost the same [26].

Biomass and carbon absorption of leaves were higher than branches, roots, and twigs, this was inseparable from the role of leaves as a place where photosynthesis occurs and carbon dioxide is
absorbed and then processed into food substances and then circulated throughout the tree. Tree growth through photosynthesis is used by plants for growth in a horizontal and vertical direction [27]. The lowest biomass found in twig organs was due to the role of twigs that are not too large in storing carbon and smaller branch sizes made least the biomass is compared to other components.

The results of biomass and carbon dioxide uptake (CO2) showed that the R. apiculata with a height of 120 cm had a biomass of 2198 g / tree and this species can be absorbed as much as 4033.33 g CO2 / tree. Conversely, R. mucronata with a height of 1219 g / tree and the carbon absorption was 3888.36 g CO2 / tree. The ability of mangrove forest to sequester and store carbon depends on plant species diversity, plant component, soil condition, climate, and geography [28]. Biomass and carbon absorption was higher in R. apiculata assumed because the diameter of the stem was bigger even though they have the same in age and height. The results of research conducted by Iswandar [29] in the coastal mangrove area of Iboih, Sabang also showed that the mangrove species of Rhizophora sp. has a very important role in the potential for carbon sequestration, this is based on the magnitude of the absorption potential and carbon content produced by this type. He found that Rhizophora sp. with a height of 180 cm had biomass and carbon absorption of 11632 g / tree and 21344.73 g CO2 / tree, respectively and this amount higher than Bruquiera sp. Mukmin [30] found that at Cawan island, Indragiri Hilir Regency, Riau Province had the average carbon absorption of Rhizophora sp. was 167.02 tons CO2 / ha. Furthermore, Bismark et al [23] stated Rhizophora sp. absorbed 180.31 tons CO2 / ha conducted at the Subulen River in West Sumatra. The amount of biomass and carbon dioxide in the mangrove species is inseparable from the height and diameter of the trees, the larger the tree, the greater of potential for carbon uptake. Trees absorb carbon dioxide from the air through the leaves, twigs, stems, roots which are then carried out by photosynthesis on the leaves, then convert it to organic carbon (carbohydrates) and then store it in the form of biomass on the stems, leaves, roots, branches and twigs [31].

The results of statistical calculations using the t-test (table 3 and 4) showed that the carbon absorption of Rhizophora apiculata and Rhizophora mucronata did not differ significantly, where the value of p > 0.05 (p = 0.33). It assumed because the time planting in two locations was similar and the size of mangroves in two locations was not significantly different. Furthermore, the differences between station also showed that the two stations were not significantly different from the carbon absorption, with a value of p > 0.05 (p = 0.47). The sampling location had similar characteristics in environmental physical and chemical of waters such as temperature, salinity, pH and dissolved oxygen and substrate characteristic (mixed between sand and silt).

### Table 3. T-test analysis between two species

| Species              | P-sig |
|----------------------|-------|
| Rhizophora apiculata | 0.33  |
| Rhizophora mucronata |       |

### Table 4. T-test analysis between two sampling location (station)

| Station | P-sig |
|---------|-------|
| Station 1 | 0.47  |
| Station 2 |       |

4. Conclusion
The number of individual of R. apiculata and R. mucronata was higher than other mangrove species. The amount of carbon absorption in the mangrove of R. apiculata was higher than R.mucronata were
4033.33g CO₂/tree and 3888.36g CO₂/tree, respectively. The biomass and carbon absorption was higher in the mangrove stem followed by leaf, root, branch and the last was a twig. The t-test showed that the carbon absorption of *Rhizophora apiculata* and *Rhizophora mucronata* did not differ significantly not only between two species but also between two sampling location where P<0.05.

**Acknowledgment**

We would like to express our gratitude to head of Gampong Jawa and Lambaro Skep for they help during the research. Our deepest thanks to the local people in study area for their supporting and very good cooperation. Thanks to Martunis, and Sri Agustina for their field work during the research study.

**References**

[1] Ati R N A, Rustam A, Kepel T L, Sudirman N, Astrid M, Mangindaan P, Salim H L, Hutahaean A A 2014 *Jurnal Segara* 10(2):98-171
[2] Suryono, Nirwani S, Edi W, Raden A, Edi F R 2018 *Buletin Oseanografi Marina* 7(1):1–8
[3] Rachmawati D, Setyobudiandi I, Hilmi E 2014 *Omni-Akuatika Journal* 10(2):85-91
[4] Kauffman J B, Heider C, Cole T G, Dwire K A, Donato D C 2011 *Wetlands* 31: 343-352
[5] Sahu S C, Manish K M, Ravindranath N H 2016 *Curr Sci* 110(12): 2253-2260
[6] Donato D C, Kauffman J B, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M 2011 *Nat Geosci* 4: 293-297
[7] Khairul M L, Aras M, Dessy Y 2017 *Estimasi Karbon Tegakan Rhizophora apiculata dan Karbon organic Tanah Di Ekosistem Mangrove Pulau Cawan, Indragiri Hilir, Riau*
[8] Widyastuti A, Ery Y, Ery K N, Rochmatino 2018 *Biodiversitas* 19(1): 246-252
[9] Imiliyana, Muryono A M, Purnobasuki H, *Estimasi stok karbon pada tegakan pohon Rhizophora stylosa di Pantai camplong, sampang-madura*. Fakultas Matematika dan Ilmu Pengetahuan Alam Institut Teknologi Sepuluh Nopember
[10] Mudiyarso D, Hairiah K, Noordwijk M V 1994 *Modelling and measuring soil organic matter dynamics and greenhouse gas emissions after forest conversion ASB-Indonesia Report number 1. Bogor*
[11] Heriyanto N M, Subiandono E 2012 *Jurnal Penelitian dan Konservasi Alam* 9(1):023-032
[12] Brown S, Sathaye J, Cannell M, Kauppi P E 1996 *Mitigation of carbon emissions to the atmosphere by forest management*. The Commonwealth Forestry Review 80-91
[13] IPPC (Intergovermental Panel on Climate Change) 2001 *Climate Change 2001: The Scientific basis* Cambridge University Press
[14] Bengen D G 2001 *Pedoman teknis pengenalan dan Pengelolaan Ekosistem mangrove. Pusat Kajian Sumber Daya Pesisir dan Lautan, Institut Pertanian Bogor*
[15] Aksornkoe S 1993 *Ecology and management of mangroves* IUCN wetlands program Bangkok, Thailand
[16] Rahmain 2017 *Jurnal Ilmu Kelautan* 11:19-28
[17] Dewiyantri I, 2005 *Jurnal Natural* 5(2):12-16
[18] Polidoro B A, Carpenter K E, Collins L, Duke N C, Ellison A M, Ellison J C, Farnsworth E J, Fernando E S, Kathiresan K, Koedam N E 2010 *The loss of species: mangrove extinction risk and geographic areas of global concern* PLoS ONE 5(4): e10095
[19] Jenkins C J, Chojnacky D C, Heath L S, Birdsey R A 2003 *Forest Science* 49:12-35
[20] Brown M S 1984 *The Mangrove Ecosystem: Research Methods*
[21] Hilmi E, Parengrengi, Resista V, Cecep K, Iskandar, Lilik K S, Setijanto 2017 *Regional Studies in Marine Science journal* 16: 0-9
[22] Donato D C, Kauffman J B, Murdiyarso D, Kurnianto S, Stidham M, Kanninen M 2011 *Nature Geoscience* 4(5) : 293-297
[23] Bismark M E, Subiandono, Heriyanto N M 2008 *Jurnal Penelitian Hutan dan Konservasi Alam* 5 (3):297-306
[24] Aminudin S 2008 Kajian Potensi Cadangan Karbon (Karbon Stock) Dengan Metode Karbonasi Pada Hutan Tanaman Jenis Acacia crassicarpa. Universitas Gadjah Mada. Yogyakarta
[25] Hapsari M R 2011 Pendugaan serapan karbon pada tanaman mangrove di Desa Sawah Luhur Serang, Banten. Fakultas Kehutanan Institut Pertanian Bogor. Bogor
[26] Nurruhwati I, Purwita S D, Sunarto, Zahidah 2018 IOP Conf. Series: Earth and Environmental Science 137:012065
[27] Ludang Y, Alpian A, Junaedi 2017 Jurnal Pengelolaan lingkungan berkelanjutan 1 (3):1-6
[28] Pandey C N, Pandey R, Khokhariya B 2012 Potential Area Mapping for Mangrove Restoration in South Gujarat Contributors Gujarat (India). Forest Department, Gujarat Ecological Education, and Research Foundation, India
[29] Iswandar M, Dewiyanti I, Kurnianda V 2017 Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan 2(4): 512-518
[30] Mukmin K L, Aras M, Dessy Y 2018 Jurnal Online Mahasiswa Vol 5
[31] Dharmawan I W S 2013 Jurnal Ilmu Pertanian Indonesia 15(1):50-56