Estimation of biomass potential, carbon stocks, and carbon sequestration of *Trigona sp* honey bees feed

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**Abstract.** This study aimed to determine the biomass potential of *Trigona sp* honey bees in Bontotiro subdistrict as well as its carbon stock and carbon sequestration. The research was carried out for two months starting from May to June 2021, located in the sub district of Bontotiro, district of Bulukumba. The biomass measurement was carried out by making 11 plots with a size of 20 x 20 for the tree level, 10 m x 10 m for the poles level, and 5 m x 5 m for the sapling level. Tree biomass was calculated using allometric equations. Measurement of carbon stocks was carried out by multiplying the total biomass with the percentage value of carbon content of 0.47, while the carbon sequestration was calculated by multiplying the average annual growth of biomass with the conversion rate of 1.4667 obtained from the photosynthesis equation. The results showed that the potential of biomass of tree, poles, and sapling levels were 4.5, 1.4, and 0.3 tons/year, respectively. The carbon stocks of the tree, poles, and sapling levels were 68.6, 13.7, and 1.8 tons/year, respectively. The carbon sequestration of the tree, poles, and sapling were 6.6, 2.1, and 0.56 tons/year, respectively.

1. **Introduction**

Global warming is one of the important issues that are being discussed by the world community. Global warming occurs due to the release of greenhouse gases into the atmosphere, especially carbon dioxide, methane, and nitrogen oxides. One of the greenhouse gases that play an important role in global warming is carbon dioxide which causes the air temperature warmer. The impact of climate change can be reduced by the presence of trees both on state-owned land and on public-owned land. These trees can absorb CO₂ gas through the process of photosynthesis and store it in the form of biomass in the roots, leaves, and stems. Plants can emit carbon through the process of making their own food, called photosynthesis. The process of photosynthesis converts carbon dioxide and water which are substrates and assisted by sunlight into carbohydrates. Measurement of the amount of carbon stored in living plant bodies or biomass in a field can describe the amount of carbon dioxide in the atmosphere. Forests can function as carbon sinks hence, it is important to maintain their function [1]. The longer the vegetation is in the forest, the greater the carbon stock will be because the rate of growth of biomass will increase from time to time. Calculation of the amount of carbon in a forest needs to be done to determine the amount of carbon present in plants and in the atmosphere [2].

Bontotiro is one of the sub-districts in Bulukumba which has great potential for human resources and natural resources. One of the potential natural resources is *Trigona sp* honey bees feed. Feed is a very important requirement for the sustainability of honey bees farming [3]. Honey bees need energy that comes from nectar. Apart from nectar, bees also collect pollen. Pollen is the male seed plasma in
plants. The protein content of pollen varies greatly, depending on the type of plant Sihombing in [4]. The nectar and pollen come from vegetation located in the forest or on plantation lands. The various vegetation that Trigona sp honey bees feed on have the potential for effective and efficient carbon storage. To determine the carbon storage, measurements were made at the plot level using the biomass estimation method in the allometric equation. Until now, there has been no measurement of carbon stocks and carbon dioxide uptake for Trigona sp honey bees feed in Bontotiro sub-district, Bulukumba. Thus, a study was conducted on the estimation of biomass, carbon stock, and carbon dioxide uptake in the area. This study aimed to determine the potential of biomass, carbon stock and carbon dioxide sequestration of Trigona sp honey bees feed in Bontotiro sub-district, Bulukumba.

2. Method
This research was conducted for three months starting from April to June 2021, which was located in Bontotiro subdistrict, Bulukumba. The research method used was a survey method by determining sample plots by purposive sampling with exploratory data collection and descriptive analysis. Sample plots were taken from 10% of the area (4.5 ha), then the area of the sample plots observed was 0.45 ha divided by the width of the sample so that 11 sample plots were obtained with a size of 20 x 20 m for trees, 10 x 10 for poles, 5 x 5 sapling. The biomass measurement was carried out by measuring the diameter of the trunk at chest height from the ground surface and then calculating the tree biomass using allometric equations.

2.1. Data analysis
2.1.1. Calculation of above ground biomass. Tree biomass was calculated using the Allometric Coefficient Value formula (a and b). To calculate the upper biomass based on tree species, a calculation formula that has been widely used by previous researchers was used, starting with felling and weighing trees [5]. The formula is as follows:

\[ Y = a \cdot D^b \]  

Description:
- Y : biomass content
- D : tree diameter at chest height
- a,b : constant

2.1.2. Calculation of above ground carbon
   a. Calculation of above ground carbon
      Calculation of above ground carbon using the following formula:

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

Description :
- Cb : carbon content of biomass, expressed in kilograms (kg)
- B : total biomass expressed in kilograms (kg)
- \%C organic : the percentage value of carbon content, of 0.47 or using the per cent carbon value obtained from the results of carbon measurements (SNI 7724, 2011).

   b. Calculation of total above ground carbon stocks
      The calculation of the above ground carbon stocks in the measurement plot using the following equation:

\[ \text{C_{total}} = \frac{\sum C_{plot}}{\sum L_{plot}} \]  

Description:
- C_{total} : carbon content per hectare, expressed in tons per hectare (tonnes/ha).
- C_{plot} : total carbon content in the whole plot, expressed in tons
- L_{plot} : The total area of the plot, expressed in hectares (ha).
2.1.3. Calculation of total carbon dioxide (CO$_2$) sequestration. Carbon dioxide sequestration was calculated based on the mass ratio of the photosynthetic reaction equation:

\[
\begin{align*}
6\text{CO}_2 + 6\text{H}_2\text{O} & \rightarrow \text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2 \\
(264) & \quad (108) & \quad (180) & \quad (192)
\end{align*}
\]

Based on the photosynthetic reaction equation above, to produce 180 grams of biomass (C$_6$H$_{12}$O$_6$) it takes about 264 grams of CO$_2$. Therefore, CO$_2$ sequestration can be determined by the formula [6]:

\[
\text{CO}_2 = \frac{264}{180} \times \text{Biomass} = 1.4667 \times \text{Biomass}
\]

3. Results and discussion

3.1. Biomass

Biomass is the mass of living organisms consisting of plants and animals in an area [7]. Biomass consists of two, namely above ground biomass and below ground biomass. The biomass value was calculated using the allometric equation. The calculation of biomass was carried out using a non-destructive method, which was a method of measuring without damaging the vegetation. Based on the allometric equation, it was found that the stored biomass was influenced by the vegetation diameter and density factors [8]. The results of the calculation of the biomass contained in Trigona sp. honey bees feed can be seen in Figure 1.

![Figure 1. Above ground biomass](image)

Tree biomass content is the sum of the biomass content of each tree organ as a picture of the total organic material resulting from photosynthesis [9]. Through the process of photosynthesis, CO$_2$ in the air is absorbed by plants with the help of sunlight and then converted into carbohydrates, then distributed throughout the plant body and stored in the form of leaves, stems, branches, fruits, and flowers [10]. Based on the results of the study, it can be seen that the above ground biomass of Trigona bee feed vegetation at the tree vegetation level is 4.5 Ton/Ha, at the pole level is 1.4 Ton/Ha, and at the sapling level is 0.3 Ton/Ha thus, the total average of biomass of Trigona Bee Feed is 6.2 Ton/Ha. Figure 1 shows that at the vegetation level, trees have the highest biomass value compared to other vegetation levels because tree has an older age, and has a large height and diameter.

This is in accordance with research conducted by Yamani (2016) that the amount of biomass at the tree growth rate is greater than at the sapling and pole growth rate. This is presumably because there is a positive correlation between the diameter and height of the stems with the amount of biomass rather than the number of individual stands [11]. In other words, every increase in diameter and height will always be followed by an increase in biomass in each part of the tree. Research conducted by Lukito and Rohmatiah (2013) shows that the amount of forest biomass is highly dependent on the results obtained during the photosynthesis process [12].
3.2. Carbon stocks

Carbon is one of the elements stored on the soil surface in the biomass of living plants, dead plant residues (necromass), and in the soil as soil organic material [13]. After the average value of the biomass content is obtained, the next step is to find the carbon stock value. The carbon stock value is obtained by multiplying the biomass value by the percentage value of the carbon content. This measurement is based on the technical guidelines for measuring carbon stocks in natural forests of the Indonesian National Standardization Agency Number 7724 of 2011 which is 0.47 or 47% of the total biomass [14] so that the carbon stock value of Trigona sp honey bees feed is obtained as shown in Figure 2.

![Figure 2. Carbon stocks](image)

Figure 2 shows that the highest carbon stock for Trigona sp honey bees feed is at the tree level at 68.6 tons, the poles level at 13.7 tons, and the sapling level at 1.8 tons. Tree tiers have more carbon stocks than poles and saplings because they have a larger diameter. For poles and sapling, although there are more of them, the diameter of the trees is small so that the carbon stocks is also small. In addition, the tree level also has a high biomass value. Adinugroho et al (2012) stated that the larger the diameter of the trees that made up a stand with a large number of individuals and composed of species that had high wood density, the potential for biomass and carbon content was also greater [15]. Rahayu et. al. (2007) in [16] stated that the larger the diameter of the tree, the more carbon would be absorbed. Tree stand biomass greatly affects the stored carbon potential. Indirectly, all parameters affecting biomass will also affect carbon storage in a stand. Parameters that affect biomass in an ecosystem are stem diameter, individual density, tree species diversity, and soil type. The density of existing trees in an area will affect the increase in carbon stocks through an increase in biomass. The amount of carbon stocks is basically influenced by the structure and composition of the vegetation making up the forest/hamlet land, it is also influenced by the size of the value of stem diameter of the vegetation itself [17]. Furthermore, [18] said that the value of stored carbon was determined by measuring tree biomass. Stored carbon is 50% of the measured tree biomass hence, carbon stock is positively correlated with the amount of biomass, which means that the greater the biomass storage, the higher the carbon stock.

3.3. Carbon sequestration

Carbon dioxide sequestration is obtained by comparing the mass of the photosynthesis process equation with the conversion factor of carbon dioxide sequestration with a value of 1.4667 then multiplied by biomass. Carbon dioxide sequestration can be seen in Figure 3.
Figure 3 shows that the tree level has a higher carbon dioxide uptake with a value of 6.6 tons/ha compared to the pile and sapling levels. This is because the tree level has a larger trunk diameter so that most of the photosynthesis results are stored in the tree trunk. Carbon dioxide sequestration is determined based on the biomass value and age of the tree. The larger the diameter of a tree, the greater the CO$_2$ it absorbs. This is related to the results of the photosynthesis process in the form of cellulose and wood constituent substances that can increase the weight of organic matter and growth in the horizontal and vertical directions. The same thing was said by [19] that the larger the diameter of the tree was caused by the storage of biomass converted from CO$_2$ which was increasing as more and more CO$_2$ was absorbed by trees in the atmosphere. The same opinion was also expressed by Darmawan Darmawan and Siregar in [20] that the amount of CO$_2$ sequestration was also directly proportional to the diameter of a tree, so the larger the diameter, the greater the CO$_2$ absorbed.

3.4. Above ground biomass, carbon stocks, annual carbon sequestration in overall Trigona sp honey bees feed

Based on the results of the research conducted in Bontotiro Subdistrict, Bulukumba, the area of Trigona bee cultivation feed was 4.5 ha. The above ground biomass, carbon stock, and annual carbon dioxide sequestration of the entire Trigona sp honey bees feed area were calculated by multiplying by the bee cultured feed area. The results can be seen in Table 1.

| No. | Variable                              | Mean (per Ha) | Square (ha) | Total  |
|-----|---------------------------------------|---------------|-------------|--------|
| 1   | Biomass (ton)                         | 6.3           | 4.5         | 28.1   |
| 2   | Carbon Stock (ton)                    | 84.2          | 4.5         | 378.9  |
| 3   | Annual Carbon Sequestration (ton per year) | 9.2           | 4.5         | 41.3   |
|     | Total                                 |               |             | 448.3  |

Based on Table 1, it can be seen that the entire Trigona sp honey bees feed has a total biomass of 28.1 tons, a total carbon stock of 378.9 tons, and a total CO$_2$ sequestration of 41.3 tons/ha per year.

4. Conclusion

Based on the results of the study it can be concluded that:
1. The average total biomass feed of *Trigona sp* honey bees in Bontotiro Subdistrict, Bulukumba Regency were 4.5 tons/ha of tree level, 1.4 tons/ha of poles level, and 0.3 tons/ha of sapling level, so the total biomass was 6.2 tons/ha. The carbon stocks at the tree level was 68.6 tons/ha, the poles level was 13.7 tons/ha and the sapling was 1.8 tons/ha with a total carbon stocks of 84.1 tons/ha.
The carbon sequestration for the tree level was 6.6 tons/Ha, the poles level was 2.1 tons/Ha, and the sapling level was 0.56 tons/Ha with a total carbon dioxide sequestration of 9.2 tons/Ha.

2. *Trigona sp* honey bees feed in Bontotiro District, Bulukumba has a total biomass of 28.1 tons, carbon stock of 378.9 tons, and CO₂ sequestration of 41.3 tons/year.

**Acknowledgment**

Special thank to: Institute for Research and Community Service (LP3M) of Muhammadiyah University of Makassar for the Internal Research Fund for the Beginner Lecturer Program period of 2021 which has been given, Rector of Muhammadiyah University of Makassar and Chair of LP3M who have provided the opportunity to take part in the Internal Beginner Lecturer program.

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