Vegetation and carbon stock analysis of mangrove ecosystem in Pancer Cengkrong, Trenggalek, East Java, Indonesia

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Abstract. Research has been conducted in March to July 2013 in the Mangrove Ecosystem Pancer Cengkrong, Trenggalek, East Java, Indonesia. The objective was to obtain composition of mangrove vegetation and potential carbon stocks. There were three stations for composition of vegetation analysis. Potential carbon stock was calculated by allometric equations. The total of 26 species were identified (17 true mangroves and 9 association mangroves). The vegetation dominated by Sonneratia alba with an average density of 596 trees/ha, followed by Rhizophora apiculata (221 trees/ha) and Avicennia alba (149 trees/ha). The Saplings and seedlings dominated by Ceriops tagal (with average density of 1,745 Saplings/ha; 34,745 seedlings/ha). More than 75% stand structure of mangrove have tree diameter of 4–9.9 cm. Total biomass and carbon stocks were 400.45 ton/ha and 185.81 ton/ha (equivalent to the total amount of CO₂ uptake by 681.91 ton/ha). Sonneratia alba was tree that contribute the largest carbon storage.

Keywords: Allometric, biomass, carbon stock, CO₂ uptake, mangrove vegetation

1. Introduction

Global warming is happening because of the high content of carbon dioxide (CO₂) and other gases in the atmosphere are called greenhouse gases. Human activities such as manufacturing, transportation and deforestation led to the release (emission) of CO₂ into the atmosphere. Approximately 8–20% of CO₂ emissions occur due to deforestation and land use change [1]. The gas makes the atmosphere to hold more heat from the sun, resulting in a temperature rise in the earth. Temperature changes in the long term lead to global climate change. Climate change caused many negative impacts, such as rising sea levels, floods, droughts, forest fires and declining yields.

Several countries in the world work to address climate change through REDD + (Reducing Emissions from Deforestation and Degradation), such a mechanism has been approved by the United Nations that the United Nations Framework Convention on Climate Change (UNFCCC). The success of the program relies on accurate data and information on potential carbon [2]. Measurement of the amount of carbon stored in the biomass in an area can describe the amount of CO₂ in the atmosphere which is absorbed by plants. While the measurement of carbon reserves stored in the nekromasa captures the CO₂ which is not released into the air through combustion [2]. Therefore, research needs to measure the potential for carbon sequestration as part of efforts to support climate change mitigation.
Mitigation of climate change due to global warming can be addressed with the preservation of mangrove forests. Mangrove forests play an important role in the ecological and socio-economic, as filters of nutrients between land and sea [3], coastal protection [4], providing commercial fishery resources [5], fish and crustaceans breeding area [6] as well as climate change mitigation [7]. In the global carbon cycle, tropical forests are generally an important component and is estimated to represent ~ 30–40 % of terrestrial net primary production [8]. Although the area of mangrove forests cover only a fraction of the tropical forests, their positions on the surface of the terrestrial-marine and material exchange with the coastal waters showed that mangrove forests provide an unique contribution to carbon biogeochemistry in coastal areas [9]. Various estimates also indicate that the majority of the mineralization and burial of organic carbon, the carbonate production and accumulation occurring in the coastal marine [10]. Bouillon et al. [11] found a small portion of the organic matter produced by mangrove trees exported to the coastal ocean through the detritus food chain that supports coastal fisheries.

The problem as was revealed by [12] that the mangrove habitat loss due to conversion of land for shrimp and fish farming, agriculture, salt production, and the development of coastal areas. Conversion of land has resulted in the loss of more than 35 % of the mangrove forests in the world during 1980–2000 [13]. Increased pressure is threatening the sustainability of the ecological functions of mangroves as primary producers and carbon cycle.

The purpose of the research was to study the vegetation composition and stand structure mangrove ecosystem Pancer Cengkrong, Trenggalek, East Java. The study also aimed to obtain information of biomass, carbon stock potential, CO₂ uptake value and diversity of mangrove trees that have the potential carbon stock at that location.

2. Materials and method

2.1. Study site

Research was located on the south coast of East Java is called Pancer Cengkrong with an estimated 94 hectares wide, stretches along the stretch of coast Karanggandu Village, Watulimo District, Trenggalek, East Java (figure 1). The location lies at 08°17'39.40" – 08°18'13.40" south latitude and 111°41'54.80" – 111°42'32.30" east longitude with an area ± 94 ha. The mangrove ecosystem in Pancer Cengkrong has the function and economic benefit as timber, livelihoods by searching the crabs, clams, white shrimp, fish consumption (mullet, snapper), ornamental fish, and lizards [14]. However, the mangrove forests have been damaged by the community in 2003, such as logging for firewood and charcoal materials, land clearance for shrimp farms, destruction of agricultural land and plantations [15]. In addition, the condition of mangrove forests also started being threatened by the construction of the southern loop line segment (JLS) that could adversely impact the ecological uniqueness of mangrove forests [16].

The study area was divided into three stations. Station 1 was the area bordering the Damas Bridge construction connecting the south loop line segment and berthing of fishing vessels, Station 2 was adjacent to residential areas and Station 3 was bordered by plantation. The substrate of the three station are almost the same with muddy and sandy substrates.

Laboratory analysis conducted at the Laboratory of Environmental, Tulungagung Environmental Agency and Laboratory of Soil in Brawijaya University, Malang, East Java, Indonesia. When the study was carried out from March to July 2013.

2.2. Data sampling

Mangrove vegetation samples were divided into seedlings, Saplings, trees and understorey. Sampling for mangrove vegetation analysis using the line transect method [17]. At each station were made transects perpendicular to the river, each transect distance of at least 100 m. At each transect were made a number of quadrants for sampling vegetation. Quadrant with a size of 10 x 10 m² for trees, sub quadrant
5 x 5 m² for Saplings, 1 x 1 m² for seedling and understorey. In each quadrant identified the species name, counted the number of individuals of each species and measured for levels of tree trunk diameter. Measurement of trunk diameter at breast height (DBH) or approximately 1.3 m from the ground [17]. In addition to the analysis of vegetation, tree diameter also used the data to estimate above ground and below ground biomass with the general allometric equation. The results of the calculations will be used for the estimation of biomass carbon content of each tree. While the lower plant biomass (including saplings, seedlings, and herbs) were measured by destructive harvesting of plants under the sub quadrant 0.5 x 0.5 m² Furthermore it were oven at a temperature of 105 °C and calculated dry weight [2].

Measurement of environmental conditions was also carried out to complement the research data. Environmental parameters examined included air temperature, water temperature and pH were measured with handylab, and water salinity was measured with a refractometer. Measurements were taken at each sampling transect.

2.3. Data analysis
Data analysis includes mangrove vegetation Species Density (K), Relative Density (Kr), Species Frequency (F), Relative Frequency (Fr), Basal Area (BA), Species Closure or Dominance (D), Relative Dominance (Dr) and Index Value of Interest (IV) [17].

Calculation of above and below ground biomass using allometric equation developed by [18]:

\[ B_a = 0.251 \times p \times (D)^{2.46} \]  \( (1) \)

\[ B_b = 0.199 \times p^{0.899} \times (D)^{2.22} \]  \( (2) \)

where:

- \( B_a \): above ground biomass (g),
- \( B_b \): below ground biomass (g),
\( \rho \): wood density \((g/cm^3)\), where the data \( \rho \) from every species of tree wood sourced from literature \([18]\) \((2005)\) and \textit{wood density database of world agroforestry trees} (www.worldagroforestry.org),

\( D \): diameter of the tree (cm).

Counting understorey biomass per quadrant was also calculated by the formula as follows:

\[
\text{Total } B_u = \frac{B_d \text{ sub sample}}{B_w \text{ sub sample}} \times \text{Total } B_w
\]  

where:

- \( B_u \): lower plant biomass (g),
- \( B_d \text{ sub sample} \): sub sample dry weight (g),
- \( B_w \text{ sub sample} \): subsample wet weight (g),
- \( B_w \): total wet weight (g).

Analysis of carbon stock is calculated by the formula:

\[
C = B \times \% C_{\text{organic}}
\]

where:

- \( C \): carbon content of biomass (kg),
- \( B \): total biomass \((B_a + B_b + B_u)\) (kg),
- \( \% C_{\text{organic}} \)\: the percentage of the value of carbon content, amounting to 0.464 \([19]\).

Estimates of CO\(_2\) uptake value determined by using the comparative period of relative molecular O\(_2\) \((44)\) and a relative atomic C \((12)\) \([20]\), in order to obtain:

\[
\text{uptake of CO}_2 = 3.67 \times \text{carbon stocks}
\]

### 3. Results

#### 3.1. Physico-chemical characteristics of water

Measurement of physico-chemical characteristics performed at each substation were presented in table 1.

#### 3.2. Vegetation composition and stand structure of mangroves Pancer Cengkong

The results of three research stations in Mangrove Pancer Cengkong, presented in table 2 with a total of 26 species were identified.

Pancer Cengkong mangrove vegetation conditions described of Importance Value Index (IV) were presented in table 3. The IV calculation resulted at tree level, illustrating that \textit{Sonneratia alba} has an important role and the influence of mangrove ecosystems Pancer Cengkong. Other species also have high value IV were \textit{Rhizophora apiculata}, \textit{Avicennia alba} and \textit{Sonneratia caseolaris}. Unlike the case with the tree level, the results of calculations IV saplings and seedlings at the highest level is

| Table 1. Physico-chemical parameter values in mangrove Pancer Cengkong. |
|-----------------|-----------------|-----------------|-----------------|
| Parameter       | Station 1        | Station 2        | Station 3        |
|                 | min.  | max.  | mean ± SE | min.  | max.  | mean ± SE | min.  | max.  | mean ± SE |
| Air temperature \((^\circ C)\) | 25.0   | 32.3  | 27.5 ± 0.39 | 26.9  | 34.0  | 29.2 ± 0.54 | 27.3  | 32.7  | 29.7 ± 0.44 |
| The water temperature \((^\circ C)\) | 26.2   | 31.7  | 28.9 ± 0.5  | 26.9  | 33.0  | 28.7 ± 0.38 | 27.1  | 34.0  | 31 ± 0.82 |
| pH              | 5.6   | 7.4   | 6.6 ± 0.14 | 6.2   | 7.8   | 7.2 ± 0.12 | 6.3   | 7.5   | 7.3 ± 0.10 |
| Salinity \((\%)\) | 8.8   | 33.0  | 24.2 ± 1.9 | 1.0   | 8.5   | 3 ± 0.53   | 0.1   | 4.5   | 2.3 ± 0.57 |
Ceriops tagal and Aegiceras corniculatum. The highest IV understory was Acantus ilicifolius at stations 1 and 3, while Finlaysonia maritima has the highest IV at Station 2.

The composition of the resident species of mangrove ecosystems are generally classified as true mangroves and mangrove associates. Comparison of the number of individuals on the basis of the classification is presented in figure 2. The figure shows that the true mangrove dominated the study site. As for the 26 species found in the study sites, 17 species of true mangroves and 9 are included mangrove associate species. However at Station 2 and 3, understory belonging to the mangrove associations more than the true mangrove.

Mangrove forest stand structure in the location of the study showed a diminishing number of trees of small diameter class to the class of large diameter are presented in figure 3.

Table 2. The number of species and individual mangroves.

| Location | Number of species | Number of individuals | Total |
|----------|-------------------|-----------------------|-------|
|          |                   | Trees | Saplings | Seedlings | Understoreys |       |
| Station 1| 20                | 149   | 307      | 207       | 35           | 698   |
| Station 2| 16                | 237   | 278      | 223       | 93           | 831   |
| Station 3| 15                | 194   | 101      | 38        | 62           | 395   |
| Total    |                   | 580   | 686      | 468       | 190          | 1924  |

Table 3. Importance value index (IV) mangrove species.

| No. | Species               | Station 1 (%) | Station 2 (%) | Station 3 (%) |
|-----|-----------------------|----------------|----------------|----------------|
|     |                       | Tree | Saplings | Seedling | Tree | Saplings | Seedling | Tree | Saplings | Seedling |
| 1   | Aegiceras corniculatum| 14.27| 52.35 | 56.16 | 38.29 | 34.91 | 21.55 | 112.44 |
| 2   | Avicennia alba        | 22.71| 9.42  | 4.23  | 58.89 | 9.71  | 16.56 | 4.02  | 16.99  |
| 3   | Avicennia marina      | 3.74 | 22.68 | 16.63 | 22.83 | 13.98 | 30.14 |
| 4   | Bruguiera cylindrica  | 5.30 | 2.44  |       |       |       |       |
| 5   | Bruguiera gymnorrhiza | 17.37| 11.88 | 8.57  |       |       |       |
| 6   | Bruguiera sexangula  | 17.42| 5.37  | 12.92 |       |       |       |
| 7   | Ceriops tagal         | 66.20| 81.64 | 68.32 | 77.87 | 4.47  | 6.00  | 16.99 |
| 8   | Clerodendrum inerme   | 2.11 | 6.74  | 3.57  |       |       |       |
| 9   | Cocos nucifera        |       |       |       |       |       |       |
| 10  | Dolichandrone spathacea|      | 20.04 | 5.01  |       |       |       |
| 11  | Excoecaria agallocha  | 41.43|       |       |       |       |       |
| 12  | Hirtitiera littoralis | 4.41 | 2.11  |       | 9.46  | 8.04  |       |
| 13  | Hibiscus tilaceus     | 4.44 | 2.44  | 25.72 |       |       |       |
| 14  | Rhizophora acipulata  | 77.86| 18.53 | 18.29 | 7.15  | 66.17 | 20.04 | 11.72 |
| 15  | Rhizophora mcracnata  | 12.77|       |       | 9.47  | 21.03 |       |
| 16  | Rhizophora stylosa    | 4.72 |       |       |       |       |       |
| 17  | Sonneratia alba       | 136.22| 18.69 | 10.75 | 147.40| 20.85 | 16.10 | 23.01 | 11.72 |
| 18  | Sonneratia caseolaris |      | 5.01  | 5.93  | 4.47  | 35.26 | 8.04  |       |
| 19  | Xylocarpus moluccensis| 6.31 | 3.69  | 4.92  |       |       |       |
3.3. Analysis of mangrove carbon stocks Pancer Cengkrong

The results of the analysis of the mangrove ecosystem carbon stocks were obtained at three stations in total carbon stocks of 185.81 tons/ha. The total value of the carbon stocks indicate the estimated carbon content stored in the biomass of mangrove trees at the top of the surface and subsurface soil and undergrowth covering seedlings, Saplings, and herbs. Carbon stocks at Station 1 as much as 38.78 tons/ha with 83.57 tons of biomass/ha. While at Station 2, the average carbon stock of 43.05 tonnes/ha with 92.78 tons of biomass/ha. And at Station 3 has the highest carbon stock value is 103.98 tonnes/ha with a biomass 224.09 tons/ha (figure 4).

Total tree carbon stocks in three research stations varies inversely with the addition of a trunk diameter is presented in figure 5. Station 1 carbon stocks decreased in diameter classes 0 to 9.9 cm of 8.68 tons/ha, 10 to 19.9 cm by 6.57 tons/ha, 20 – 29.9 cm by 2.39 tons/ha but increased in diameter classes ≥ 30 cm by 4.90 tons/ha. At Station 2, the total carbon stocks continued to decline in diameter classes 0 to 9.9 cm by 14.50 tonnes/ha, 10 to 19.9 cm by 7.91 tons/ha, 20 to 29.9 cm for 2.82 tons/ha and no individual trees in diameter classes ≥ 30 cm. While at Station 3, carbon stocks in diameter classes 0 to 9.9 cm by 16.64 tonnes/ha, an increase in diameter classes from 10 to 19.9 cm by 43.85 tonnes/ha, but decreased in diameter classes 20 to 29.9 cm by 21.09 tonnes/ha and continued to decrease in diameter classes ≥ 30 cm by 16.26 tonnes/ha.

Largest proportion of carbon stocks at the level of the tree in three mangrove sampling stations Pancer Cengkrong generated from family Sonneratiaeaceae of 56.98 tons. Another family also contribute to mangrove carbon stocks in that location which is Rhizophoraceae of 49.87 tons, Avicenniaceae

![Figure 2. Comparison of individual’s number true mangroves and associates mangrove.](image1)

![Figure 3. Number of individual mangrove based on stem diameter.](image2)
28.83 tons, *Bignoniaceae* 7.22 tons, *Euphorbiaceae* 1.28 tons, *Myrsinaceae* 1.07 tons, *Sterculiaceae* 0.20 tons, *Meliaceae* 0.15 tons and *Malvaceae* 0.02 tons (figure 6).

**Figure 4.** Potency of carbon storage in mangrove Pancer Cengkrong, Trenggalek.

**Figure 5.** Potential carbon stocks by diameter class of mangrove tree.

**Figure 6.** The proportion of carbon stocks in mangrove ecosystems Pancer Cengkrong, Trenggalek.
Figure 7. Value of CO2 uptake in the mangrove forest Pancer Cengkrong, Trenggalek.

Measurement of the amount of carbon stocks on land can describe a number of CO2 in the atmosphere that can be absorbed by mangrove vegetation. Based on the analysis conducted, the obtained value of absorption CO2 at Station 1 at 142.31 tons / ha, Station 2 at 158.00 tons / ha and the highest value at Station 3 at 381.60 tons / ha (figure 7).

4. Discussion

4.1. Vegetation composition and stand structure of mangroves Pancer Cengkrong

The mangrove vegetation analysis results indicated that the most abundant species identified from Station 1 (table 3). It was alleged substrate conditions at Station 1 was quite diverse, ranging from sandy to muddy substrate, there was even a very dry part of the substrate that allows non mangrove plants can grow. In addition, the physical condition of the water also affected the substrat, such as pH and salinity. The range of pH values at Station 1 was larger than two stations, namely from 5.56 to 7.35. Similarly, the range of salinity at Station 1 was also larger than the other station (8.8–33 ppt). The Station 1 located in the estuary. It effected on the number of species found at Station 1.

Although the number of species identified at Stations 2 and 3 was lower, but they have a larger density of trees. The density of trees in Station 3 highest, but the density of saplings and seedlings lowest. This was expected, when the tree was getting tight, then the floor will be shaded mangrove forests and the intensity of sunlight that enters the forest floor was lower, consequently inhibiting the growth of saplings and seedlings. Meanwhile, in Station 2, the density of saplings and seedlings highest compared to other stations. The density of trees so densed that caused not too much sunlight that reaches the mangrove forest floor.

The highest density of tree species originating from species Sonneratia alba, both at Station 1,2 and the highest density at Station 3 followed by Rhizophora apiculata, and Avicennia alba. Average density in all three stations for S. alba as many as 596 trees / ha, R. apiculata 221 trees / ha and A. alba 149 trees / ha. This is presumably because the environmental conditions in the mangrove ecosystem Pancer Cengkrong suitable for growth of S. alba. S. alba like soil mixed with mud and sand, sometimes on rocks and coral. Noor et al. [21] stated that the species are often found in coastal locations sheltered from the waves and in the estuary. This is in accordance with the conditions at the study site is a sheltered area, the tide went into the area only through the mouth of the river. The mangrove areas have also experienced large-scale logging in 2003 that according to the statement Noor et al. [21] that in locations where other plants have been harvested, the type of S. alba can form dense stands. Flowering also occurred throughout the year so that a new individual ready to grow to replace the trees that have been felled or dead. Mangrove species in the mangrove forests Pancer Cengkrong include Ceriops tagal,
Density of seedlings and Saplings was highest in species *Ceriops tagal* at Station 1 and 2. The species formed dense thickets on the edge of the forest land from tidal and/or in areas that were flooded by the high tide with the soil has good drainage system [21]. These conditions correspond to the ecology in Station 1 and 2, in which many parts of area was flooded only by tides. Most of the *C. tagal* in the study site, can not grow tall, these species have many branches and twigs that form a dense bush and it has a diameter < 4 cm. As at Station 3, the highest density of Saplings and seedlings are owned by *Aegiceras corniculatum*. *A. corniculatum* have a high tolerance to salinity, soil, and light are varied and generally grow on land, mangrove areas are inundated by normal high tide, and at the edge of the brackish waterways that are seasonally [21]. These conditions correspond to the conditions at Station 3, these plants grow on the banks of the river, where freshwater supply more in from the mountains around when the tide is low. *A. corniculatum* forming shrub that grows well categorized into levels of chicks. Average density in all three stations for *Ceriops tagal* (1,745 Saplings / ha; 34 745 seedlings / ha) and *Aegiceras corniculatum* (14,94 tillers / ha; 23 042 seedlings / ha).

At the study site there are also many lower plants (including types of ferns and vines). The data is presented in Appendix I.2. *Acanthus ilicifolius* at high densities at stations 1 and 3 because of suspected physiological and ecological capability of the species to survive in the mangrove ecosystem. *Acanthus ilicifolius* relatively insensitive to pH and salinity gradients because it has the ecological range wide [22]. The species also dominate a location that has regular diurnal tidal inundation. While *Finlaysonia maritima* has the highest density at Station 2. These results presumably because Station 3 has a sandy substrate, according to [21] the species commonly grown on a sandy beach, but also right on the shoreline, and sometimes on the waterways.

Importance Value Index results analysis (INK) showed that *Sonneratia alba* INK highest value that has a considerable influence on the location of the study. This is because it is supported by the values of density, frequency and dominancy are also high. As described in the previous paragraph that the ecological conditions in the mangrove ecosystem Pancer Cengkrong strongly supports the growth of *S. alba*. Meanwhile, at the level of Saplings and seedlings, *Ceriops tagal* and *Aegiceras corniculatum* have the highest INK. It has also been described in the preceding paragraph that the ecological conditions of the region sufficient to support the growth of these two species. Meanwhile, herbaceous plants, the highest INK owned by *Acanthus ilicifolius* at Station 1 and 3, while at Station 2 is the highest INK *Finlaysonia maritima*. Both of these species have an important role at each station, but according to [23] on a degraded mangrove forests, *Finlaysonia maritima* and *Acanthus ilicifolius* an inhibitor of the growth of weed seedlings are planted.

True mangroves differ from mangrove associate in physiology and ecology in the survival in the mangrove environment. A total of 17 species of the 26 species found at the study site is a true mangrove species and nine others, including mangrove associates. Based on figure 2, true mangroves dominate the study site. However at Station 2 and 3, herbaceous plant belonging to the mangrove associations more than the true mangrove. Wang et al. [24] stated that a true mangroves and mangrove associates true halophil is glikofit with certain salt tolerance. The low salinity conditions at the station resulted in the growth of two species of mangrove associates are more than the true mangrove. These conditions can threaten the existence of true mangrove species if the sea water supply continues to diminish. As explained earlier, that the supply of sea water only comes from one estuary, coupled with the right Damas bridge construction at the site will reduce the supply of sea water. Nevertheless, the overall composition of the vegetation is still normal. Construction of roads, railway lines and other structures in the boundary towards inland wetlands may hinder the spread of mangrove vegetation and coupled with rising sea levels, it can reduce the area of mangrove habitat [12].

Grouping of a number of species the researchers are still in controversy. The results of classifying research *Excoecaria agallocha*, *Heritiera litoralis* and *Acrosticum aureum* into a true mangrove, but the results of the study [24] classify them as mangrove associates. *Clorodendrum inerme* in the study were classified as mangrove associates, in contrast to Wang et al. [24] which states that the species is a true

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[21] A. corniculatum forming shrub that grows well categorized into levels of chicks.
mangrove since the measurement parameters studied were in the range of true mangroves. These parameters include the water content on the basis of leaf area, leaf nitrogen concentration, Na and Cl ion content, the ratio of K / Na, and leaf sap osmolality [24].

Stand structure can be interpreted as the distribution of trees per unit area in different diameter classes [25]. In general, the structure of forest stands in the study site show characteristics of diminishing the number of trees of small diameter class to the class of large diameter (figure 3). The condition is similar to [26] in the National Park Alas Purwo the number of its distribution resembles the letter “J” reversed. More than 70% of trees in the third station has a diameter of 4 to 9.9 cm which showed that mangrove forests in Pancer Cengkrong not reached the climax phase of growth forests are characterized by the dominance of young plants. Information from [15] said that around 2003 there is deforestation by locals for firewood and building materials, and even now it still happens on a small scale harvesting by fishermen to repair the ship. However, the disorder can still be controlled thanks to conservation efforts and the supervision of the group, so it can be said that the forest is still normal.

4.2. Analysis of the mangrove ecosystem carbon stocks Pancer Cengkrong

Total carbon stocks in mangrove ecosystems Cengkrong Pancer, Trenggalek of 185.81 tons / ha. The value of carbon stocks can already be categorized as a tropical forest with values ranging between 161-300 tonnes / ha [27]. The figure shows that the mangrove ecosystem in addition to functioning as biodiversity conservation, hydrological, and also has the role of aesthetics and function as a carbon sink. Here also presented a comparison of potential biomass, carbon stocks and uptake of CO₂ in table 4. The data illustrates that the estimated potential carbon stocks in mangrove forest Cengkrong Pancer, was quite high. The data also indicate the magnitude of the absorption ability of CO₂, the greater the value of mangrove carbon stocks, the greater the ability of mangrove ecosystems to absorb CO₂ from the atmosphere so it can support the world to reduce emissions of greenhouse gases in climate change mitigation efforts.

Based on the analysis of tree carbon stocks at the three sampling stations, gained an average of mangrove vegetation carbon stocks of 61.94 tons / ha. If converted to a land area of mangrove forests across the region who have wide Pancer Cengkrong about 94 ha, it will result in tree carbon stocks greater the 5821.95 tons. Carbon storage capacity is directly proportional to the percentage increase in land area.

The results of the analysis of carbon stocks also showed the largest carbon stocks derived from Station 3 (figure 4). This was presumably because 3 station directly adjacent to the plantation population and far enough away from residential areas and the location of reliance ships. Unlike the case with Station 1 adjacent to berthing of fishing vessels and bridge construction in Damas, the connecting segment Jalus South Rim, and Station 2 which was directly adjacent to residential areas. At Station 1, the fishermen utilize mangrove trees to repair their ships as well as at Station 2, the locals also utilize wood as fuel or building homes that affect the total carbon stock in the station.

| No. | Research Sites       | Biomass (tons / ha) | Carbon stocks (tonnes / ha) | Uptake of CO₂ (tonnes / ha) | Reference                          |
|-----|----------------------|---------------------|-----------------------------|------------------------------|------------------------------------|
| 1.  | HM Siberut           |                     |                             |                              | Bismark et al. (2008)             |
| 2.  | HM Ciasem, West Java | 364.9               | 182.5                       | 669                          | Dharmawan and Siregar (2008)       |
| 3.  | HM TN Alas Purwo     | 217.22              | 108.61                      | 398.60                       | Heriyanto & Subiandono (2012)     |
| 4.  | HM Cengkrong Pancer, | 400.45              | 185.81                      | 681.91                       | Research Pancer Cengkrong         |

Description: HM: The mangrove forests; TN: National Parks
In addition to economic factors, the magnitude of carbon stocks in Station 3 was also influenced by ecological factors. These factors include the high density of trees and the size of the diameter of the tree. Kusmana et al. [28] and Rahayu et al. [29] stated that one of the important factors that determine the magnitude of a carbon stock of trees is the tree trunk diameter. However, if viewed by diameter class presented in figure 5, Carbon stock value was inversely proportional to the increase in the diameter class. The increase only occurred in diameter classes \( \geq 30 \) cm at Station 1 and the diameter from 10 to 19.9 cm at Station 3, while the diameter of the other class of impaired carbon stocks. The decrease in carbon stocks due to the small number of trees or low tree density on the stem diameter classes. This was in accordance with the statement [29] who said that in addition to stem diameter, tree density also affects the enhancement of carbon stocks through increased biomass.

The growth of the tree through photosynthesis results are then used by plants to make growth in horizontal and vertical directions. The larger the diameter caused by the conversion of biomass storage CO\(_2\) that increase in size as more and more CO\(_2\) is absorbed by the tree. In general, the forest with net growth (especially trees that are in the growth phase) were able to absorb more CO\(_2\), whereas the growth of mature forest with small holding and storing carbon inventory but can not absorb the excess CO\(_2\) [30].

The high density of trees was also the reason for the magnitude of carbon stocks on family Sonneratiaceae, Rhizophoraceae and Avicenniaceae. Majority of donations carbon stocks derived from species Sonneratia alba, Rhizophora apiculata and Avicennia alba. These results are consistent with the analysis of vegetation also obtained results that these species have a high INK anyway. It reinforces the statement that these species are species that have a great influence on the Mangrove Ecosystem Cengkrong Pancer, Trenggalek.

Besides mangrove species with high densities, there was also a species that has a fairly large carbon reserves because it has a greater diameter, namely Bruguiera gymnorrhiza. Species has only one individual trees in the study site, precisely at Station 1 with a diameter of 36.68 cm. Although there was only one individual tree, around the tree but there was a lot of tillers and seedlings of these species. When the seedlings and Saplings maintained its existence, it will provide greater carbon stocks in these locations.

Mangrove Ecosystem Cengkrong Pancer, Trenggalek plays an important role not only as a carbon sink, but naturally also serves as an absorbent CO\(_2\). Total emissions of CO\(_2\) would further increase with the development of the South Circle Line segment and residential areas as well as places berthing of fishing vessels on the south coast of Trenggalek. The thing to look out for the balance amount of absorption of CO\(_2\) in order to reduce and prevent the greenhouse effect or further warming. Application of REDD + programs in the area is one of the efficient approaches to climate change mitigation. Donato et al. [7] stated efforts to maintain deposits of C will require two things: mitigation in situ (eg, lowering the conversion rate) and facilitating adaptation to sea level rise. The second challenge requires a watershed-scale approach (DAS), such as landscape buffers to accommodate the migration of species to the mainland, keeping sediment input from upstream section and follow the degradation of mangrove productivity of pollution and the impact of other exogenous [31, 32].

5. Conclusion

Based on the results of this study concluded that the Mangrove Ecosystem Pancer Cengkrong Trenggalek, East Java, there are 26 species consisting of 17 true mangrove species and 9 species of mangrove associates. Vegetation at tree level dominated by species Sonneratia alba with an average density of 596 trees / ha, Rhizophora apiculata 221 trees / ha, and Avicennia alba 149 trees / ha, while the rate of Saplings and seedlings dominated by Ceriops tagal (density 1,745 Saplings / ha; 34 745 seedlings / ha) and Aegiceras corniculatum (14.94 tillers / ha; 23 042 seedlings / ha). The structure of the vegetation was largely dominated stands of trees with a diameter of 4 to 9.9 cm. Potential carbon stock and total biomass at the study site respectively by 185.81 tons / ha and 400.45 t / ha (equivalent to the total amount of uptake of CO\(_2\) at 681.91 tons / ha). Most of the contribution of carbon stocks derived from species Sonneratia alba, Rhizophora apiculata and Avicennia alba.
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