Species composition and carbon stock estimation in Pulau Sembilan secondary mangrove forests, North Sumatra, Indonesia

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Abstract. This study aimed to identify the species composition and measure the carbon stock estimation from the secondary mangrove forest. Analysis of vegetation (tree, sapling, and seedling) was carried out at Pulau Sembilan, Langkat, North Sumatra, Indonesia. The development of the seedlings, saplings, and trees was determined from four transect lines. Each transect had 100 m length. Each measured plot of total four transects contained 30 plots. The result showed that Rhizophora apiculata predominated vegetation types of seedlings, saplings, and trees in the mangrove forest, with the highest importance value index (116.13%). On the other hand, Bruguiera parviflora had the highest IVI (71.37%) of saplings, while at seedlings and tree levels were dominated by R. apiculata with IVI, 65.30%, and 75.48%, respectively. The diversity index of Shannon-Weiner ranged 1.11-1.49 at the secondary mangrove forest. In secondary mangrove forests had total biomass of trees at 51,589.83 kg/ha with a carbon potential of 23.73 tons/ha. This study provided a basis for rehabilitation, mangrove management and enrichment information in secondary mangrove forests.

1. Introduction

Indonesia has the most extensive mangroves in the world. Mangroves, as a component of coastal ecosystems, play an important role in maintaining the productivity of coastal waters and supporting the lives of residents in the region [1-2]. For coastal areas, mangrove forests, especially as a green belt along the coast/river estuary, is fundamental to supply firewood, fish, and shrimp [3-4]. Furthermore, to maintain the quality of the agricultural, fisheries, and settlement ecosystems behind them from abrasion, instrumentation, and sea wind disturbances [5-6].

Damage to mangrove ecosystems due to massive deforestation to be converted into several forms of economic use such as aquaculture, agriculture, industry, settlement, tourism, mining, and fishing [7-8]. This fact is a general condition in the coastal regions of North Sumatra. The reduction in fish and shrimp in this area means reducing the income of small fishermen who usually operate around the coast, shrimp fishermen, crab seekers, and fishers [9-10]. On the east coast of North Sumatra, the reduction in fish catch has caused some fishermen to switch professions as loggers in the mangrove forest or cut down the wood to become an alternative activity during the off-season season [11]. Therefore, research on species diversity and estimation of carbon stocks stored in secondary forests and ponds in Pulau Sembilan village, Langkat, North Sumatra are significant. This research produces data and information about the flora of secondary mangrove forests in Pulau Sembilan, North Sumatra.
2. Materials and Method

2.1. Sampling site and vegetation analysis
Analysis of vegetation stage (tree, sapling, and seedling) was carried out at Pulau Sembilan Village, Langkat, North Sumatra Indonesia. The sampling sites consisted of secondary mangrove forests, which located at 4˚ 10’ 26” N, 98˚ 15’ 58” E. Sample plots are made in the form of transects starting from the edge of the sea to the mainland, with the following observation steps in the sample plots: subplot 10 example x 10 m for tree-level (diameter ≥ 10 cm), subplot example 5 m x 5 m for sapling level (5-10 cm in diameter), and sample subplot 2 m x 2 m for seedling level. Each measured plot of total four transects contained 30 plots. The data measured includes the height of the tree, sapling, and seedling, the diameter of the tree at breast height (dbh), and records the names of all species of vegetation. Data obtained from the results of measurements in the field are calculated to determine the following variables [3]. These data were used to analyze the importance value index (IVI) and the diversity index (H’) of mangrove species.

2.2. Carbon stock estimation
Measurement of mangrove vegetation’s biomass in the mangrove forest of Pulau Sembilan village was performed by making observation sample plots with a sampling intensity of 10% with an area of 1 ha of secondary mangrove forests. The initial determination of sample plots was done by purposive random sampling. Sample plots were taken in areas with mangrove growth potential and relatively uniform plant species, for further sub-sample plots were made, which were part of sample plots in the field. Biomass data obtained from the measurement of mangrove vegetation > 5 cm in diameter was calculated using an allometric approach using a formula that was introduced by [12]. The final estimate of the amount of carbon (C) stored is calculated by the formula: C = Total biomass (kg ha-1) x 0.46.

3. Results and Discussion

3.1. Species diversity and density
The analysis of vegetation shows the level of diversity and density of mangrove vegetation from secondary forests based on the level of growth found in 22 sample plots. In the secondary forest, location recorded five species of vegetation found at all levels of growth, namely at the seedling level, sapling level, and tree-level can be seen in Table 1. Dominant species are found in R. apiculata species at each growth, while the lowest are in A. marina at seedling and sapling growth rates, and the lowest tree growth rates are in A. marina and L. racemosa species.

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| Species          | Family        | Individual stage |
|------------------|---------------|------------------|
| Avicennia marina | Acanthaceae   | 2                |
| Lumnitzera racemosa | Combretaceae  | 3                |
| Excoecaria agallocha | Euphorbiaceae | 4                |
| Rhizophora apiculata | Rhizophoraceae | 8                |
| Sonneratia alba  | Sonneratiaceae| 3                |
| **Total**        |               | **20**           |
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The dominance of the R. apiculata species is also due to the ease with which the propagules grow and are supported by a particular life cycle of the mangrove species. The propagules can germinate in the parent so that they are very supportive of the broad distribution process of the species [13-14]. At the tree level, the species that dominates is the mangrove plant. The number of dominating mangrove
broodstock can be a producer of seed distribution in large quantities so that the spread of seeds is enough to produce a wide distribution of seedlings and broad saplings of that species.

Another thing that the dominant factor why *R. apiculata* was so dominant was the existence of rehabilitation activities on the coastal forest land in Pulau Sembilan Village in the 1990s forest had been cut down by residents for daily needs such as firewood. Data obtained from residents that replanting that was held in that year used *R. apiculata* with plant spacing arranged so that the coastal forest in Pulau Sembilan Village was included in forests that were of the same age with high and canopy densities. This rehabilitation activity is also why other species have a low dominance compared to *R. apiculata* [15].

Furthermore, this rehabilitation efforts can be seen with the growth in height and diameter of each mangrove species, which is relatively the same in each plot. *R. apiculata* is mostly found is at the level of tree growth, while vegetation with seedling growth rates is very little found [16]. Mangroves cause this at the level of trees around the area, not all of them can produce fruit so that the spread is relatively low. This result is caused by the condition where the majority of growth is inundated by water, so the spread is classified as higher compared to those in the mangrove forest location [17].

### Table 2. Diversity index

| Species              | Diversity Index |
|----------------------|-----------------|
|                      | Seedling | Sapling | Tree   |
| *Avicennia marina*   | 0.23      | 0.23    | 0.18   |
| *Lumnitzera racemosa*| 0.29      | 0.24    | 0.18   |
| *Excoecaria agallocha*| 0.32      | 0.30    | 0.26   |
| *Rhizophora apiculata*| 0.37      | 0.35    | 0.28   |
| *Sonneratia alba*    | 0.28      | 0.27    | 0.20   |
| **Total**            | **1.49**  | **1.38**| **1.11**|

The results of species diversity measurement (H') that have been carried out from secondary forest location at 22 sample plots at both research sites for seedling, sapling, and tree-level growth, displayed in Table 2. The composition of vegetation in a forest type is essential to know; the intended composition includes vegetation in the canopy layer at the top (trees) and vegetation at the bottom layer (forest floor). The high level of biodiversity in mangrove forests is influenced by many factors, including the conditions under which the mangroves grow [18-19]. The diversity index used in this study is the Shanon-wiener diversity index. Criteria for species diversity index values based on Shanon-wiener (H') ranged from 0 to 3 with the following criteria: if H' (0 < 2) is classified as low, H' (2-3) is classified as moderate, H' (> 3) or more high [3]. So that it can be seen from Table 2, the biodiversity contained in each of these study sites is classified as low (H ' = 0 < 2).

High species diversity is an indicator of the stability or stability of a growth environment. High stability indicates a high level of complexity. This is due to the high interaction also so that it will have a higher ability to deal with interference with its components [20-21].

Table 3 showed the dominant species at the tree level are found in *R. apiculata* (IVI = 116.13%), and the lowest is in *A. marina* (IVI = 41.71). At the sapling level, the dominant species were still found in the type of *R. apiculata* (IVI = 88.67%), and the lowest was also in the type *A. marina* (IVI = 21.80%). Likewise, at the seedling level, the dominant species were found in the *R. apiculata* species (IVI = 82.11%), and the lowest was also in the *A. marina* (IVI = 19.75%) as depicted in Table 3.
Table 3. Important value index (VI) in the site

| Species               | IVI Stage (%) |       |       |
|-----------------------|---------------|-------|-------|
|                       | Seedling      | Sapling | Tree  |
| *Avicennia marina*    | 19.75         | 21.80  | 41.71 |
| *Lumnitzera racemosa* | 31.18         | 24.12  | 44.97 |
| *Excoecaria agallocha*| 41.06         | 36.34  | 50.32 |
| *Rhizophora apiculata*| 82.11         | 88.67  | 116.13|
| *Sonneratia alba*    | 25.90         | 29.07  | 46.88 |
| **Total**             | 200           | 200    | 300   |

Whether or not the growth of mangroves in a community can be seen from the analysis of the condition of the vegetation, which shows the size of the role of a type of existing community. This situation can be seen in the critical value index, which is owned by a mangrove species [22]. A high IVI illustrates that these types can compete with their environment and are called dominant types or dominate the community's space. This is because the species has suitable suitability for growing and has a good endurance compared to other species in the community. Conversely, the low IVI in certain types indicates that this type is less able to compete with the surrounding environment and other types. The low resistance to natural phenomena and a large amount of exploitation can reduce these types from year to year.

3.2. Carbon stock estimation

Table 4 shows that the *L. racemosa* had the highest biomass potential with the amount of biomass 35,944.45 kg/ha, and the lowest is in *A. marina* with the amount of biomass 2,421.07 kg/ha. The measurement results on the sample plot of the study at the secondary mangrove forest location had total biomass of mangrove stands of 51,589.83 kg/ha with a carbon potential of 23.73 tons/ha.

Table 4. Total biomass and carbon

| Species               | Total biomass |
|-----------------------|---------------|
| *Avicennia marina*    | 2,421.07      |
| *Lumnitzera racemosa*| 35,944.45     |
| *Excoecaria agallocha*| 6,827.31      |
| *Rhizophora apiculata*| 3,251.54      |
| *Sonneratia alba*    | 3,145.46      |
| **Total**             | 51,589.83 kg ha |

According to [23-24] biomass is the result of photosynthesis in the form of cellulose, lignin, sugar along with fat, starch, protein, resin, phenol, and various other compounds as well as nutrients, nitrogen, phosphorus, potassium and various other elements that plants need through rooting. In nature, the most significant proportion of carbon storage is generally found in the tree stand or biomass component.

The difference in the amount of carbon stock in study location to other locations is due to differences in plant density. The type of vegetation also influences carbon reserves in a land-use system [25]. A land-use system that consists of trees with species that have high wood density values, the biomass will be higher when compared to land that has species with low wood density values [26]. The high and low number of species in mangrove forest is influenced not only by habitat conditions.
and environmental factors but also by the level of disturbance both from animals and mainly due to human activities [4, 27-28]. Given the increasing amount of carbon at this time must be balanced with the amount of absorption by plants to avoid global warming. Thus it can be predicted how much vegetation must be planted on a field to compensate for the amount of carbon trade [29-30]. The stored carbon value states how much carbon can be absorbed by plants in the form of biomass. The amount of carbon that is increasing at this time must be balanced with the amount of absorption by plants to avoid global warming. Thus it can be predicted how many plants must be planted on land to compensate for the amount of carbon trade.

4. Conclusions
The present study provided a basis and reference for (a) rehabilitation of damaged mangroves, (b) mangrove management for the present and future, and (c) as well enrich data and knowledge about secondary mangrove forests.

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