Potential of stock carbon in mangrove Sonneratia alba in Passo coastal waters, Inner Ambon Bay

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Abstract. The increase in CO₂ in the air has caused global warming, the impact of which is felt by everyone in the world. One way to control climate change is to reduce greenhouse gas emissions by maintaining the integrity of natural forests and increasing the density of trees outside the forest. Mangrove forests have a role as absorbers of CO₂ from the air, and save more carbon than most tropical rainforests. The purpose of this study was to determine the biomass, stock carbon and CO₂ uptake of mangrove Sonneratia alba in the Passo coastal waters, Inner Ambon Bay. Sampling of mangrove S. alba belt transect method with a belt width of 10 m. Data collected included the number of trees, diameter (DBH) and area of observation. Biomass analysis and carbon content of S. alba trees were carried out in a non-destructive way (without damaging plants), which was using biomass estimation allometric equations. Carbon (CO₂) uptake in S. alba is 564.48 tons.ha⁻¹ which is stored on above of the ground at 111.50 tons.ha⁻¹ and below the ground at 42.31 tons.ha⁻¹. Total stock carbon of 153.81 tons.ha⁻¹ were converted from total biomass of 327.26 tons.ha⁻¹. High carbon sequestration and storage is supported by high biomass and high biomass is supported by a high number and diameter of trees.

1. Introduction

Global warming is one of the problems of the balance of energy between the earth and the atmosphere that disrupts the Earth’s climate and the balance of the ecosystem. The main cause of global warming is greenhouse gases, especially airborne combustion, namely CO₂ gas. Increasing the amount of CO₂ in the atmosphere causes the greenhouse effect [1]. One effort that can be done to reduce the concentration of greenhouse gases is to maintain the presence of forests. Forest is an important absorber of CO₂ gas apart from phytoplanktons, seagrasses and seaweed in the ocean. Forests can prevent global warming by absorbing CO₂ from the atmosphere and storing it as carbon in the form of plant organic matter [2]. According to Soemarwoto (1998) [3], biomass is a place for storing carbon in this case it is called a carbon sink.

Mangrove forest is one of the ecosystems in Indonesia which is a tropical and sub-tropical coastal vegetation community dominated by several mangrove species that are able to grow and develop in tidal areas. The mangrove ecosystem has a role as an absorbent CO₂ from the air. Mangrove forests store more carbon than most tropical rainforests. This is in line with Donato et al. (2011) [4], who stated that mangroves have high assimilation and carbon absorption rates. By measuring the amount of carbon stored in the body of a living plant on a land it can describe the amount of CO₂ in the atmosphere absorbed by plants.

Mangrove forest in Inner Ambon Bay (IAB) is one of the important ecosystems that support the development and protection of Ambon City. In addition to protecting the sea as well as protecting the land, mangrove forests in this area have a function as a conservation area and prevent sedimentation. However, in recent years there have been various utilization activities by the community such as resource use, livestock, settlements and other development activities that are feared to be able to
disrupt and damage this ecosystem. One of the mangrove ecosystems found in the IAB, which is still relatively good is the Passo mangrove ecosystem [5]. The condition of the mangrove in this area has been carried out by repairing vegetation by replanting. As the issue of global warming develops, the mangrove ecosystem has an important role to be able to reduce the increase in greenhouse gases. This study aims to determine the biomass, stock carbon and carbon uptake of the mangrove Sonneratia alba in the Passo Coastal Waters, IAB.

2. Method

2.1. Sampling method
This research was carried out in the Passo mangrove forests, IAB (Figure 1). Mangrove data collection uses the belt transect method. The transect is spread out perpendicular to the mangrove area towards the sea, with a belt width of 10 m and a distance between transects is 50 m. Mangrove data collection includes the number of tree and diameter of S. alba species and area. The diameter of the tree is measured at a height of 1.3 m (DBH = diameter at breast high).

2.2. Data analysis method

2.2.1. Biomass analysis and carbon content. Biomass analysis and carbon content of S. alba trees were carried out in a non-destructive way (without damaging plants), that is, using biomass estimation equations [6]. According to Komiyama et al., (2005) [7], allometric equations for species S. alba are as follows:

Above ground biomass B = 0.251ρD^{2.46}
Below ground biomass B = 0.199ρ^{0.899} D^{2.22}

where: B = Biomass
D = DBH
ρ = 0.475
According to IPCC (2006)[8], the carbon concentration contained in organic matter is 47%, so the estimated amount of stock carbon by multiplying 0.47 with biomass:

\[ C = B \times 0.47 \]

where:  
\[ C = \text{Amount of carbon stocks} \]  
\[ B = \text{Biomass} \]

2.2.2 \( CO_2 \) Uptake Analysis. According to Murdiyarso (1999) [9], the potential of \( CO_2 \) absorption is obtained by the multiplication of carbon content with the amount of \( CO_2 \) absorption by following formula:

\[ W_{CO_2} = C \times FK_{CO_2} \]

where:  
\[ W_{CO_2} = \text{The amount of } CO_2 \text{ absorbed} \]  
\[ C = \text{Amount of carbon stocks} \]  
\[ FK_{CO_2} = \text{conversion factor of carbon (C) to } CO_2 = 3.67 \]

3. Result and Discussion

3.1. Sonneratia alba

Passo which is located in IAB has the largest mangrove forest in Ambon Island. True mangroves found in Passo coastal waters are 16 species as reported by Tuapattinaja and Tupan (2011) [10] (Table 1).

| No. | Family       | Species                  |
|-----|--------------|--------------------------|
| 1.  | Rhizophoraceae| Rhizophora apiculata     |
| 2.  |              | R. mucronata             |
| 3.  |              | Bruguiera cilindrica     |
| 4.  |              | B.parviflora             |
| 5.  |              | B.gymnorrhiza            |
| 6.  |              | Ceriops tagal            |
| 7.  | Sonneratiaceae| Sonneratia alba        |
| 8.  | Avicenniaceae| Avicennia alba           |
| 9.  | Myrsinaceae  | Aegiceras corniculatum   |
| 10. | Sterculiaceae| Heritiera littoralis     |
| 11. | Myrtaceae    | Osbornea octodonta       |
| 12. | Bombacaceae  | Camptostemon scultchii   |
| 13. | Areaceae/Palmae| Nypa fruticans     |
| 14. | Euphorbiaceae| Excoecaria agalocha      |
| 15. | Polypodiaceae| Acrosticum aureum        |
| 16. | Acanthaceae  | Acanthus ilicifolius     |

The species that has the most distribution and the largest species cover is \textit{S.alba} [10]. This species is one of the species which also has the most widespread distribution in the IAB [5]. This mangrove species found grew on various types of substrates, namely mud, sand and clay substrates. According to Dahuri (2003) [11], mangroves can grow well in protected and sloping areas with mud and sand substrates, and good water circulation and are supported by low salinity due to the influence of fresh water supply.
Species of *S. alba* have a widespread and are mostly found in the upper zone on muddy sand substrates. Generally, the spread of mangroves in an area forms zoning because it is influenced by salinity, fresh water supply, substrate and tidal influences [11]. One type of zoning for mangrove forests in Indonesia is as follows:

- Zone close to the sea with a rather sandy substrate, often overgrown by *Avicennia* spp and *Sonneratia* spp.
- Zone more to land, found mangrove forests are generally dominated by *Rhizophora* spp. In this zone also found *Bruguiera* spp. and *Xylocarpus* spp.
- The next zone is dominated by *Bruguiera* spp.
- The transition zone between mangrove forests and lowland forests is usually overgrown by *Nypa fruticans*

### 3.2. Biomass

Biomass is the amount of living matter in a tree and expressed in units of tons of dry weight per unit area [12]. Calculation of *S. alba* biomass in this study using non-destructive methods, namely without damaging the tree or also called indirect methods. This indirect method is used to estimate vegetation biomass with a diameter ≥ 5 cm [6]. The maximum diameter data is 49 cm according to the biomass allometric equation used [13]. The diameter range of *S. alba* obtained is 7 - 49 cm. Mangrove tree biomass is calculated using allometric equations that have been determined and developed by previous researcher [7]. The biomass analyzed is above ground biomass and below ground biomass. Mangrove biomass can be classified into two categories, namely above ground biomass and below ground biomass [14]. Above ground biomass consists of the main stem, branches, twigs, leaves, flowers and fruit while below ground biomass consists of roots.

Density and biomass of mangrove *S. alba* at various diameters is shown in Table 2. It can be seen in Table 2 that the number of *S. alba* tree decreases with increasing tree diameter. This result is in line with the statement of Husch *et al.* (2002) [15] who stated that distribution of trees diameter in the forest is not at the same age which is indicated by a lot of trees in small diameter and then decrease in number when diameter increase.

**Table 2.** Density and biomass of mangrove *S. alba* in various diameter classes

| Diameter class (cm) | Density (N.ha<sup>-1</sup>) | Above ground biomass (Ton.ha<sup>-1</sup>) | Below ground biomass (Ton.ha<sup>-1</sup>) | Total biomass (Ton.ha<sup>-1</sup>) |
|---------------------|-----------------------------|------------------------------------------|------------------------------------------|----------------------------------|
| 7.0 - 10.2          | 42                          | 1.00                                     | 0.51                                     | 1.50                             |
| 10.3 - 13.5         | 69                          | 3.64                                     | 1.72                                     | 5.36                             |
| 13.6 - 16.8         | 106                         | 10.21                                    | 4.54                                     | 14.75                            |
| 16.9 - 20.1         | 80                          | 12.49                                    | 5.30                                     | 17.80                            |
| 20.2 - 23.4         | 76                          | 17.77                                    | 7.25                                     | 25.02                            |
| 23.5 - 26.7         | 74                          | 24.48                                    | 9.65                                     | 34.13                            |
| 26.8 - 30.0         | 65                          | 29.14                                    | 11.16                                    | 40.29                            |
| 30.1 - 33.3         | 59                          | 34.66                                    | 12.92                                    | 47.58                            |
| 33.4 - 36.6         | 61                          | 45.72                                    | 16.65                                    | 62.37                            |
| 36.7 - 39.9         | 29                          | 27.13                                    | 9.67                                     | 36.80                            |
| 40.0 - 43.2         | 9                           | 10.32                                    | 3.60                                     | 13.92                            |
| 43.3 - 46.5         | 9                           | 12.45                                    | 4.27                                     | 16.72                            |
| 46.6 - 49.8         | 5                           | 8.23                                     | 2.78                                     | 11.01                            |
| Total               | 684                         | 237.24                                   | 90.02                                    | 327.26                            |
The total *S. alba* biomass obtained was 327.26 tons ha\(^{-1}\) consisting of 237.24 tons ha\(^{-1}\) of above ground biomass and 90.02 tons ha\(^{-1}\) of below ground biomass (Table 2). Above ground biomass is greater than below-ground biomass. This is in accordance with the opinion of Hairiah et al. (2011) [6] who stated that the largest proportion of carbon stocks is found in tree biomass above ground level. According to IPCC (2006) [8], tree biomass above ground level consisting of main stems, branches, twigs, leaves, flowers and fruit. Furthermore, Hairiah et al. (2011) [6] stated that the content of tree biomass is the sum of the biomass content of each tree organ which is a total picture of organic material from the results of photosynthesis.

### 3.3 Carbon stock
Carbon stock is estimated from the amount of biomass potential that exists. According to IPCC (2006) [8], the concentration of carbon contained in organic matter is 47%, so the estimation of the amount of carbon stock is multiplying the biomass by 0.47. The estimation results of carbon stock based on the tree diameter of *S. alba* can be seen in Table 3.

| Diameter class (cm) | Density (N ha\(^{-1}\)) | Above ground stock carbon (Ton ha\(^{-1}\)) | Below ground stock carbon (Ton ha\(^{-1}\)) | Total stock carbon (Ton ha\(^{-1}\)) |
|---------------------|-------------------------|---------------------------------------------|---------------------------------------------|-----------------------------------|
| 7.0 - 10.2          | 42                      | 0.47                                        | 0.24                                        | 0.71                             |
| 10.3 - 13.5         | 69                      | 1.71                                        | 0.81                                        | 2.52                             |
| 13.6 - 16.8         | 106                     | 4.80                                        | 2.13                                        | 6.93                             |
| 16.9 - 20.1         | 80                      | 5.87                                        | 2.49                                        | 8.36                             |
| 20.2 - 23.4         | 76                      | 8.35                                        | 3.41                                        | 11.76                            |
| 23.5 - 26.7         | 74                      | 11.51                                       | 4.54                                        | 16.04                            |
| 26.8 - 30.0         | 65                      | 13.69                                       | 5.24                                        | 18.94                            |
| 30.1 - 33.3         | 59                      | 16.29                                       | 6.07                                        | 22.36                            |
| 33.4 - 36.6         | 61                      | 21.49                                       | 7.82                                        | 29.31                            |
| 36.7 - 39.9         | 29                      | 12.75                                       | 4.54                                        | 17.29                            |
| 40.0 - 43.2         | 9                       | 4.85                                        | 1.69                                        | 6.54                             |
| 43.3 - 46.5         | 9                       | 5.85                                        | 2.01                                        | 7.86                             |
| 46.6 - 49.8         | 5                       | 3.87                                        | 1.31                                        | 5.18                             |
| **Total**           | **684**                 | **111.50**                                  | **42.31**                                   | **153.81**                       |

Carbon stock increased with increasing biomass which is influenced by diameter and number of trees. The highest carbon is found in trees with a diameter of 33.4 - 36.6 cm, and then the carbon content decreases in the largest diameter trees because it has a small number of trees. The total carbon storage obtained is 153.81 tons ha\(^{-1}\). This value is greater than the value of carbon stock for the same tree (*S. alba*) found in several locations in Tobelo District, North Halmahera [16]. Similar to biomass, larger carbon stock are found above ground level (111.50 tons ha\(^{-1}\)) than below ground level (42.31 tons ha\(^{-1}\)). Above ground carbon stock have many components for carbon storage, including the main stem with the most carbon content, twigs, branches, and leaves, while below ground level is only stored in the roots. According to Brown (1997) [12], the percentage of below-ground carbon (roots) ranges between 4 - 23%. This study obtained a percentage of below ground carbon of 28% (Figure 2). It can be understood that mangroves have large and many roots. Species of *S. Alba* does not have large roots but it has many roots which are widespread around the tree. The percentage of above ground carbon is 72%. According to Hairiah et al. (2011) [6], the greatest part of carbon stocks are generally
at the above ground, and the largest biomass is found in the main stem because organic material formed from photosynthesis is mostly distributed to stem parts for growth and as food storage.

![Diagram showing percentage of stock carbon above and below ground](figure2.png)

**Figure 2.** Percentage of stock carbon above ground level (1) and below ground level (2)

3.4. Carbon (CO₂) uptake
Plants absorb carbon (CO₂) from the air through photosynthesis, and then convert it to carbohydrates, then spread throughout the plant's body and eventually accumulated in the body of the plant [6]. CO₂ that enters the air comes from two sources, namely, natural sources and artificial sources [1]. The most important natural source is the process of respiration from living things and changes in organic matter, while artificial sources are the result of burning fossil materials, industry, forest fires and land use changes. The potential for CO₂ absorption in *S. alba* trees is 564.48 tons.ha⁻¹. The absorbed carbon is stored in the body of *S. alba*, especially in the main stem, so that the larger the diameter of the tree, the larger storage of biomass from carbon conversion.

4. Conclusion
Carbon stock are related to biomass, so the greater the biomass in *S. alba* tree the higher carbon stock and carbon uptake.

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