Potential of above-ground biomass (AGB) of mangrove vegetation restoration in Lubuk Kertang

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Abstract. Mangrove forests have a critical role in supporting coastal areas. Mangrove forests have various functions of environmental services, one of which is a store of carbon stocks. The existence of mangrove forests continues to experience extensive damage and decline. Mangrove restoration is an effort to restore the damaged mangrove to its original condition, as was done by Lubuk Kertang Village. The purpose of this study was to determine the potential for AGB the restorations of mangrove vegetation. The method used is to calculate AGB of mangrove vegetation using allometric equations for estimating AGB from several researchers. The results showed the potential AGB content of the restoration of mangrove vegetation was 114.44 tons/ha. This yield is greater than the natural mangroves in the area, which is only 97.83 tons/ha.

1. Introduction
Mangrove forests have high ecosystem service benefits [1]. One of the mangrove ecosystem services is to store carbon stocks. Mangrove forests can store carbon stocks higher than the carbon stocks that tropical forests can store [2]. Mangroves are forest ecosystems with high productivity in tidal zones [3], and the structure of mangrove vegetation affects the characteristics of AGB. Understanding the characteristics and distribution of AGB of mangroves is essential to estimate above-ground organic carbon [4].

In South Asian countries, mangrove areas have continued to decline due to the conversion of mangroves into ponds and settlements [5]. In Indonesia, especially in Lubuk Kertang Village, Langkat Regency, North Sumatra Province, extensive mangrove forest has also experienced extensive degradation [6]. In 2009, the people of Lubuk Kertang Village began to carry out the restoration of damaged mangroves by planting mangrove vegetation. Knowing the amount of potential AGB from mangroves is needed as an indicator of the success of mangrove restoration. This study objective to determine the AGB of restored mangrove vegetation in the Village of Lubuk Kertang, Langkat Regency, North Sumatra Province.
2. Materials and methods

2.1. Research location
This research was conducted in Lubuk Kertang Village, Langkat Regency, North Sumatra Province. Lubuk Kertang village has a geographic position in 04° 07' 39.71'' North latitudes, and 98° 30' 97.87'' East longitudes. The location of the research can be seen in figure 1.

![Figure 1: Map of research location in Lubuk Kertang](image)

2.2. Measurements of AGB
Direct measurements obtain data collection to determine AGB and carbon in the field. Measurements were made on a sample plot with a size of 20x20m, which was spread evenly over the study area. Measurements of tree dimensions include measurement of diameter at breast height (dbh) using phi-band, tree height using haga hypsometer, and plot coordinates using a global positioning system (GPS). The value of the above-ground carbon is 46% of the AGB. Table 1 contains information on AGB estimator model used to calculate AGB of mangrove vegetation restoration in the field.

| Mangrove Vegetation       | Estimator of AGB          | Source |
|---------------------------|---------------------------|--------|
| *Avicennia marina*        | AGB = 0.185 D^{2.352}     | [7]    |
| *Sonneratia alba*         | AGB = 0.258 D^{2.287}     | [8]    |
| *Xylocarpus granatum*     | AGB = 0.1832*D^{2.21}     | [9]    |
| *Bruguiera gymnorrhiza*   | AGB = ρ*0.0754*D^{2.505}  | [10]   |
| *Avicennia alba*          | AGB = 0.079211*D^{2.470895} | [11]   |
| General Model of AGB      | AGB = 0.251ρD^{2.46}      | [12]   |

Note: AGB = Above Ground Biomass (kg); D = Diameter at breast height (cm); ρ = wood density (gr/cm²)
3. Results and Discussion
The results of measuring 31 plots of the AGB of the mangrove vegetation in the field showed varied values for each mangrove tree and the biomass content in the plot. The results of measurements of tree dimension can be seen in table 2, and AGB can be seen in table 3.

| Table 2. Result of measurement of the tree dimension |
|-----------------------------------------------------|
| Planting Year | Average of dbh (cm) | Average of tree height (m) |
|----------------|---------------------|----------------------------|
| 2009           | 7.1                 | 7.8                        |
| 2010           | 6.0                 | 7.4                        |
| 2011           | 5.5                 | 6.9                        |
| 2013           | 5.0                 | 6.0                        |
| Natural        | 7.2                 | 7.1                        |

| Table 3. Result of measurements of AGB |
|---------------------------------------|
| Planting Year | Sum of vegetation/ha | AGB (ton/ha) | Carbon (ton/ha) |
|----------------|----------------------|--------------|-----------------|
| 2009           | 4,404                | 173.38       | 79.75           |
| 2010           | 4,011                | 102.16       | 46.99           |
| 2011           | 5,600                | 108.08       | 49.71           |
| 2013           | 4,967                | 74.14        | 34.10           |
| Natural        | 2,536                | 97.83        | 45.00           |

Based on table 2, the carbon content in each plot varies considerably, this is due to differences in the characteristics of the diameter and height of the plot, the planting year of mangrove vegetation, and the type of mangrove vegetation. Most of the mangrove vegetation types planted by the community are *Rhizophora apiculata* and *Rhizophora mucronata*.

The results of the recapitulation of AGB and carbon content in table 3 show that the mangrove vegetation plot for the 2009 planting year had the highest average number of trees, namely 4,405 trees/ha, while the 2010 mangrove vegetation plot showed the average number of trees per hectare the smallest is 4,011 trees/ha. The largest average AGB content was in the 2009 planting year plot of 173.38 tonnes/ha, while the smallest average above-ground biomass content was in the 2013 planting year plot of 74.14 tons/ha. This is because the older the vegetation, the bigger the tree dimensions so that the biomass content will be even greater.

Based on field measurements, the average above-ground biomass content in the restoration of mangrove vegetation plots is greater than the natural mangrove vegetation plots in the area. This is because the restoration results of mangrove vegetation are denser and more regular so that the number of trees per hectare is more than in natural mangrove vegetation. The vegetation in the natural mangrove plots in Lubuk Kertang Village is natural mangrove vegetation that varies in age. Most of the existing natural mangrove vegetation is thought to be secondary mangrove forests that are not too old. This can be derived from the relatively small mean tree diameter of breast height (Table 2).

Carbon storage can describe how much tree stores carbon. The amount of biomass contained in trees, soil fertility, and vegetation absorption affects the amount of carbon storage [8,13]. Meanwhile, [9,14] said that 46% of the biomass of vegetation is carbon, so the higher the biomass in mangrove vegetation, the higher the carbon storage. The carbon content of plants describes how much they can bind CO₂ from the air [10,15]. Plants absorb CO₂ from the air and then convert it into organic material through photosynthesis, which is used for growth. The high above-ground biomass content at the study location was due to differences in the planting age of the mangroves and the types of mangrove vegetation planted. The longer the mangrove age, the bigger the tree diameter and height.
4. Conclusions
The AGB of restored mangrove vegetation in the Village of Lubuk Kertang is greater than that of the natural mangroves in the Lubuk Kertang area. The restoration results of mangrove vegetation are denser and more regular so that the number of trees per hectare is more than in natural mangrove vegetation.

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