Estimation of Potential Carbon Stocks in Mangrove Ecosystems in the Riau Islands

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Abstract. Global warming is characterized by high concentrations of greenhouse gas emissions, namely CO2, in the atmosphere. Mangrove ecosystems play a role in mitigating global climate change because they can absorb carbon through photosynthesis and then store it in a carbon pool, which includes Above Ground Biomass (AGB), Below Ground Biomass (BGB), litter or dead wood, and sediment. This study aimed to determine the value of biomass, carbon stocks, and CO2 sequestration in the mangrove ecosystem in the Riau Island. Carbon stocks were estimated by collecting data on AGB, BGB, and dead wood using the non-destructive allometric modeling method, and sediment sampling was carried out at 30 cm intervals until the discovery of humus soil. There are eight research stations spread across Riau Island. The results of the biomass calculation are then converted into carbon stock values and CO2 sequestration. The result showed that the mangrove ecosystem in Riau Island had a biomass value of 1854,54 tons/ha, estimated carbon stocks of 2052,78 tonsC/ha, and a CO2 sequestration of 7527,52 tonsC/ha. The mangrove ecosystem in Riau Island has an area of 79.228,91 Ha so it can store carbon reserves of 162.639.342 tonsC. The amount of CO2 can be minimized or controlled by reducing emissions and conserving forests, namely by improving mangrove management according to the function of mangrove forests.

1. Introduction

Global warming is caused by the increase in the earth's temperature due to the sun's heat being trapped in the atmosphere, so the planet absorbs more energy than it releases into space. This causes an increase in gas emissions, one of which is carbon emissions. CO2 gas concentrations will increase by 40%, and annual global gas emissions will equal 50 billion tons of carbon dioxide [4]. This causes negative impacts on life including; increasing intensity of natural disasters, reduced biodiversity, scarcity of water sources and so on. Efforts can be made to slow down the problem of increasing CO2 gas emissions by carrying out a forest conservation role and minimizing forest degradation and deforestation activities. Forests have an essential role in absorbing and storing carbon on earth but can contribute to gas emissions of 20% of total global emissions if not appropriately managed [15].

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One forest ecosystem that is able to absorb carbon is the mangrove ecosystem through the process of photosynthesis. Mangroves are able to absorb and store carbon around more than 4 MgC/year to 112 MgC/year [23]. Mangroves store carbon in the form of biomass in carbon pools, namely: AGB, BGB, litter and dead wood and sediment or soil. Mangroves absorb carbon optimally, in part because the morphological system of mangrove roots is capable of trapping mud substrates which have great potential for storing carbon and the mangrove ecosystem does not release carbon into the atmosphere because it is classified as a wetland forest where rotting litter components do not release carbon into the air [23]. So an alternative way to control carbon concentrations can be done by rehabilitating mangroves as an increase in carbon sinks.
The Riau Islands Province has a mangrove area of 79,228.91 Ha spread across seven districts/cities [20], the Riau Islands Provincial government in this case supports climate change mitigation action activities with efforts to prepare the Indonesian Renja FOLU Net Sink 2023, one of the efforts made is identify forest and land areas.
This research needs to be carried out as a basic study to determine the total carbon contained in the mangrove ecosystem in the Riau Islands as well as an environmental mitigation effort, especially due to global warming, so that the results obtained can be used as material for government policy in making decisions regarding mitigation efforts.

2. Material and Methods

2.1Time and Research Site

This research was carried out in September – October 202. The data collection was carried out at eight stations spread across the Riau Islands (Figure 1), namely Pengudang (A), Busung (B), Penaga (C), Tembeling (D), Dompak (E), Sei. Jang (F), Sei Carang (G), Kp. Bugis (H). Meanwhile, the location for sediment analysis was carried out at the ICBB Laboratory (Indonesian Center for Biodiversity and Biotechnology) in Bogor City.

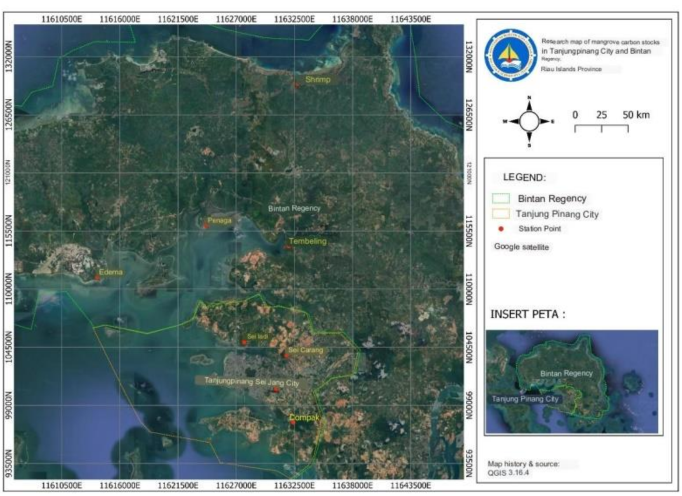

Fig. 1. Study Area

2.2. Vegetation Biomass Measurement Procedure

Tree biomass is measured by measuring the diameter at a height of 1.3 m (DBH). The rod diameter measurement procedure is based on SNI (7724:2011). Vegetation measurements were carried out according to the research plot, in this case a circular research plot was used (Figure 2).

2.3. Deadwood Measuring Procedure

Deadwood includes standing dead wood and fallen dead wood. Measuring standing dead trees by measuring the tree's diameter at 1.3 m (DBH) > 10 cm, then measuring the tree's height. Meanwhile, the procedure for measuring fallen dead wood is carried out by measuring the base diameter, tip diameter, and length of fallen deadwood. It is categorized as fallen dead wood with a stem diameter of > 5 cm and a minimum stem length of 0.5 m [6].

2.4. Sediment Sampling Procedures

Sediment sampling was taken using a sediment core with a drill length of 30 cm with a diameter of 6 cm. Sediment cores are inserted at 30 cm intervals until sand or humus soil is found. Sediment samples taken are only 10 cm of the total sediment per interval. Sampling is done by taking 5 cm of sediment found in the sediment core at the top, bottom or middle, then the sample is stored in a plastic sample and labeled to facilitate identification and analysis in the laboratory.

2.5. Data Analysis

2.5.1. Vegetation Biomass Calculation

Analysis of AGB and BGB values using allometric equations presented in Table 1.

Table 1. Allometrik Equation for *Above Ground Biomass (AGB)*

Mangrove Species	Allometrik Equation
Avicennia alba	$W= 0{,}079211(D^{(2{,}470895)})$
Avicennia lanata	$W= 0{,}251\ p(\ D^{(2{,}46)})$
Avicennia marina	$W= 0{,}2901(D^{(2{,}2605)})$
Avicennia officinalis	$W= 0{,}1848(D^{(2{,}3524)})$
Rhizopora apiculata	$W= 0{,}43(D^{(2{,}13)})$
Rhizopora mucronata	$W= 0.1466(D^{(2.3136)})$
Sonneratia alba	$W= 0.0825(D^{(0.89)})$
Bruguiera cylindrica	$W= 0{,}0754(D^{(2{,}505)})0{,}741$
Bruguiera gymnorrhiza	$W= 0{,}0754(D^{(2{,}505)})0{,}741$
Ceriops tagal	$W= 0.251(0.8859)D^{2.46}$
Ceriops decandra	$W = 0.251(0.725)D^{2.46}$
Lumnittzera littorea	$W= 0{,}251p\ (D^{(2{,}46)})$
Xylocarpus granatum	$W = 0.1832(D^{(2.21)})$

W = Biomass, D= Tree diameter

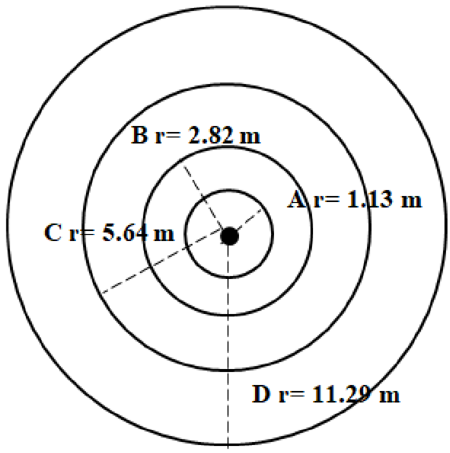

Fig. 2. The research plot is circular

Subsurface biomass calculations were carried out using a regression model between WR and ρD2 to produce the root weight allometric equation [11], as follows:

$$W_R = 0.199 \; x \; \rho^{(0,899)} \; x \; D^{(2.22)}$$

WR= BGB biomass from root weight; ρ= specific gravity of the species; D= stem diameter (cm).

2.5.2. Deadwood Biomass Calculation

Standing Deadwood Biomass Equation:

$$Vpm = \frac{1}{4}\pi\left(\frac{dbh}{100}\right)^2 x \; t \; x \; f$$

Vpm= volume of dead trees (m3); dbh= diameter at breast height of dead tree 1.3 m (cm); t= total height of dead trees (m); f= shape factor (0.6).

Fallen Deadwood Biomass Equation:

$$Vkm = \frac{1}{4}\pi\left(\frac{dp + du}{2 \; x \; 100}\right)^2 x \; p$$

Vkm= volume of fallen dead wood (m3); dp= diameter of dead wood base (cm); du= deadwood tip diameter (cm); p= length of dead wood (m); π= circumference of a circle with its diameter (3.14).

2.5.3. Sediment Sample Analysis

Sediment analysis was carried out using the LOI (Loss On Ignition) method to determine the total carbon organic matter content. Soil carbon calculations can be carried out using the following formula by SNI (Indonesian National Standard) 7724: 2011.

$$Ct = Kd \ x \ \rho \ x \ \%C$$
$$\rho = \frac{Bkt}{Vt}$$
$$Vt = \pi r^2 t$$

Ct= soil carbon content (g/cm2); Kd= depth of soil sample (cm); ρ= bulk density (g/cm3); %C= percentage of carbon content; Bkt = dry weight of soil (g); Vt= soil volume (cm3).

2.5.4. Calculation of Biomass Carbon Value

$$Cb = B \ x \ \% \ C \ organic \ [2]$$

Cb= carbon content of biomass (kg)'; B= total biomass (kg); %C organic= percentage value of carbon content (0.47).

2.5.5. Calculation of Sediment Carbon Value

$$CSoil = Ct \ x \ 100 \ [2]$$

Csoil= soil organic carbon content per hectare (ton/ha); Ct= content; soil carbon (g/cm3); 100= conversion factor from g/cm3 to tonnes/ha.

2.5.6. Calculation of Carbon Sequestration Value

$$eCO2 = \frac{Mr \ CO_2}{Ar \ C} \ x \ Stock \ C \ [2]$$

Mr CO2= relative molecular weight of CO2 (44); Ar CO2= relative atomic weight C (12); C content = amount of carbon stock (tons/ha).

3. Results and Discussion

The composition of mangroves in the Riau Islands was found to be a total of 13 species spread across 8 stations (Table 2). Species that are only found in one location are: *Avicennia officinalis*, *Ceriops decandra* and *Lumnitzera littorea*. Research station F or Sei Jang has high diversity because it found eight types of mangroves, while the station with low species diversity was found at station G, namely Sei Carang, only two species were found. This is confirmed by research [24] that station G has low diversity.

Table 2. Composition of Mangrove Species in Riau Islands

Species	A	B	C	D	E	F	G	H
Avicennia alba	-	-	+	+	-	-	-	-
Avicennia lanata	-	-	-	+	-	-	-	-
Avicennia marina	-	+	-	-	-	+	-	+
Avicennia officinalis	-	-	-	-	-	+	-	-
Bruguiera cylindrical	-	+	-	-	-	+	-	-
Bruguiera gymnorizha	+	-	+	-	+	+	+	+
Ceriops decandra	+	+	+	+	-	-	-	-
Ceriops tagal	-	-	+	-	+	+	-	-
Lumnittzera littorea	-	-	-	+	-	-	-	-
Rhizophora apiculata	+	+	+	+	+	+	+	+
Rhizophora mucronata	+	-	+	-	-	-	-	-
Sonneratia alba	-	+	+	-	+	+	+	-
Xylocarpus granatum	+	+	+	+	+	+	-	+

+ (available); - (not available).

Biomass values of above-ground plants, below-surface plants and dead wood (Figure 3) with the highest biomass values found in above-surface biomass, this is because the above-ground plants have many storage components or parts and the largest biomass values are found in The stem is a place for the distribution of photosynthesis and growth, and the stem contains wood constituents which cause the cell cavities in the stem to be composed mostly of wood constituents rather than water, so that the weight of the trunk biomass will be greater than that of other tree components [26]. Meanwhile, dead wood is one of the carbon pockets that stores carbon that is not released into the atmosphere because it no longer carries out respiration and photosynthesis processes, so measurements need to be carried out to determine the value of the carbon stored [23]. The total biomass value of the three carbon pockets is 1854.54 tons/Ha.

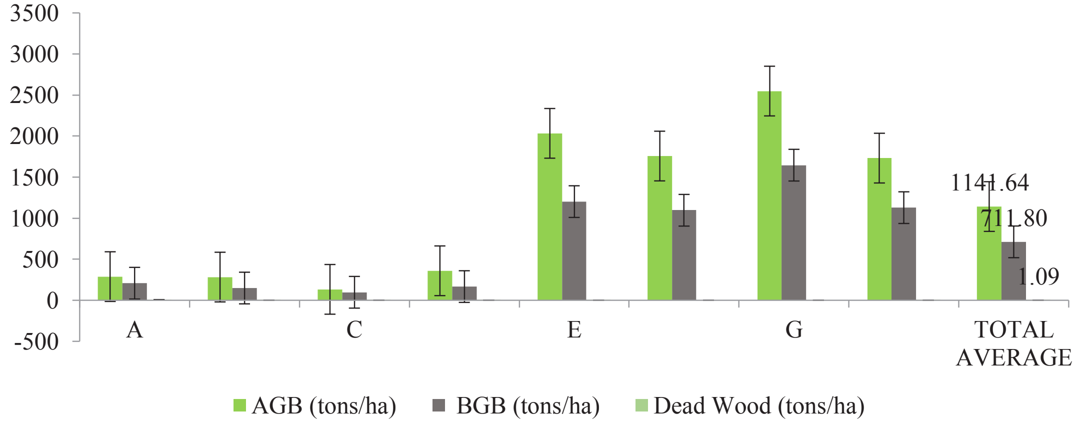

Fig. 3. Mangrove Biomass Value in the Riau Island

The carbon stock value at each research station for above-surface plant carbon, below-surface plant dead wood and sediment carbon has a total average value of 2052.78 tonC/Ha (Figure 4). The details of the value of each carbon pool are upper plants of 544.80 tonsC/Ha, lower plants of 333.61 tonsC/Ha, dead wood of 0.51 tonsC/Ha and sediment of 1173.86 tonsC/Ha. Sediment has the largest carbon value compared to the other 3 carbon pockets. The largest carbon content is in the soil at 78%, the remainder is in plant biomass above the soil surface at 20% and below the soil surface at around 2% [17]. The research results obtained are in accordance with previous researchers' explanations regarding carbon composition in mangrove ecosystems.

This is because sediment accumulates more organic material [9], sediment accumulates organic material from the decomposition of leaves, twigs, stems, fruit and roots which is then degraded in sedimentary deposits. Sediment carbon storage at the research location is relatively large compared to research conducted in Batupara Village, Lolak District, Bolaang Regency, North Sulawesi Province, precisely in the river flow towards the estuary, which obtained a sediment carbon value of 398.82 tons/ha [27]. Sediment has the ability to store greater carbon compared to stores in mangrove trees [18, 19]. Organic carbon stored in sediment is influenced by sediment grain size, % Organic C, bulk density and soil depth. If it is estimated that the area of the mangrove ecosystem in the Riau Islands has a carbon reserve value of 162,639,342 tonsC.

The results of the calculation of carbon sequestration or carbon absorption are obtained from the results of the analysis of the carbon stock value with the relative molecular value of the CO2 compound being 44 and the relative atomic value of the element C being 12. The average value of total carbon sequestration obtained was 7527.52 tonC/Ha. If estimated by the area of the mangrove ecosystem in the Riau Islands, it has a carbon reserve value of 596397337.1 tonsC.

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The condition of the mangrove ecosystem located in the Riau Islands has various characteristics, found in sandy beach areas, estuary areas, as well as areas that are directly influenced by human activities because they are close to community settlements, government agency offices, fishing boat dock, and on the edge of the main road, and also found piles of rubbish scattered around the mangrove ecosystem [12].

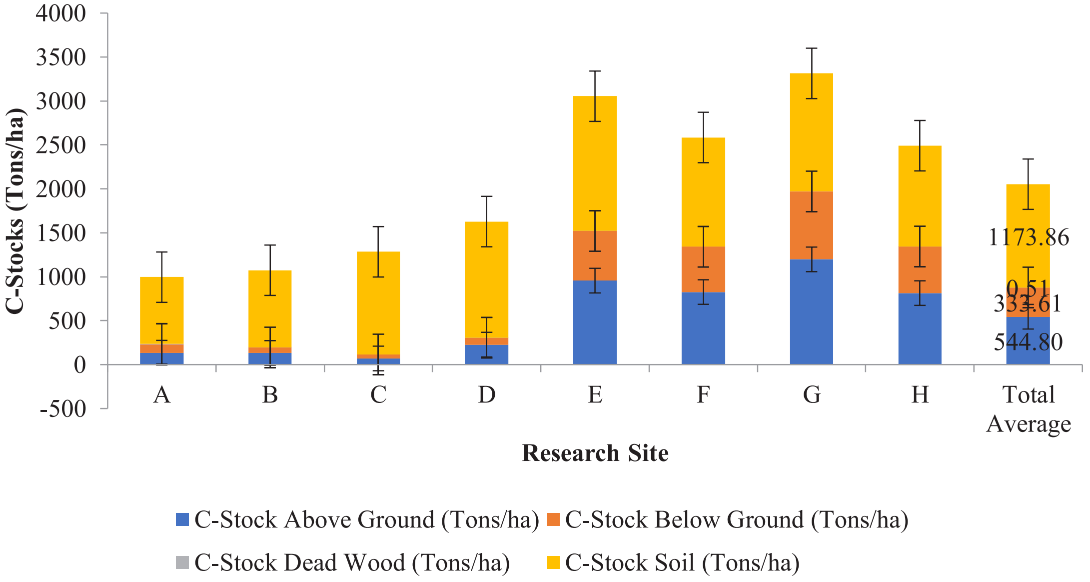

Fig. 4. Carbon Stock Mangrove in Riau Island

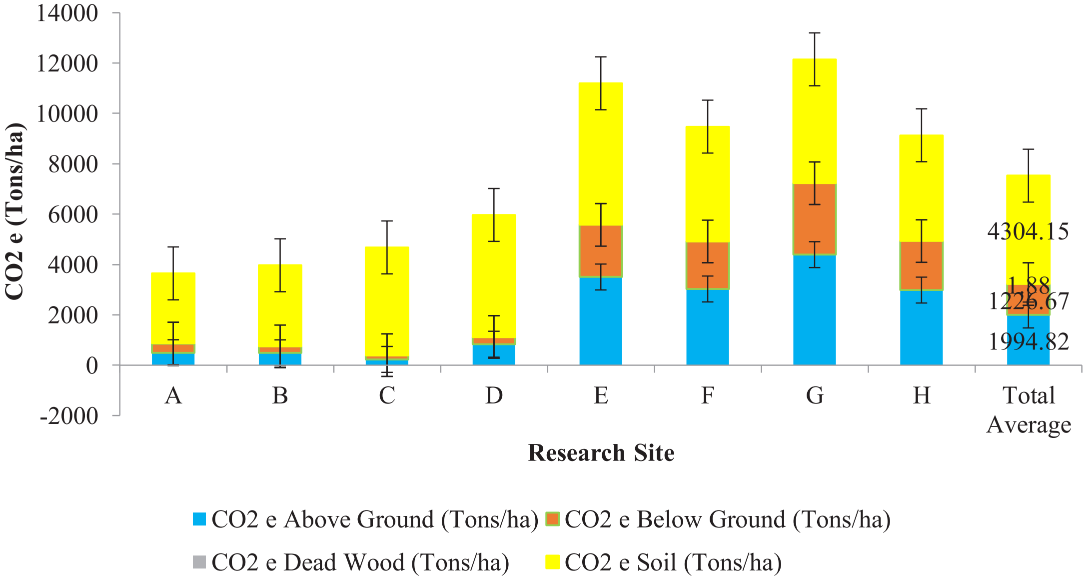

Fig. 5. Carbon Sequestration Mangrove in Riau Island

The consequences of this condition will put pressure on the mangrove ecosystem, which can have an impact on reducing the environmental services that this ecosystem can provide, including the ability of the mangrove ecosystem to produce biomass and store carbon [8]. So, it is necessary to preserve forests by replanting or reforesting. The important role of mangrove forests in absorbing and storing carbon needs to be used as a reference for climate change mitigation to improve mangrove management following the function of mangrove forests.

4. Conclusions

Based on research regarding the estimation of carbon reserves by calculating the value of biomass, carbon stock, and carbon sequestration in four carbon pockets (upper vegetation, lower vegetation, dead wood, and sediment) in the Riau Islands, the total biomass value is 1854.54 tonnes/ Ha, then the average total carbon stock value is 2052.78 tonC/Ha and the carbon sequestration value is 7527.52 tonC/ha with an estimated carbon stock for the area of the mangrove ecosystem in the Riau Islands of 162,639,342 tonC.

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