Estimation of carbon stock in true mangrove stands in the Cipalawah Block of Sancang Sea Nature Reserve Garut West Java

L Amalia*, Y Juniarti, C Ardiana and I D Saputra

Program Studi Pendidikan Biologi, Institut Pendidikan Indonesia, Jl. Pahlawan No.32 Tarogong, Garut, Jawa Barat, Indonesia

*lidaamalia@institutpendidikan.ac.id

Abstract. This research aims to determine the estimation of biomass, carbon stock, density, and CO2 absorption of true Mangrove stands. This is important to know how much the area of the mangrove forest is able to absorb CO2 from the air, so that it can support the area's sustainable management activities in relation to reducing the concentration of CO2 in the atmosphere. The research method used is a quantitative descriptive method with purposive sampling data collection techniques. Based on the research results obtained 6 types of mangroves namely Sonneratia alba, Rhizophora gymnorhiza, Aegiceras corniculatum, Avicenia marina, Bruguiera gymnorhiza, and Xylocarpus granatum. Based on the calculation using allometric equations, biomass results were 277.945 tons/Ha, estimation of carbon stock was 127.855 tons/Ha, true mangrove stand density was 737 individuals/Ha, and total CO2 absorption of true Mangrove stands was 468.802 tons/Ha.

1. Introduction

The carbon element is one of the important chemical elements in human life. The respiration process of living things releases carbon in the form of carbon dioxide (CO2). Tree felling, burning, industrial activities, and motor vehicles also contribute to the release of carbon in nature. The main source of CO2 in the last decade has come from burning fossil fuels such as lubricating oil, gas, and fuel for motor vehicles, and industrial activities. The contribution from this sector is estimated at 65% of total emissions worldwide. In addition, 14% came from agricultural activities, 18% from forest destruction, domestic activities and waste decomposition [1,2].

Mangrove forest functions as a protector’s beaches and rivers from the risk of erosion and abrasion, withstand storms/strong winds from the sea and other natural disasters, also serves to treat toxic waste, producing O2 and CO2 absorbers [3].

Mangroves are able to store carbon from photosynthesis in the form of biomass that is spread to leaves, stems, wood, and litter. This shows that the mangrove ecosystem can play a role in efforts to mitigate global warming and global climate change by reducing CO2 concentrations [4]. Factors affecting carbon yields in mangroves are thought to be due to the shape of vegetation, species density, and tides [5]. Calculation of carbon stocks in a mangrove ecosystem can be used to determine the ability of the mangrove ecosystem to absorb gases that cause global warming. Efforts are made to reduce the concentration of CO2 in the atmosphere through the calculation of carbon stocks in mangrove stands [4,6].
South and Southeast Asia are the centers of the spread of the world's mangrove forests. This area has 41.5% of the world's mangrove area. While Indonesia has 25% of the total area of mangroves in the world, and 75% of the area of mangroves in Southeast Asia. Even today, Indonesia is still recognized as an area that has the largest mangrove habitat in the world [7].

Research on estimation of carbon stored in mangrove vegetation is important to know how large the area of mangrove forest is able to absorb CO$_2$ from the air. It can support sustainable management of the area in relation to reducing CO$_2$ concentrations in the atmosphere. If you already know the magnitude of carbon stocks stored in forests then the magnitude of the function of the area can be known in mitigating climate change [8,9]. The effort to find out the potential of mangrove forests as carbon sinks and their role in climate change mitigation can be done through research on estimations of stored carbon in mangrove forests.

One of the mangrove forests in the West Java region is located in the forest of the Sancang Sea Nature Reserve which is a conservation area located on the South coast of Garut, with an area of 15.061 Ha. Mangrove forest waters have unique characteristics because they are influenced by fluctuations in physical and chemical factors caused by tides.

Based on the description above, the purpose of this research is to find out:

- Biomass value and estimation of carbon stock in true mangrove stands in the Cipalawah Block of Sancang Sea Nature Reserve Garut West Java.
- Carbon dioxide (CO$_2$) uptake value for true mangrove stands in the Cipalawah Block of Sancang Sea Nature Reserve Garut West Java.

2. Methods

The research sample in the form of true mangrove plants sampled in each observation plot in the Cipalawah block. To determine the number of sample plots, the calculation is as follows:

- Sampling intensity (IS) = 10 %
- Research area sample = 15.061 Ha x 10 % = 1.5061 Ha (15,061 m$^2$)
- The area of the observation plot = 20 m x 20 m = 400 m$^2$
- Number of sample plots = (15,061 m$^2$) / (400 m$^2$) = 38 plots

This research is quantitative descriptive. Determination of the sampling station is done by purposive sampling method, which is to determine the location of the research intentionally by considering and attention to the condition of around the research area [10]. To get the data, the plot path technique is used [11]. Mangrove sampling was carried out using the quadrant plot transect method. Observation technique begins by making a stub line from the sea towards the mainland with the length of the stub line in accordance with the width of the beach to the land (coastal forest). Then a plot of 20 m x 20 m is continuously made along the pioneering line, starting from the mangrove area leading to the coastline (inland forest). In a plot measuring 20 m x 20 m a plot of 10 m x 10 m is then made, dividing it into 5 m x 5 m, then a 2 m x 2 m and a 5 m x 5 m plot [10]. This research was conducted in January - February 2020, at 9 observation stations where each station consisted of 1 transect line.

To determine the sampling intensity, the IS 10% is used, because for forest areas less than 1,000 Ha, the sampling intensity should be used 5% -10% [8]. To calculate the carbon stock is carried out by measurement and calculation as follows:

2.1. Stem diameter

The diameter of the tree trunk measured is the diameter at the breast height (1.3 m).

\[ D = 2r \]
\[ r = \frac{k}{2\pi} \]
2.2. Density
Density is the total number of individuals found during observation [3].
\[ K = \frac{I}{L_{Plot}} \times 10,000 \]

2.3. Mangrove biomass
Standing biomass measurements are based on diameter data obtained, then entered into the allometric formula [12]. Table 1 presented the allometric formula for the 6 species found at the research area.

| Species               | Allometric Model | \( \rho \)  |
|-----------------------|------------------|-------------|
| Sonneratia alba       | \( B = 0.3841 \times \rho \times D^{2.101} \) | 0.6443      |
| Rhizophora mucronata  | \( B = 0.1466 \times D^{2.3136} \) | 0.8483      |
| Aegiceras corniculatum| \( B = 0.251 \times \rho \times D^{2.46} \) | 0.5967      |
| Avicenia marina       | \( B = 0.1848 \times D^{2.3524} \) | 0.6987      |
| Bruguiera gymnorrhiza | \( B = \rho \times 0.0754 \times D^{2.505} \) | 0.741       |
| Xylocarpus granatum   | \( B = 0.1832 \times D^{2.21} \) | 0.6535      |

Information:
\( \rho \) = wood specific gravity.

2.4. Carbon stock
Carbon stock is estimated from biomass, by following the rules 46 % of biomass is carbon. Thus the estimated amount of carbon stock is by multiplying 0.46 with biomass [13].

2.5. Carbon dioxide uptake
To find out the carbon dioxide uptake by true mangrove plants, the results of the C (carbon) calculation must be converted to CO₂ using the following formula [14]:
\[ CO_2 = \frac{Mr \times CO_2}{Ar \times C} \times \text{Carbon content} \]

Information:
Mr = relative molecular mass (44)
Ar = relative atomic mass (12)

3. Results and discussion

3.1. Biomass
Based on observations of mangroves in the Cipalawah block of the Sancang Sea Nature Reserve, there were 6 species of true mangroves namely Sonneratia alba, Rhizophora mucronata, Aegiceras corniculatum, Avicenia marina, Bruguiera gymnorrhiza, and Xylocarpus granatum. Estimation values of biomass in true mangrove stands presented in the table 2 and 3.
Table 2. Biomass estimation based on station.

| Station | Biomass (tons/Ha) |
|---------|------------------|
| 1       | 23.152           |
| 2       | 24.467           |
| 3       | 25.029           |
| 4       | 19.894           |
| 5       | 18.450           |
| 6       | 47.899           |
| 7       | 64.118           |
| 8       | 47.474           |
| 9       | 7.462            |
| Total   | 277.945          |

Table 3. Biomass estimation based on species.

| Species                     | Biomass (tons/Ha) |
|-----------------------------|-------------------|
| *Sonneratia alba*           | 134.777           |
| *Rhizophora mucronata*      | 54.556            |
| *Aegiceras corniculatum*    | 2.607             |
| *Avicenia marina*           | 6.032             |
| *Bruguiera gymnorhiza*      | 14.289            |
| *Xylocarpus granatum*       | 65.684            |
| **Total**                   | **277.945**       |

Based on table 2, it can be seen that the results of the calculation of biomass from all types of true mangroves contained in the Cipalawah block using the allometric equation formula for each type obtained a total biomass value of 277.945 tons/Ha. The highest biomass was found at station 7 at 64.118 tons/ha and the lowest biomass was at station 9 at 7.462 tons/ha. Based on the species, in the table 3 the highest biomass was found in *Sonneratia alba* at 134.777 tons/Ha, while the lowest was in *Aegiceras corniculatum* at 2.067 tons/ha.

3.2. Carbon stock

The total carbon stock based on station, is in Table 4.

Table 4. Carbon stock estimation based on station.

| Station | Carbon Stock (tons/Ha) |
|---------|------------------------|
| 1       | 10.699                 |
| 2       | 11.255                 |
| 3       | 11.513                 |
| 4       | 9.151                  |
| 5       | 8.487                  |
| 6       | 22.034                 |
| 7       | 29.494                 |
| 8       | 21.838                 |
| 9       | 3.433                  |
| **Total** | **127.855**           |

The total carbon stock based on species is shown in Table 5.
Table 5. Carbon stock estimation based on species.

| Species                        | Carbon Stock (tons/Ha) |
|--------------------------------|------------------------|
| Sonneratia alba                | 61.997                 |
| Rhizophora mucronata           | 25.096                 |
| Aegiceras corniculatum         | 1.199                  |
| Avicenia marina                | 2.775                  |
| Bruguiera gymnorrhiza          | 6.573                  |
| Xylocarpus granatum           | 30.215                 |
| Total                          | **127.855**            |

Based on table 4 it can be seen that the Carbon stock that can be stored in true mangrove stands in the Cipalawah Block is 127.855 tons/Ha assuming that 46% of the biomass is Carbon stock [13]. Based on table 4, the highest Carbon stock is at station 7 with 29.494 tons/Ha and the lowest Carbon stock is at station 9 with 3.433 tons/Ha. Based on table 5, the highest Carbon stock was found in the Sonneratia alba at 61.997 tons/Ha and the lowest was in Aegiceras corniculatum at 1.199 tons/Ha. If compared with previous research on Shimma wallichii which has Carbon stock 49.766 tons/Ha, the Sonneratia alba stores more Carbon stock [15,16].

3.3. True mangrove density

The total density value of true mangroves in the Cipalawah Block of the Sancang Sea Nature Reserve is presented in Table 6.

Table 6. Value of density based on station.

| Station | Density (Individuals/Ha) |
|---------|--------------------------|
| 1       | 41                       |
| 2       | 69                       |
| 3       | 45                       |
| 4       | 55                       |
| 5       | 51                       |
| 6       | 122                      |
| 7       | 144                      |
| 8       | 173                      |
| 9       | 37                       |
| **Total** | **737**                 |

Table 7. Value of density based on species.

| Species                        | Density (Individuals/Ha) |
|--------------------------------|--------------------------|
| Sonneratia alba                | 198                      |
| Rhizophora mucronata           | 221                      |
| Aegiceras corniculatum         | 87                       |
| Avicenia marina                | 23                       |
| Bruguiera gymnorrhiza          | 103                      |
| Xylocarpus granatum           | 107                      |
| **Total**                      | **737**                  |

Based on table 6, the density of all true mangrove stands using the density index formula yields 737 individuals/Ha consisting of 6 species of true mangrove. The highest density at station 8 with a density value of 173 individuals/ha and the lowest density at station 9 with a density value of 37 individuals/ha. Based on table 7 species of Rhizophora mucronata has the highest density value of 221 individuals/Ha and Avicenia marina has the lowest density value with a density value of 23 individuals/Ha.
Each addition of biomass content will be followed by additional carbon content. This explains that carbon and biomass have a positive correlation so that anything that causes an increase or decrease in biomass will cause an increase or decrease in carbon content [17].

The greater the value of biomass in a tree stand, the greater the carbon stock stored in the tree stand. Based on the calculation of the estimated value of the largest carbon storage found in the type of *Sonneratia alba* of 61.997 tons/Ha. This is because of *Sonneratia alba* was found at every sampling station and almost sampled in every observation plot. In addition, the *Sonneratia alba* has a large trunk diameter, so it is able to store carbon in a greater amount than other true mangrove species.

The lowest carbon stock estimation is in *Aegiceras corniculatum* of 1.199 tons/Ha. Although *Aegiceras* is sampled in many stations, the stem size is relatively small compared to other types, because most *Aegiceras* diameters fall into the category of sapling whose diameters range from 2-10 cm and only a few belong to the type of poles that has diameter of 10-20 cm.

However, if carbon storage is calculated based on the total number of each sample per station, Station 7 stores the largest carbon stock of 29.494 tons/Ha. This is because in sampling locations many types of *Sonneratia alba* and *Xylocarpus granatum* are sampled. This station is bordered by direct plain forest which causes the *Xylocarpus granatum* type which has buttressed roots or plank roots to grow sturdy with a relatively larger trunk diameter compared to other stations, indicating that the age of the tree is relatively old.

While the sampling station that stores the least carbon reserves is at Station 9 with carbon deposits of 3.433 tons/Ha. This is because the sampling location of mangrove species sampled is dominated by *Rhizophora mucronata* which has a relatively small tree diameter and at this station observations were made on the mangrove island area which is separate from other sampling stations. It is located opposite the other station. Station 9 which is located on the mangrove island never recedes so that *Rhizophora mucronata* that grows even the diameter is not too large compared to *Rhizophora mucronata* that grows in other stations. This type of mangrove is not too tolerant of water salinity with high salt levels so that growth is stunted.

Factors that can cause differences in carbon storage at each station not only due to the composition of the true mangrove species sampled at each station, but also influenced by other factors, namely the type of substrate. The difference in the substrate at each station results in the composition of the mangrove species growing at each station being different, because each type of mangrove can only grow on the right type of substrate. In addition to the type of substrate, the width of the beach also affects whether or not many mangrove trees grow in the area.

In addition to the substrate, which causes different biomass and carbon stocks in each type and each station is the size of the diameter of the mangrove stand itself. Carbon stocks at various types and ages differ, so carbon and biomass reserves tend to get bigger with increasing plant age. The greater the diameter of a plant indicates its age is old, resulting in more stored biomass and carbon, then the value of stored biomass and carbon stock will be even greater. The size of the carbon stock stored in a mangrove ecosystem also depends on biomass and soil fertility and the absorption capacity of the mangrove itself [18].

Other major environmental parameters that determine the survival and growth of mangroves related to biomass are determined by fresh water supply, nutrient supply, and substrate stability [7]. Also influenced by abiotic factors of tides, sandy mud, ocean waves, gently sloping beaches, and so on [19].

Fresh water supply and salinity concentration control the metabolic efficiency of mangrove forest vegetation. Availability of fresh water depends on the frequency and volume of river and irrigation water systems from the land, the frequency and volume of tidal exchange water, and the rate of evaporation to the atmosphere. Nutrient supply, for the mangrove ecosystem is determined by various interrelated processes through the recycling of nutrient-based food webs based on detritus. The more nutrients that are processed, the better the growth of mangroves.

The true mangrove density is 737 individuals/ha. True mangroves grow in areas up littoral flooded by sea water at high tide. Based on observations of the highest density found at station 8. This is due to
station 8 the longest beach width which is approximately 160 m, as well as the large number of true mangrove species sampled in the observation process.

3.4. \( \text{CO}_2 \) (Carbon dioxide) absorption

The results of the calculation of the estimated conversion of carbon to \( \text{CO}_2 \) (carbon dioxide) are as follows:

\[
\text{CO}_2 = \frac{M_r \cdot \text{CO}_2}{A_r \cdot C} \times \text{Carbon content}
\]

\[
\text{CO}_2 = \frac{44}{12} \times 127.855
\]

\[
= 468.802 \text{ tons/Ha}
\]

Based on the calculation of total \( \text{CO}_2 \) absorption that can be absorbed in the Cipalawah block of Sancang Sea Nature Reserve 468.802 tons/Ha. The result of carbon dioxide uptake by mangroves that has been converted from the amount of carbon stock into the amount of carbon dioxide using the formula, the carbon dioxide absorption results are 468.802 tons/Ha. Carbon is one of the elements that undergo a cycle in the ecosystem. Carbon in the atmosphere moves through green plants (producers), consumers, and decomposition organizations, and then returns to the atmosphere. Marine and coastal areas including mangrove ecosystems are very influential on the world atmosphere [7]. Carbon dioxide is an essential part of air that can influence heat radiation from the earth and can form an inorganic carbon stock. The process of photosynthesis that occurs in green plants is the process of converting carbon dioxide as inorganic carbon into carbohydrates as hydrocarbon compounds in the plant’s body as energy as complex organic compounds through the help of sunlight.

Mangrove forests are able to absorb more carbon than terrestrial forest types, the process of photosynthesis converts inorganic carbon (\( \text{CO}_2 \)) into organic carbon in the form of vegetation material. In most ecosystems, this material decays and releases carbon back into the atmosphere as \( \text{CO}_2 \). However, mangrove forests contain large amounts of organic material that does not rot because the mangrove ecosystem is an aquatic ecosystem so that litter decomposition does not release carbon into the air but is stored in the form of organic deposits on the substrate. Therefore, mangrove forests function more as carbon sinks compared to carbon sources. In addition, mangrove plants have many leaves so they have the potential to absorb more carbon compared to other plants such as tropical forest plants which die releasing 50% of carbon into the air [1].

In addition to being one of the supporters in efforts to mitigate climate change by absorbing carbon in the form of \( \text{CO}_2 \) in the process of photosynthesis, mangroves can also reduce and absorb other types of pollutants, such as \textit{Rhizophora mucronata} can absorb Mn (Manganese) 300 ppm, Zn (Zink) 20 ppm, and Cu (Cufrum) 15 ppm. \textit{Avicenia marina} leaves accumulate Pb (Plumbum) 15 ppm, Cd (Cadmium) 0.5 ppm, and Ni (Nickel) 2.4 ppm [3].

4. Conclusion

Based on the results of research and data analysis that has been done, it can be concluded that the estimated value of biomass in true mangrove stands in the Cipalawah Block of the Sancang Sea Nature Reserve is 277.945 tons/Ha, while the estimated carbon stock is 127.855 tons/Ha, with a density of 737 individuals/Ha. The uptake of carbon dioxide in true mangrove stands in the Cipalawah Block of the Sancang Sea Nature Reserve is 468.802 tons/Ha.

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References

[1] Purnobasuki H 2012 Pemanfaatan Hutan Mangrove sebagai Penyimpan Karbon. Bulletin PSL Universitas Surabaya 28 3-5

[2] Chen H, Ye J, Zhou Y, Wang Z, Jia Q, Nie Y, and Benoit G 2020 Variations in CH$_4$ and CO$_2$ Productions and Emissions Driven by Pollution Sources in Municipal Sewers: An Assessment of the Role of Dissolved Organic Matter Components and Microbiota. Environmental Pollution 263, 114489

[3] Suryono A 2013 Sukses Usaha Pembibitan Mangrove Sang Penyelamat Pulau (Bantul: Pustaka Baru Press.)

[4] Irsadi A, Martuti N K T, and Nugraha S B 2017 Estimasi Stok Karbon di Dukuh Tapak Kelurahan Tugerejo Kota Semarang. Jurnal Sains dan Teknologi 15(2): pp 119-127

[5] Lestariningsih W A, Soenardjo N, and Pribadi R 2018 Estimasi Cadangan Karbon pada Kawasan Mangrove di Desa Timbulokslo, Demak, Jawa Tengah. Bulletin Oceanografi Marina 7(2) pp 121-130

[6] Palacios Peñaranda M L, Cantera Kintz J R, and Peña Salamanca E J 2019 Carbon Stocks in Mangrove Forests of the Colombian Pacific. Estuarine, Coastal and Shelf Science, 106299

[7] Dahuri R 2003 Keanekaragaman Hayati Laut: Aset Pembangunan Berkelanjutan Indonesia (Jakarta: Gramedia Pustaka Utama)

[8] Windarni C, Setiawan A, and Rusita 2018 Estimasi Stok Karbon Tersimpan Pada Hutan Mangrove Di Desa Margasari Kecamatan Labuhan Maringgai Kabupaten Lampung Timur. Jurnal Sylva Lestari 6(1) pp 66-74

[9] Aryapratama R, and Pauliuk S 2019 Estimating in Use Wood Based Materials Carbon Stocks in Indonesia: Towards a Contribution to the National Climate Mitigation Effort. Resources, Conservation and Recycling, 149 pp 301–311

[10] Fachrul M F 2012 Metode Sampling Biokologi. (Jakarta: Bumi Aksara)

[11] Indriyanto 2010 Ekologi Hutan (Jakarta : Bumi Aksara).

[12] Kusumaningtyas M A et al. 2019 Variability In The Organic Carbon Stock, Sources, And Accumulations Rates Of Indonesian Mangrove Forest. Estuarine, Coastal and Shelf Science 218 (2019) pp 310-332

[13] Hairiah K, Ekadinata A, and Rahayu S 2011 Pengukuran Cadangan Karbon: dari Tingkat Lahan ke Bentang Lahan. Edisi kedua. (Bogor: World Agroforestry Centre ICRAF South East Asia Regional Office)

[14] Manafe G, Kabo M R, and Risamasu F 2016 Estimasi Biomassa Permukaan dan Stok Karbon pada Tegakan Pohon Avicennia marina dan Rhizophora mucronata di Perairan Pesisir Oebelo Kabupaten Kupang. Jurnal Bumi Lestari 16(2) pp 163-173.

[15] Amalia L et al. 2018 Analysis of biomass estimation and carbon stock on Puspa (Schimma wallichii Korth.) in Talaga Bodas Nature Reserve Garut. J. Phys: Conf. Ser. 1280 022008.

[16] Rao R G, Woitchik A F, Goeyens L, van Riet A, Kazungu J, and Dehairs F 1994 Carbon, Nitrogen Contents and Stable Carbon Isotope Abundance in Mangrove Leaves from an East African Coastal Lagoon (Kenya). Aquatic Botany, 47(2) pp 175–183

[17] Syarif M, Nurrachmi I, and Efiyeldi 2016 Analysis Of Biomass And Carbon Stock On Mangrove Forest Ecosystem The Teluk Pulai, Village Of Pasir Limaukasap, Rokan Hilir Riau Province.

[18] Dharmawan I W S, and Siregar C A 2008 Karbon Tanah dan Pendugaan Karbon Tegakan Avicenia marina Di Ciasem, Purwakarta. Pusat Litbang dan Konservasi Alam 4(4) pp 317-328.

[19] Kustanti A 2011 Manajemen Hutan Mangrove. (Bogor: IPB Press.)