



Estimation of *Rhizophora mucronata* carbon stock in Youtefa bay, Jayapura, Papua

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ABSTRACT

Papua island has the largest mangrove forest area in Indonesia, reaching 1,350,600.00 Ha which accounts for half of the entire area of mangrove forests in Indonesia. One of the locations with a fairly extensive mangrove forest in the Jayapura area is in Youtefa Bay. Although mangroves have large environmental potential, local people use the forest as building materials, food, fishing tools, and medicines. Mangrove forests have an active role in maintaining global climate stability in the world, forest vegetation will fix CO₂ through the process of photosynthesis. Mangrove forests per hectare can store up to four times more carbon than other tropical forests worldwide. This research aims to estimate the amount of carbon stock *Rhizophora mucronata* can store in mangrove forests in Youtefa Bay, particularly in Tobati, Enggros and Entrop Villages, Jayapura, Papua. The method used in this study was using Allometric Equations to estimate the biomass carbon from *Rhizophora mucronata* and compared to three different satellite imagery algorithms. The research results showed that the biomass of *Rhizophora mucronata* stands in Entrop Village was the highest and the lowest in Enggros Village. In addition, the results of measurements of carbon stocks in Tobati and Enggros Villages showed that the values were similar, only 0.23 kgC/m² with carbon stocks in Entrop Village reaching 19.46 kgC/m². Based on the results of measuring satellite imagery with three different algorithms, it was found that using the EVI algorithm produced the smallest Standard Error of Estimate, which was 1.63 kg C/m². The estimated total carbon in Youtefa Bay is 213,424.69 kg C/m².

Introduction

Environmental issues have recently become a matter of world concern, and one is global warming due to increasing concentrations of carbon dioxide (CO₂) gas in the atmosphere. The accumulation of increasing CO₂ concentrations and the other greenhouse gases in the air such as burning fossil fuels and land clearing, results in the severity of the effects of global warming (Polli *et al.*, 2021). Global warming is being exacerbated by the decreasing forest area, which stores of CO₂. One of the steps that can be taken to overcome the effects of global warming is to reduce CO₂ gas using the important role of natural ecosystems in capturing and absorbing CO₂.

Dinilhuda *et al.* (2020) state that forests have an important role in maintaining global climate stability in the world; forest vegetation will fix CO₂ through

the photosynthesis. If the forest is disturbed, the CO₂ and O₂ cycle in the atmosphere will be disrupted. In addition, CO₂ absorption from the atmosphere can go through not only forest ecosystems (land plants) but can also through marine and coastal ecosystems such as phytoplankton, seagrass beds, mangroves and brackish swamps (Ganefiani *et al.*, 2019). Marine and coastal ecosystems in Indonesia have good potential to absorb CO₂ from the atmosphere. These ecosystems have a major role in the global carbon cycle, around 93% of CO₂ on Earth is circulated and stored in the oceans (Putra, 2017). In additions Dinilhuda *et al.* (2020) show that mangrove forests ecosystems per hectare can store up to four times more carbon than other tropical forests worldwide.

Mangrove is a form of plant formation in coastal areas and occupies protected areas (Rahmad *et al.*, 2020). The mangrove ecosystem is the most

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productive and biologically has complex properties. Mangrove ecosystems support for various marine biota by providing spawning grounds, nursery areas, and places to find food and shelter (Suhardjono, 2014; Rahmad et al., 2020). Sofyan et al. (2019) stated that mangroves provide ecosystem services such as storing carbon stocks, soil formation, trapping and stabilizing sediments, cycling nutrients for biota, and functioning in coastal protection. In addition, mangroves can absorb carbon in the atmosphere and store it in biomass such as in stems, leaves, and roots, so mangroves play an important role in mitigating global climate change (Ati et al., 2014; Dinihulda et al., 2020).

Research on mangrove carbon stocks has been carried out in many areas. Rahmatin and Hidayah (2020) analyzed the availability of mangrove carbon stocks on the coast of Surabaya, East Java, which was carried out in two locations, namely Kenjeran and Rungkut Districts, showing significant differences. Also in 2020, Nugraha et al. conducted a study of changes in mangrove area a to predict carbon stocks in Brebes which showed that the area affected the value of carbon stocks. Amanda et al. (2021) measured estimated mangrove carbon stocks in the Muara Sungai Batang Apar, Pariaman, West Sumatra and obtained an absorption total of 1,149.56 Tones/ha.

Papua and West Papua have the largest mangrove forest area in Indonesia, reaching 1,350,600.00 Ha out of the total area of 3,416,181.71 Ha in Indonesia (Wanma et al., 2019). What needs to be considered in Papua is the utilization of mangroves by the surrounding community which makes them as building materials, food ingredients, fishing tools, and medicines (Mahmud and Wahyudi, 2014; Okoseray et al., 2017). In the Youtefa Bay area, around Tobati Villages, the community collects wood from the mangroves for the to make charcoal, wood and furniture. In addition, there was also a change in the area of mangrove cover, it had an area of 511.24 Ha in 1967 and in 2008 it was only 241.24 Ha also there was an area reduction for 8,12 Ha in 2017 (Handono et al., 2014; Hamuna et al., 2018). One type of mangrove commonly found in these two villages is the type of *Rhizophora mucronata* (Paulangan, 2014; Hamuna et al., 2018).

This research aims to estimate the amount of carbon stock that *Rhizophora mucronata* can store in mangrove forests in Youtefa Bay, Papua, so that studies can be carried out on the utilizing of mangrove wood in the area.

Materials and Methods

Location and time of research

The material used in this research is DBH (Diameter Breast High) carried out in the mangrove forest in the Youtefa Bay area which is located in Tobati, Enggros, and Entrop Villages, Jayapura, Papua (Figure 1) in October 2022. Data was collected using a purposive sampling method to measure the diameter at the breast height (DBH) of the tree stand. The diameter of the stand was collected using the DBH method. This method is used for mangrove vegetation in the tree category, where measurements are calculated around an adult's chest high or about 1.3 meters from the ground. Data were collected using the quadrant plot transect method or transect plots measuring 10 x 10 m. According to Nedhisa and Tjahjaningrum (2010) mangrove data collection uses a plot of 10 x 10 m for tree stands.

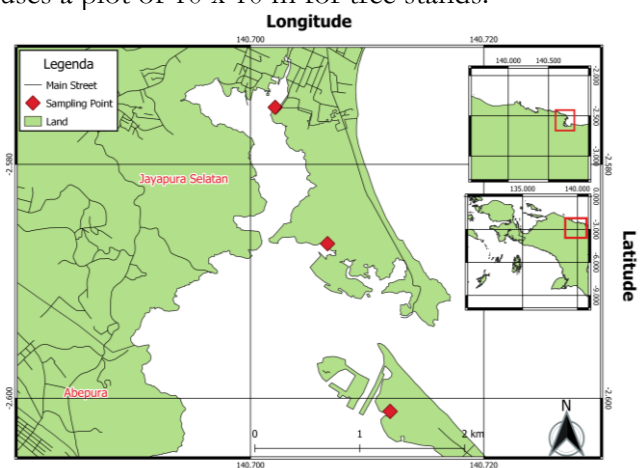


Figure 1. Mangrove data collection locations in Youtefa Bay, Jayapura, Papua

Data analysis

The measurement of mangrove carbon stocks is carried out in a non-destructive way (not damaging individual mangroves) starting with measuring biomass using an Allometric equation model according to the types of mangroves found in the area. This allometric formula estimates the estimated content in the tree or above (aboveground biomass). The allometric formula used to measure the biomass of the *Rhizophora mucronata* species use the equation from Dharmawan (2013) as follows:

$$W = 0.1466 \times DBH^{2.3136}$$

Where,

W : total biomass (kg)

DBH : High Breast Diameter

The measurement results of the biomass are then converted into carbon content using the equation from the Badan Standardisasi Nasional (2011) as follows:

$$Cb = W \times \%C_{organic}$$

Where:

Cb : carbon content of biomass (kg)

%C_{organic} : the percentage value of organic carbon content, which is equal to 0.47

The percentage value of organic carbon content of 0.47 comes from the amount of carbon stored in trees of 47% of the total biomass following the rules of SNI 7724:2011. This carbon content value will then be processed to find the carbon uptake value using the equation in Nuraini et al. (2021):

$$CO_2 = 3.67 \times Cb$$

Environmental quality parameters taken in this study included temperature, pH, and salinity. This environmental quality data collection was carried out indirectly using data from data.marine.copernicus.eu. This environmental quality data collection was using E.U. Copernicus Marine Service Information; <https://doi.org/10.48670/moi-00016> and <https://doi.org/10.48670/moi-00015>. This data is the result of modeling carried out using satellite by marine.copernicus.eu.

The carbon content value of the biomass that has been obtained will then be analyzed by correlating it with the vegetation index value from Sentinel-2 image processing. The transformations of the vegetation index that will be used are NDVI, EVI, and SAVI by conducting a regression analysis to see the effect of the transformation of the vegetation index on the estimation of mangrove forest carbon stocks. NDVI is an algorithm based on the observation that different surfaces reflect different types of light waves. SAVI is the result of a modification of NDVI by considering the appearance characteristics of the soil in the image caused by color, humidity and soil variability. EVI is schemed to correct for NDVI by atmospheric and soil background influences, particularly in dense tree canopies (Dharmawan et al., 2020).

In addition, an accuracy test of the estimated carbon stock was also carried out on the transformation of the vegetation index used using the standard error of estimate to see how accurate the use of the vegetation index was on carbon stock.

Results

The results of taking environmental parameter data showed an average temperature value of 30.4°C, a pH value of 7.9, and a salinity value of 34.9‰. The value of the stand diameter obtained, had been calculated, and this value would produce the value of

the biomass or energy stored in the mangrove stand itself, the data used the value of the dependent diameter in mangrove forests in Tobati, Enggros and Entrop Villages, Jayapura, Papua. The observation results also found that all mangrove species recorded in the transect were *Rhizophora mucronata* species (Table 1; Figure 2).



Figure 2. The observation of *Rhizophora mucronata* in Youtefa Bay, Jayapura, Papua

The mangrove community in the Entrop Village location had the largest DBH range with the highest standing biomass level of 4,140.76 kg compared to Enggros and Tobati Village which were 3,077.32 kg and 3,126.93 kg

Table 1. Biomass of *Rhizophora mucronata* Stands

Location	DBH (cm)	Total Biomass (kg)	Average Biomass (kg)
Tobati	3.18-28.64	3,126.93	86.85
Enggros	2.1-27.89	3,077.32	38.19
Entrop	2.22-38.03	4,140.76	103.51

The results of calculating the biomass of mangrove stands that had been calculated will then be followed by calculating the carbon stock in *Rhizophora mucronata* stands (Table 2) this was a follow-up calculation of the biomass of mangrove stands presented in Table 1. The value of the Carbon Stock in the stands that had been calculated will have units of kgC/m².

Table 2. Mangrove Carbon Stock

Location	Carbon Stock (kgC/m ²)
Tobati	14.69
Enggros	14.46
Entrop	19.46

There was a large difference in carbon stocks between Tobati and Enggros villages, namely at 14.69kgC/m² and 14.46 kgC/m². The highest carbon

stock value was found in Entrop Village with a value of 19.46 kgC/m².

Carbon uptake value from *Rhizophora mucronate* in Tobati, Enggros and Entrop Villages represented in Table 3. This result shows carbon uptake in Tobati and Enggros Villages was not so different on value of 53.91 kgC/m² dan 53.06 kgC/m². Carbon uptake in Entrop Village, in another hand, set the highest value of 71.42 kgC/m².

Table 3. Mangrove Carbon Uptake in Tobati and Enggros Villages

Location	Carbon Uptake (kgC/m ²)
Tobati	53.91
Enggros	53.06
Entrop	71.42

The image processing results show that using the NDVI (Figure 3) and SAVI (Figure 4) algorithms produced the same maximum carbon value of 54.04 kgC/m² for 1 pixel. The processing results of the EVI algorithm (Figure 5) showed a higher value at 54.99 kgC/m² per 1 pixel.

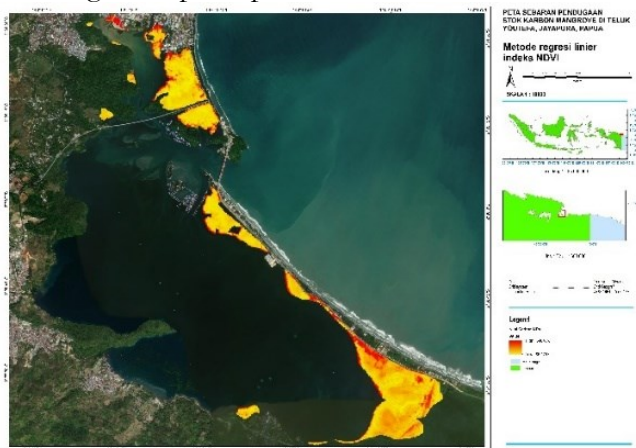


Figure 3. Map of carbon stock estimation using the NDVI algorithm

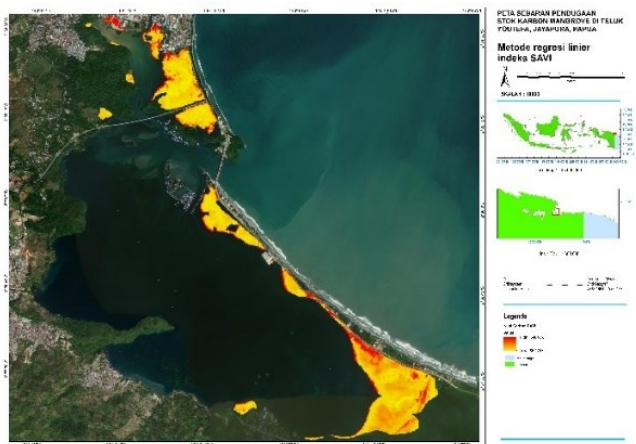


Figure 4. Map of carbon stock estimation using the SAVI algorithm

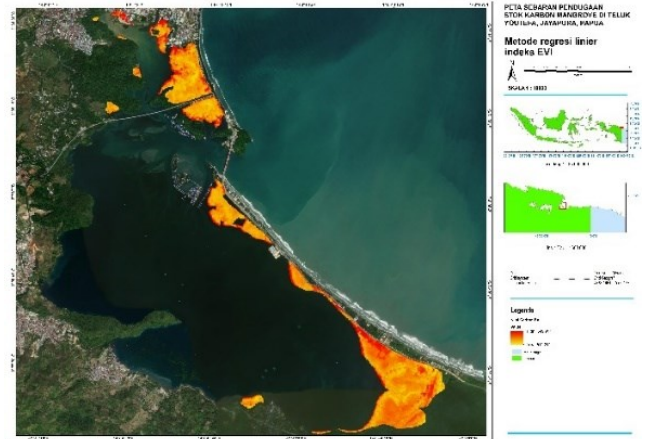


Figure 5. Map of carbon stock estimation using the EVI algorithm

Discussion

Based on Table 1, the mangroves in the two study locations were still in a condition suitable for growth which is not less than 20°C (Schaduw, 2018). Mangrove, namely *Rhizophora mucronata*, can grow well at a pH value of 7.7 which is not much different from the pH value obtained (Muharrahmi et al., 2016). The salinity value obtained was 34.9‰ indicating that it was still included in the area with the range of salinity that *Rhizophora mucronata* found according to Kolinug et al., (2014). Kolinug et al., (2014) also stated that the area where *Rhizophora mucronata* was found had a salinity range between 31.8‰ to 33.7‰.

Based on the results of biomass measurements (Table 1), Entrop Village had a higher total biomass compared to two the other villages where the average *Rhizophora mucronata* biomass in Entrop Village was 103.51 kg while in Tobati dan Enggros Villages was 86.85 kg and 38.19 kg. The DBH value in Entrop Village caused this condition to have a bigger range in the range of 2.22-38.03 cm compared to the other villages. The condition of the mangrove forest in the the other two villages showed that in Tobati village was denser than that in Enggros village, which is in line with the results of the study by Randongkir et al. (2019).

Based on the results (see Table 2), the Carbon Stock between the two villages did not have a big difference between Tobati and Enggros Villages, namely at 14.69 kg/m² and 14.46 kg/m². This value is still in *Rhizophora mucronata* carbon stocks range conducted by Ramba et al. (2021).

Rahman et al. (2017) stated that density has positive correlation with carbon stock and biomass, however the total standing carbon is also affected by the diameter of a tree and the wood density of the

mangrove species. Wood density can affect the calculation and growth of the mangrove species itself, the greater the value of the wood density in a mangrove species, the longer the mangrove species will grow, so the longer the growth process of a mangrove species, it will affect the size of the diameter of the trunk of this type of mangrove. It will ultimately affect the total amount of carbon present in the stand of a type of mangrove itself (Aini et al., 2021).

The results of carbon uptake values (Table 3) show similar carbon uptake at values of 53.91 kg/m² and 53.06 kg/m² between Tobati and Enggros Village with only 0.23 kgC /m² difference. Nevertheless of the three villages, Entrop Village had the highest carbon uptake with value of 71.42 kgC/m². The absorption of CO₂ or carbon dioxide in mangroves results from their ability to absorb CO₂ in the atmosphere. This result is used as a material for photosynthesis, so that it will have a direct impact on the amount of CO₂ concentration in the atmosphere (Nuraini et al., 2021). In the body part of the mangrove, it is the trunk that has the greatest carbon content because during the growth and productive period, trees absorb carbon through their leaves in the process of photosynthesis and the results are immediately distributed to all other parts of the tree (Heriyanto et al., 2020). The results of this CO₂ calculation show results that are directly proportional to the results of standing carbon stocks in mangrove vegetation. According to Dinilhuda et al. (2020), mangroves can to absorb CO₂ in the atmosphere, which is used for photosynthesis. This photosynthesis process is carried out by mangrove leaves so that it will affect the results of CO₂ absorption in an area of mangrove vegetation. This uptake is also quite large compared to the statement of Sasmito et al. (2020) which states that the estimated global mangrove carbon uptake is estimated at 0.12 kg/m²/year.

From the use of these three algorithms (Figure 3, 4, 5), it can be seen that the Entrop location points appear to have a higher carbon value following the results of measurements in the field. In addition, the Standard Error of the Estimate value of the EVI algorithm is much smaller at a value of 1.63 kgC/m² compared to the same NDVI and SAVI at 3.4 kgC/m². The estimated carbon stock in Youtefa Bay is 213424.69 kgC/m² from the average use of the three algorithms.

This difference in value is generated because the composition of the bands used by each algorithm is different. the EVI algorithm has a higher carbon value due to its composition which uses the Blue

band outside the Red and NIR band. This makes the EVI correlation value higher than NDVI and SAVI which only use Red and NIR bands in their processing (Frananda et al., 2015). Ramba et al. (2021) added that using the EVI algorithm for estimated carbon of *Rhizophora Mucronata* was better than using NDVI or SAVI because the correlation of EVI was higher than NDVI and SAVI.

Conclusion

Stand biomass of *Rhizophora Mucronata* calculated using the allometric method showed a significant difference with the location of Entrop Village having the most biomass and Enggros Village having the least. Even so, the results of carbon stock measurements in Tobati and Enggros Villages showed that the values were similar, only 0.23 kgC/m², with carbon stocks in Entrop Village reaching 19.46 kgC/m². The carbon absorption obtained in Entrop Village showed the highest value meanwhile there was no big difference, only 0.85 kg/m² between Enggros and Tobati Villages. Based on the results of measuring satellite imagery with three different algorithms, it was found that the using the EVI algorithm produced the smallest Standard Error of Estimate, which was 1.63 kgC/m². The estimated total carbon in Youtefa Bay is 213424.69 kgC/m² from the average use of the three algorithms.

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