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ESTIMATIONS OF CARBON STORAGE AND ECONOMIC VALUE OF MANGROVE FOREST ON THE NORTH COAST OF CAWAN ISLAND, INDRAGIRI HILIR

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ABSTRACT

Mangrove forests are important for human life and the surrounding environment, one of which is as a CO_2 absorber and carbon storage. The North Coast of Cawan Island in Indragiri Hilir has a relatively good mangrove forest that is estimated to absorb and store more carbon. This study aims to (1) estimate the value of carbon storage in stands (stems), below-ground carbon (roots), litter, and sediment of mangrove forests, (2) estimate the CO_2 absorption capacity of mangrove forests, and (3) estimate the economic value of absorption CO_2 by mangrove forest on the North Coast of Cawan Island. The station determination method uses purposive sampling of five stations, each consisting of a transect with three plots measuring 10x10 m^2. Measurement of stem and root biomass using the allometric method. Litter biomass measurement used the dry weight weighing method, and sediment carbon measurement used the Loss on Ignition (LOI) method. The result showed that average carbon storage in stems was 34.56 tons/ha, roots were 16.41 tons/ha, litter was 0.10 tons/ha, and sediment was 32.91 tons/ha. The estimated ability of mangrove forests to absorb CO_2 is an average of 187.10 tons/ha or 636,450.59 tonnes for the entire North Coast of Cawan Island. The estimated economic value of mangrove forest carbon is an average of IDR 149,809,099 /ha or IDR 509,599,619,024 for the entire North Coast of Cawan Island.

Keywords: Mangrove, CO_2 absorption, Carbon Economic Value.

1. INTRODUCTION

Mangrove ecosystems can support human life and the surrounding environment through their various functions, such as ecological, economic, and social functions. The ecological functions of mangrove forests are to maintain coastal stability, retain and dissolve pollutants, absorb CO_2 and store carbon, produce oxygen, and serve as a habitat for aquatic animals. The economic function of mangroves is to produce building materials, food, and medicines and serve as a fishing area. The social function of mangroves is as an area of conservation, education, tourism, and as a cultural identity for the local community.

Based on their ecological function, mangrove forests can store carbon from the air by converting CO_2 into biomass in plant parts such as stems, branches, leaves, and roots. The ability of mangrove forests to absorb CO_2 and store carbon is better than other terrestrial forest types. According to Murray et al.[1], mangrove ecosystems can absorb an average of 8 tons of CO_2/ha/year. This value is approximately 2 to 4 times greater than the average tropical forest value (1.8–2.7 tons CO_2/ha/year). This is due to the high rate of population growth, which requires resources to meet the necessities of life. The extensive use of mangrove forests without regard to their ecosystems can result in extinction and reduced area of mangroves due to the lack

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of value given to mangrove ecosystem areas.

High human activity encourages CO_2 concentrations in the air to rise, which can trigger global warming and result in world climate change. Global climate change has resulted in an increase in the earth's temperature, an increase in average sea levels, changes in rainfall patterns, and disruption of the natural balance. According to Hidayah et al.[2], climate change is an intensively discussed environmental issue. Global climate change can occur, one of which is due to an increase in greenhouse gas concentration due to increased CO_2 gas. The Ambarsari & Tedjasukmana[3] also show that CO_2 significantly contributes to a greenhouse gas of 63% due to its long lifetime and rapid increase in the atmosphere.

Indragiri Hilir Regency, Riau Province, is one area with the broadest mangrove forest, which is ±129,455.56 ha. Indragiri Hilir Regency consists of 20 sub-districts, one of which is Mandah District, which has the most expansive mangrove forest, 34,147.84 ha, including the Cawan Island mangrove forest[4]. The condition of the mangrove forest on Cawan Island is critical to maintaining its sustainability because almost all of the people who live in the area work as fisherman, so the mangrove forest plays an essential role in the community. The existence of mangrove forests on the North Coast of Cawan Island needs to be studied for their potential, as it becomes a solid reason to maintain its sustainability.

Based on Syafruddin et al.[5], the estimated carbon storage of mangrove stands (stems) on Cawan Island is 2,199.54 tons C/ha with a CO_2 absorption capacity of 8,064.97 tons/CO_2/ha. It classifies mangrove forests in a suitable category, 67.81% of the total mangrove area. This prompted the authors to research carbon storage and economic value in stands (stems), below-ground carbon (roots), litter, and sediment of mangrove forests on the North Coast of Cawan Island, Indragiri Hilir. The condition of the mangrove forest on the North Coast of Cawan Island, which is classified as good, can also be calculated for its ability to absorb CO_2 and its carbon economic value.

2. RESEARCH METHOD

Time and Place

This research was conducted from September to October 2022. Data and samples were collected from the North Coast of Cawan Island, Mandah District, Indragiri Hilir Regency. Mangrove litter and sediment samples were analyzed at the Marine Chemistry Laboratory, Departement of Marine Science, Faculty of Fisheries and Maritime, Universitas Riau. This research was conducted by establishing five stations on the North Coast of Cawan Island. A map of research locations can be seen in Figure 1.

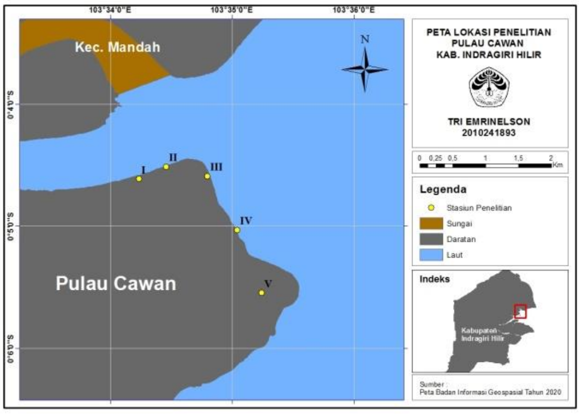

Figure 1. Research Location Map

Methods

The research method was carried out by purposive sampling to determine observation stations based on specific considerations in the field. Data collection on the structure of the mangrove community was carried out using the transect line plot method. A total of 5 stations were observed, and each Station was made a transect line from shore to the land. Each transect consists of 3 plots measuring 10 x 10m^2 spaced 20 m apart for trees with trunk diameter of ≥5 cm and a sub-plot measuring 0.5 x 0.5 m^2 for litter.

The tree trunk's diameter is measured at a breast height of 1.3 m. Measurement of mangrove stem and root biomass was carried out using the allometric method based on the diameter of the tree trunk. The biomass obtained was converted to a carbon value. Mangrove litter biomass was measured using the dry weight weighing method, and sediment carbon measurements were carried out using the Loss on Ignition (LOI) method.

Procedures

Measuring the Diameter of a Tree Trunk

Tree trunk diameter was measured based on the Cintron & Novelli method[6], namely collecting tree biomass data by measuring the diameter of a tree trunk at breast height in an adult (1.3 m). Measurements were made using a measuring tape around the tree trunk, and then the number obtained was divided by 3.14 (π) to obtain the tree trunk's diameter. Stem diameter measurements for each plot were carried out on stems measuring ≥5 cm[7].

Mangrove Litter Sampling

Mangrove litter samples were taken by making subplots measuring 0.5 x 0.5 m^2 in each plot at random positions. The litter was in the form of dead leaves and tree branches, then cleaned of silt and weighed to get the total wet weight. Furthermore, the litter samples that have been collected are put into plastic containers and labeled for analysis in the laboratory.

Mangrove Sediment Sampling

Mangrove sediment samples were taken using a 1 m long PVC with a diameter of 5 cm, and then the PVC pipe was inserted into the soil surface to a depth of 10 cm. Based on English et al.[8], mangrove sediments with sand, silt, and clay textures can be taken at a depth of 10 cm. Mangrove sediment sampling was carried out using the Round[9] method, which used a sediment corer with a diameter of 5 cm and a length of 1 m. The tool is made of PVC pipe that has been modified so that its function and use are the same as a sediment corer. Mangrove sediment samples taken using a PVC pipe are then put into a plastic container to be weighed and labeled, then analyzed in the laboratory.

Carbon Measurement of Mangrove Litter and Sediment

Carbon in mangrove litter was measured using the dry weight weighing method. Stages of sample analysis, namely the mangrove litter, are mashed using a mortar until it is homogenous. It is weighed as much as 30 g and put into an alumunium foil container. Furthermore, the litter samples were oven-dried at 105°C for 48 hours to obtain a constant dry weight[10]. Litter samples in the oven are then cooled and weighed as dry weight. The measurement results obtained are entered into the formula.

Carbon in mangrove sediments is measured using the Loss on Ignition (LOI) method[11]. Stages of sample analysis, namely the mangrove sediment, are mashed using a mortar until it is homogenous, then weighed as much as 30 g and put into an aluminium foil container. Furthermore, the sediment samples were dried using an oven at 105°C for 48 hours. Sediment samples heated in the oven are weighed, noted as a constant dry weight, and then burned in a furnace at 550°C for 4 hours. The sediment sample was weighed again and noted as the final weight. The measurement results obtained are entered into the formula.

Data Analysis

Analysis of Carbon Storage in Mangrove Stands

The biomass of mangrove stands was carried out non-destructively by measuring the tree trunk's diameter at breast height (1.3 m) and using allometric equations for each mangrove species. The allometric equation of mangrove stand biomass is presented in Table 1.

Table 1. Allometric Equation of Mangrove Stand Biomass

Species	Allometric Equations	Source
Rhizophora apiculata	$B = 0{,}043\ (D)^{2,63}$	Amira[12]
Sonneratia alba	$B = 0{,}3841\ (D)^{2,101}\rho$	Kauffman & Donato[13]
Soneratia ovata	$B = 0{,}258\ (D)^{2,287}$	Kusmana et al.[14]
Xylocarpus granatum	$B = 0{,}145\ (D)^{2,55}$	Poungparn et al.[15]
Nypa fruticans	$B = 0{,}098\ (D)^{1,4934}$	Rahman et al.[16]
Excoecaria agallocha	$B = 1{,}0996\ D)^{0,8572}$	Hossain et al.[17]
Lumnitzera racemosa	$B = 0{,}184\ (D)^{2,384}$	Kangkuso et al.[18]
Mangroves in general	$B = 0{,}251\ (D)^{2,46}\ \rho$	Komiyama et al.[7]

Note: ρ = wood density (g/cm^3), B = biomass (kg/m^2, tons/ha), D = stem diameter (cm)

Wood density was obtained based on previous studies of each mangrove species. Wood density is used to complete the allometric formula for calculating stand biomass and mangrove roots, presented in Table 2.

Table 2. Wood density[19]

Species	Wood density (g/cm^3)
R.apiculata	0,843
S.alba	0,509

Calculation of carbon storages of mangrove stands (stems) is carried out by multiplying the value of biomass by the carbon fraction using the SNI 7724[20] formula as follows:

$$C = 0.47 \times B$$

Where: C = Carbon storage, 0.47 = Carbon fraction, and B = Biomass

Analysis of Carbon Storage in Mangrove Root

Analysis of carbon storage below-ground (roots) of mangroves was carried out using the allometric method, in which the tree trunk's diameter was measured at breast height. Root carbon storage is calculated based on the same formula as stem carbon storage using SNI 7724[20]. The allometric equation of mangrove root biomass is presented in Table 3.

Table 3. Allometric Equation of mangrove Root Biomass[7]

Species	Allometrik Equations
S.alba	$B = 0{,}199\ \rho^{0,899}\ (D)^{2,22}$
S.ovata	$B = 0{,}045\ (D)^{2,320}$
R.apiculata	$B = 0{,}00698\ (D)^{2,61}$
Mangroves in general	$B = 0{,}199\ \rho^{0,899}\ (D)^{2,22}$

Analysis of Carbon Storage in Mangrove Litter

Analysis of carbon storage in mangrove litter was carried out by weighing the dry weight of the samples and converting it into the value of biomass[21]. The following formula can determine biomass:

$$\text{Biomass} = \frac{\text{Sample dry weight (g)}}{\text{Sample wet weight (g)}} \times \text{total wet weight}$$

Furthermore, after obtaining the biomass value, the carbon content is calculated by multiplying the biomass with the estimated value of carbon in organic matter (0.47%). The calculation is carried out with the following formula:

Litter carbon estimation = biomass x organic carbon content (0.47)

Analysis of Carbon Storage in Mangrove Sediment

Carbon storage analysis in mangrove sediment is calculated using the sediment sample's depth, carbon density, soil density, carbon estimation, and percentage of sediment organic carbon. The calculation is as follows[22]:

Calculation of bulk density (BD) of each sample using the following formula:

$$\text{Bulk density} = \frac{\text{oven-dry mass}}{\text{sample volume}}$$

Next, the percentage of organic matter lost during dry ashing is calculated using the following formula:

$$\% \text{ BO} = \left(\frac{wo-wt}{wo} \text{ x } 100\right)$$

Where: %BO = percentage of sediment organic matter lost in the combustion process, wo = initial weight (g), wt = final weight after combustion

Then, convert the percentage of organic matter to the percentage of carbon using the following formula:

%C = (1/1.724) x % BO

Where: %C = carbon content in organic matter, 1.724 = constant to convert % organic matter to % organic C

Then, the carbon density is calculated using the following formula:

Soil C density ($gCcm^3$) = %C x BD

Furthermore, carbon storage in mangrove sediments is estimated using the following formula:

Soil C (Mg/ha) = BD x SDI x %C

Where SDI = Soil depth interval

Analysis of CO_2 Absorption Capability

The ability to absorb carbon dioxide (CO_2) is obtained from the carbon (C) calculation and then converted into CO_2[13]. The formula used is as follows:

CO_2 = (Mr.CO_2/Ar.C) x Cn

Where: CO_2 = carbon dioxide absorption (tons/ha), Mr.CO_2 = the relative molecolar weight of the CO_2 compound, Ar.C = the relative atomic weight of carbon, Cn = carbon storage

Analysis of Carbon Economic Value

A carbon economic valuation is carried out to estimate the price of carbon using the Social Cost Carbon (SCC), which is USD per ton of carbon. The obtained price is converted into a Rupiah exchange rate of 1$= IDR 15,700 (November 2022). The social cost of carbon is a general concept for understanding and implementing a policy on climate change. This term represents the economic cost caused by 1 ton of carbon dioxide (CO_2) emissions released into the air[23]. The carbon storage value obtained is multiplied by the SCC value, and then the results are converted into the rupiah exchange rate. Carbon economic valuation can be formulated as follows:

Carbon economic valuation = (SCC x total carbon storage) x exchange rate to rupiah

3. RESULT AND DISCUSSION

Mangrove Stand Carbon Storage

The result of the average carbon storage of mangrove stands (stems) from each Station can be seen in Table 4.

Table 4. Average Carbon Storage of Mangrove Stands (stems)

Station	Biomass (tons/ha)	Carbon storage (tons/ha)	CO_2 absorption (tons/ ha)
I	204,43	96,08	352,62
II	49,60	23,31	85,55
III	46,46	21,83	80,13
IV	52,87	24,85	91,20
V	14,36	6,75	24,76
average	73,54	34,56	126,85

Based on Table 4, the average carbon storage of mangrove stands (stems) from each Station shows that the highest average carbon storage of mangrove stands (stems) was at Station I at 96.08 tons/ha, while the average the lowest carbon storage is at Station V of 6.7 tons/ha. The average carbon storage of mangrove stands (stems) at Station II, III, and IV were not much different, namely 23.31, 21.83, and 24.85 tons/ha, besides having different densities, average stem size, and mangrove species. The high carbon storage of a mangrove forest area is seen from the high biomass in the area, and high biomass is known from the number of trees with large trunk diameters and high density.

Mangrove plants at Station I are dominated by mangrove species *R.apiculata* with an average stem size of 20.59 cm, so they have a high average biomass and carbon storage. The mangrove species *R.apiculata* has a stem classified as a hardwood species. Based on Senoaji & Hidayat[24], mangroves belonging to hardwood species store much carbon compared to softwood species; the carbon content in each mangrove species will differ depending on the wood density. The higher the density of the wood, the higher the biomass content.

The lowest biomass was found at Station V at 14.36 tons/ha, with a large number of individuals but a small diameter, so the carbon stores at the Station were also low. According to Rahmawati[25], each mangrove species has a different biomass depending on the density of the wood, tree trunk diameter, tree height, and the influence of the sequestration process. Station V contains the mangrove species *R.apiculata*, with an average trunk diameter of 10.65 cm. This can affect the value of biomass and carbon storage at the Station. Other mangrove species found at Station V were two sticks of *N.fruticans* and one stick of *S.ovata*. The number of mangrove species that grow slightly at Station V is the leading cause of the average biomass and carbon storage at this Station being smaller than other stations.

This study's average stem carbon storage was 34.56 tons/ha. This was greater than the results of Mandari et al.[26] research in the Bandar Bakau Dumai, and it was 19.30 tons/ha. The average diameter of a tree trunk influences this study, which is greater than the result of the study by Mandari et al.[26] According to Hairiah & Rahayu[27], biomass, and stored carbon content can differ in various mangrove ecosystems depending on the diversity of species, stem size and density in the area.

Mangrove Root Carbon Storage

The average results of mangrove root carbon storage from each observation station can be seen in Table 5.

Table 5. Average Carbon Storage of Mangrove Root

Station	Biomass (tons/ha)	Carbon storage (tons/ha)	CO_2 absorption (tons/ha)
I	35,09	16,49	60,53
II	24,32	11,43	41,95
III	71,25	33,49	122,90
IV	41,18	19,35	71,03
V	2,79	1,31	4,81
Average	34,93	16,41	60,24

Based on Table 5, the average carbon storage of mangrove roots from each Station shows that the highest average carbon storage in mangrove roots is at Station III at 33.49 tons/ha. The lowest average carbon storage at Station V is 1.31 tons/ha. The average carbon storage of mangrove roots at Stations I, II, and IV was not much different, namely 16.49, 11.43, and 19.35 tons/ha, besides having different conditions of species, average stem diameter, and number of mangroves at each Station. The carbon storage of mangrove roots was obtained from an allometric model based on the tree trunk's diameter in each mangrove species.

The highest carbon storage value of mangrove roots was obtained at Station III, which is thought to be more influenced by the number of mangrove species found there. Station III has 7 mangrove species namely *R.apicuata, N.fruticans, E.agallocha, S.alba, S.ovata, L. littorea,* and *L. racemosa*. Station III also contains the mangrove species *E.agallocha*, which has a high density, so the root carbon stores are also high. The number of species and the high density found, especially in the mangrove species *E.agallocha,* is a factor causing the high carbon storage of mangrove roots at Station III, even though the average diameter of the stems found is relatively small. The allometric calculation also affects the average root carbon storage because each mangrove species has a different root shape.

Station V has high mangrove vegetation in plot 1, but plots 2 and 3 have very little vegetation, affecting the low carbon storage value in the roots. According to Adame et al.[28], root biomass estimated using the general equation[7] tends to be higher than root biomass measured in the field. This is due to the differences in the structure of each sediment, which has its peculiarities. Station V tends to have a type of mud substrate. According to Syarif et al.[29], the ability of each type of mangrove to environmental conditions causes differences in the composition of mangrove forests with unique boundaries.

This study's average carbon storage of mangrove roots was 16.41 tons/ha. This was lower than the result from Heriyanto et al.[30], in Kawal Village, Bintan Regency, namely 50.06 tons/ha, because, in this study, the average carbon stock of the stems was also high compared to the results. The average carbon storage of mangrove roots in this study is not much different from the result of Ibrahim & Muhsoni[31] research in Lembung Paseser Village, Bangkalan Regency, which is 16.95 tons/ha, which has nine mangrove species compared to this study which has eight mangrove species, this can cause the average carbon storage of mangrove roots not to be much different. Mangrove root carbon stores are smaller than mangrove stem carbon stores but also affect other carbon stores, namely in sediments.

Mangrove Litter Carbon Storage

The average results of mangrove litter carbon storage from each Station can be seen in Table 6.

Table 6. Average Carbon Storage of Mangrove Litter

Station	Biomass (g/m^2)	Carbon storage (g/m^2)	Carbon storage (tons/ha)
I	32,44	15,25	0,15
II	19,68	9,25	0,09
III	8,17	3,84	0,04
IV	8,12	3,82	0,04
V	35,47	16,67	0,17
Average			0,10

Based on Table 6, the results of the average mangrove litter carbon storage from each Station show that the highest average mangrove litter carbon storage was at Station V, which was 0.17 tons/ha, while the lowest average carbon storage found in Station III and IV, which are both 0.04 tons/ha. Station V plots 2 and 3 have very high bush vegetation, and this is the cause of the high mangrove litter content at these stations. Station IV has *L.racemosa* as a dominant mangrove species, which can affect the litter produced at that Station because this type of mangrove has relatively small leaf sizes.

Station V plots 2 and 3 are dominated by *A.aureum* and *A.speciosum* with very high densities, which is the reason for the high production of mangrove litter in the area. Station V is dominated by bush vegetation due to the area's minimal influence of seawater. Bush vegetation can interfere with the growth of true mangroves because they can grow quickly and have a large number of leaves, thus blocking sunlight for the growth of true mangrove propagules. The existence of bush-type vegetation that has many leaves can increase the average value of mangrove litter carbon stores at Station V. Based on

Leksono et al.[32], the mangrove density affects the production of the resulting litter in vegetation that has a high density, it will produce more litter in the amount.

Carbon storage at Stations III and IV obtained the lowest yield of 0.04 tons/ha. This is influenced by the mangrove species found at the Station. For example, there is the mangrove species *L. racemosa* at Station IV, which has small leaves, so its carbon stores are also small. Sea tides also affect litter carbon storage in mangrove vegetation, where the vegetation is often submerged; therefore, the fallen litter will be carried away by seawater. The carbon storage of mangrove litter is influenced by the rate of litter production in vegetation. Mangrove litter production rates varied depending on the age of the trees and the season when the research was conducted.

The average carbon storage of mangrove litter in this study was 0.10 tons/ha, which was lower than that of Windarni et al.[33] in Margasari Village, East Lampung Regency, it was 1.25 tons/ha; this could be influenced by the species and season when the research was conducted. The differences in the research results on mangrove litter carbon storage varied depending on the mangrove species and seasonal conditions during sampling. Mangroves can shed more leaves in some seasons than in others.

Mangrove Sediment Carbon Storage

Based on Table 7, the average mangrove sediment carbon storage from each Station shows that the highest average sediment carbon storage was at Station III, 46.71 tons/ha. In comparison, the lowest average sediment carbon storage was at Station V, 23.54 tons/ha. Station III has many species and mangrove trees found, so organic matter, such as fallen litter, will settle and accumulate there. Station V has dry soil conditions and is far from the shoreline, so the sedimentation process occurs very slowly, resulting in low carbon storage at the Station.

Table 7. Average Carbon Storage of Mangrove Sediment

Station	Carbon storage (g/cm^3)	Carbon storage (tons/ha)
I	3,31	33,13
II	3,27	32,67
III	4,67	46,71
IV	2,85	28,48
V	2,35	23,54
Average		32,91

The highest mangrove sediment carbon storage in this study, namely at Station III, is thought to be closely related to the highest mangrove root carbon storage, which is also present at Station III. The number of mangrove species and the high density at this Station cause the source of sedimentary organic matter to be high and varied. Each mangrove species has a specific season to shed its leaves, produce fruit and flowers which causes the accumulation of organic matter falling into the sediments to occur throughout the year. The condition of the substrate at Station III is dominated by black mud which is rich in organic matter, this makes the sediment carbon stores at that Station higher than other Station.

The average of carbon storage in mangrove sediment in this study was 32.91 tons/ha, this value was lower than that of Susilowati et al.[34], in Tabakbulusan Village, Demak, Central Java, it was 57.74 tons/ha. The research results of Rahmah et al.[35], in the coastal area of Banda Aceh City, it was higher than this studies namely 55.31 tons/ha. The dominant type of muddy substrate in both studies can be the cause of the high carbon storage of mangrove sediments in each of these studies compared to this study.

Total Carbon Storage

The average results of carbon storage from each carbon pool of mangrove forests on the North Coast of Cawan Island can be seen in Table 8.

Table 8. Average Results of Carbon Storage from Each Carbon Pool

Station	Carbon pool				Amount	North Coast of Cawan Island 3.401,66 ha
	Stem	Root	Litter	Sediment		
I	96,08	16,49	0,15	33,13	145,85	(83,98 * 3.401,66) = 285.671,40 ton
II	23,31	11,43	0,09	32,67	67,5	
III	21,83	33,49	0,04	46,71	102,07	
IV	24,85	19,35	0,04	28,48	72,72	
V	6,75	1,31	0,17	23,54	31,77	
Average (tons/ha)	34,56	16,41	0,10	32,91	83,98	

Table 9. Average Results of CO_2 Absorption Capability of Mangrove Forests

No.	Carbon Pool	Amount (tons/ha)	CO_2 absorption (tons/ha)	North Coast of Cawan Island (3.401,66 ha)
1	Stems	34,56	126,85	636.450,59
2	Roots	16,41	60,24	
Total		50,99	187,10	

Based on Table 8, the average carbon storage of each carbon pool shows that, the most extensive carbon storage is from mangrove forests on the North Coast of Cawan Island, which is located in the stands (stems) of 34.56 tons/ha and mangrove sediments of 32.91 tons/ha, while the lowest carbon storage is located in mangrove litter of 0.10 tons/ha. The total carbon storage per hectare of mangrove forest obtained was 83.98 tons/ha. The area of the mangrove forest on the North Coast of Cawan Island is 3,401.66 ha, so the estimated carbon storage obtained is 285,671.40 tons.

The highest stem carbon storage is at Station I, this is estimated to be more influenced by the average stem diameter at that Station, especially the mangrove species *R.apiculata*. The highest root carbon storage is at Station III, this is thought to be influence by the number of species found and the condition of the substrate in the form of fine mud causing growing mangrove to require more root systems to be able to survive. The highest litter carbon storage was found at Station V, this was thought to be influenced by the high density of *A.aureum* and *A. speciosum* species which were able to produce more litter. The highest sediment carbon storage is found at Station III, this is thought to be related to root carbon storage, which is influences by the number of species that grow at that Station.

Estimation of CO_2 Absorption Capability

Estimating the CO_2 absorption capability is obtained from carbon storage value of mangrove stems and roots converted to carbon dioxide (CO_2) values. This part was chosen because the process of sequestration by plant tissue still occurs. Sequestration is the process of absorbing carbon from the atmosphere and storing it in the form of plant biomass (Table 9).

Based on Table 9, the average CO_2 absorption capability of mangrove forests show that the CO_2 absorption capability obtained in the stem is 126.85 tons/ha and in the roots is 60.24 tons/ha. The abilityto absorb CO_2 per hectare is 187.10 tons/ha, so the total ability to absorb CO_2 by mangrove forest on the North Coast of Cawan Island is 636,450.59 tons. According to Sondak[36], CO_2 absorption by mangrove forests is closely related to mangrove biomass, both standing biomass such as from stems, branches, leaves, flowers and fruit as well as subsurface biomass namely roots.

The average CO_2 absorption capability obtained was 187.10 tons/ha, this is lower than the results of Apriliana et al.[37], in Mangunharjo Semarang, namely

575.71 tons/ha. The ability to absorb CO_2 in this study was higher than that of Ledheng et al.[38], at Wini Beach, Oepuah Beach, and Tuamese Beach in East Nusa Tenggara Province with values of 17.38, 19.67, and 33.79 ton/ha. According to Isnaini et al.[39], differences in the amount of carbon dioxide (CO_2) absorbed in a mangrove forest area can be affected by the density and diameter of the mangroves.

The mangrove forest on the North Coast of Cawan Island has an area 3,401.66 ha, so the estimated CO_2 absorption capability of the mangrove forest is 636,450.59 tons. This value is very important to increase considering the increasing number of emissions released into the air, thus requiring more CO_2 absorption capabilities. The opinion of Fargione et al.[40], through the result of his research, states that the most potential solution to climate change in the United States is by increasing carbon sequestration with plant biomass which can reduce world carbon emissions by 63%.

Estimation of the economic value of carbon storage

The estimated economic value used in this study is the Social Cost Carbon (SCC) value. The estimated economic value of CO_2 absorption of mangrove forests on the North Coast of Cawan Island is presented in Table 10.

Table 10. Estimated Economic Value of CO_2 Absorbance of Mangrove Forests on the North Coast of Cawan Island

Carbon pool	CO_2 absorption (tons/ha)	USD ($)	Rupiah (IDR)	North Coast of Cawan Island (3.401,66 ha)
Stems	126,85	6.469,54	101.571.842	Rp 509.599.619.024
Roots	60,24	3.072,44	48.237.257	
Total	187,10	9.541,98	149.809.099	

Note: Convert currency exchange rates during research 1$ = IDR 15,700 (November 2022)

Based on Table 10, the estimated economic value of CO_2 absorption of mangrove forests on the North Coast of Cawan Island shows that the estimated economic value of mangrove stem carbon is IDR 101,571,842 /ha and the economic value of mangrove root carbon is IDR 48,237,257 /ha. The economic value of the mangrove forest carbon storage obtained is IDR 149,809,099 /ha. The economic value of carbon storage is obtained by multiplying the Sosial Cost Carbon (SCC) value with each CO_2 absorption value. The current value of SCC is $51[41]. Estimation of the economic value of CO_2 absorption in mangrove forests is obtained from the average CO_2 absorption capacity of mangrove stems and roots. The average value of stems and roots is then multiplied by the current SCC price which is $51. The carbon value obtained is then converted into rupiah, which is IDR 15,700 (November 2022). Furthermore, after the economic value of carbon per hectare is obtained multiplied by the area of mangrove forests on the North Coast of Cawan Island, which is equal to 3,401.66 ha.

The result of the economic value of CO_2 absorption in this study amounted to IDR 149,809,099 /ha, which is smaller than the results of research by Farahisah et al.[42], at the mouth of the Musi River, which is IDR 275,513,837/ha. The total economic value of mangrove forest carbon on the North Coast of Cawan Island was IDR 509,599,619,024. The economic value of carbon storage can also be different even in the exact location, depending on the carbon multiplication standard used. Changing policies by the government can also affect the existing carbon price.

According to research by Fauzi & siregar[43], the calculation of carbon price using the economic value approach of forest areas has not been widely studied at this time. Low carbon price will reduce the interest of carbon owners to maintain their carbon storage, which will result in short-cycle investments that provide results in a short period of time more desirable than just maintaining their carbon deposit. It's important to pay attention to the welfare of the people living around the forest so that the community can protect the forest together. According to Warningsih et al.[44], community involved in the management of mangrove forests is still being considered, especially for sustainable mangrove management plans which are the criteria for management strategies. Communities who participate in managing mangroves can guarantee the preservation of marine resources ensure the welfare and survival of the surrounding community.

4. CONCLUSION

Based on the results of the study is was concluded that the estimated carbon storage of mangrove stands (stems) was 34.56 tons/ha, below-ground (roots) carbon storage was 16.41 tons/ha, carbon storage in mangrove litter was 0.10 tons/ha and carbon storage in mangrove sediment was 32.91 tons/ha. The average carbon storage of mangrove forests on the North Coast of Cawan Island is 83.98 tons/ha or 285,671.40 tons for the entire North Coast of Cawan Island. The estimated ability to absorb CO_2 by mangrove forests is an average 187.10 tons/ha or 636,450.59 tons for the entire North Coast of Cawan Island. The estimated economic value of mangrove forest carboon is an average of IDR 149,809,099 /ha or IDR 509,599,619,024 for the entire North Coast of Cawan Island.

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