Carbon storage and sequestration potentials in Sulawesi endemic species

S A Paembonan¹, S H Larekeng² and S Millang¹

¹ Silviculture Laboratory, Faculty of Forestry, Hasanuddin University, Makassar
² Biotechnology Laboratory, Faculty of Forestry, Hasanuddin University, Makassar

Email: samuelpaembonan@yahoo.co.id

Abstract. Several endemic species of Sulawesi have different growths and are generally influenced by local environmental factors. There are three well-known endemic species of Sulawesi, namely Macadamia (Macadamia hildebrandii), Elmerillia (Elmerillia ovalis), and Gophasa (Vitex cofassus). These three species are widely developed in community forests and are the mainstay of the community as building materials and for other purposes. These three species can be used as good absorbers of carbon dioxide from the atmosphere in the context of mitigating climate change. Macadamia and Elmerillia species grow well in the highlands, while Gophasa species is generally found in the lowlands. From the results of the growth analysis, it is known that Macadamia and Elmerillia are medium growing species, while gophasa are slow-growing species. The results showed that the three endemic species have a good ability to absorb carbon from the air. At the age of 20 years, these three species can store carbon which is quite high, namely 132.38 tons/ha for Macadamia, 152.04 tons/ha for Elmerillia, and 82.65 tons/ha for gophasa. When converted to the ability to absorb CO₂ from the atmosphere, the three species can absorb 485.85 tons CO₂/ha, 557.99 tons CO₂/ha, and 303.33 tons CO₂/ha, respectively.

1. Introduction

As it is known that now global warming has occurred which has an impact on climate change. CO₂ emitted from the earth as one of the greenhouse gases is mostly caused by forest degradation and deforestation [1,2].

The layer in the atmosphere that is formed due to CO₂ emissions causes some of the electromagnetic waves that are reflected into the air cannot penetrate the atmospheric layer, causing global warming. Therefore, we need vegetation in the form of trees that can absorb CO₂ faster from the atmosphere and store carbon in large quantities and for a long time in their biomass [3,4].

Several endemic species of Sulawesi grow in different environmental conditions and generally adapt to grow in certain environments [5]. There are three well-known endemic species of Sulawesi, namely: macadamia, cempaka, and gophasa [6–9]. These three endemic species grow well at different altitudes, namely, the Macadamia and Elmerillia species growing in the highlands with a range of 600 to 1500 m above sea level, while the gophasa species grow well in the lowlands with an altitude of 100 m to 700 m above sea level [7–10].

These three species are widely developed by the community in community forests and are the mainstay of the community because they have economic advantages when compared to other types, namely: they can be used as quality building materials to build houses and for other raw material needs. Macadamia species is a versatile tree species, apart from being a building material as well as edible fruit and seeds, the elmerillia species has the advantage of being a building material for the
Toraja ethnicity, while the gofasa species, apart from being a building material, are also the main material for the construction of the famous Phinisi Nusantara ship [8–10]. Ecologically, these three species can be used as good CO₂ absorbers from the air in the context of mitigating climate change. Moreover, these three species are widely developed by the community in community forests, so if managed properly they can be relied upon to have the ability as a potential CO₂ absorber. In this study, an analysis of the growth of each species and the difference in absorption capacity of the three Sulawesi endemic tree species was carried out based on the difference in the age of the stands.

2. Methods
This research was carried out at three different locations according to where each species grows, namely: for macadamia species carried out in Mamasa Regency at an altitude of 912 m above sea level, Elmerillia species in North Toraja Regency at an altitude of 755 m above sea level and Bitti species in Bulukumba Regency with 75 m above sea level (Figure 1). This research was conducted from April to August 2020.

![Research Sites](image)

**Figure 1.** Research sites

2.1. Tree measurement for biomass estimation
The plot area for observing trees is 25 m x 25 m (Figure 2). All trees included in the plot were measured in diameter to be used to estimate stand biomass.
2.2. **Data analysis**

To measure the Basal Area (BA) of individual trees, it is calculated using the formula:

\[ BA = \frac{1}{4} \pi D^2 \]  

(1)

Where D is average tree diameter

Calculation of tree biomass using the [11] formula involving the variables of plant diameter and density.

\[ W = 0.11 \rho D^{2.62} \]  

(2)

Where:

- \( W \) = Biomass (kg)
- \( D \) = Diameter at breast height (cm)
- \( \rho \) = Density of wood (gr/cm³)

From the results of measurements of tree biomass then converted into Carbon (C) using the Indonesian National Standard (SNI 7724: 2011)

\[ C = 0.47 W \]  

(3)

Where 0.47 is the percentage value of carbon content, which is 0.47

To calculate the Carbon Dioxide (CO₂) equivalent absorption, the equation [12]

\[ CO2 = C \times 3.67 \]  

(4)

3. **Results**

3.1. **Tree diameter growth analysis**

The diameter of the tree increases with the increase in the age of the stand. Measurement of tree diameter in the field was carried out as a basis for estimating tree biomass using allometric formulas [13–15]. In this study, measurements were made at the age of young stands (5 years) and mature age (20 years) to compare the acceleration of tree growth.

Increasing the diameter of the tree will also have an impact on the increase in the average area of the tree base. The area of the base area needs to be known as an indicator of the level of control of the tree canopy on the surrounding land.

From the observation data in the field, it can be seen that the Basal Area (BA) of individual trees increases according to the age of the stand, this is also seen in the Total Basal Area (TBA) per hectare. Data on the average diameter and BA increase of individual trees and their TBA per hectare at the age of 5 years and 20 years can be seen in Table 1 and Figure 3A.

The difference in the rate of increase in tree diameter and TBA on average per hectare increased from the age of 5 years to the tree phase at the age of 25 years (Table 1).

| Species | Stand Ages (year) | Average Diameter (cm) | TBA (m²/ha) |
|---------|------------------|----------------------|-------------|
| Makadamia | 5                | 4.86                 | 2.93        |
|          | 20               | 32.71                | 40.32       |
| Elmerillia | 5               | 5.86                 | 2.59        |
|          | 20               | 34.92                | 45.95       |
| Gofasa   | 5                | 4.45                 | 1.46        |
|          | 20               | 18.59                | 13.02       |
The difference in the rate of increase in diameter with the difference in age for each species can be clearly distinguished in Figure 3.

Figure 3. Increase in diameter (A) and basal area (B)

The increase in diameter of each species is different. From the results of diameter measurements, it can be seen that the development of diameter from the age of 5 years to the age of 20 years showed a different increase, namely for Macadamia 27.85 cm, Elmerillia 29.06 cm, and Gofasa 14.14 cm.

3.2. Biomass and carbon storage
In general, the biomass potential of the three Sulawesi endemic species shows a significant increase from the age of 5 years and 20 years (Table 2). The ability to increase this biomass is related to the ability to absorb CO₂ from the atmosphere which is then converted into biomass [15,16]. These three endemic species can form different biomass. Macadamia and elmerillia species can form biomass faster than gophasa species. This is related to the ability to absorb CO₂ from the atmosphere as the main ingredient in forming biomass.

At the age of 5 years and the age of 20 years, each species has a different diameter increase. Elmerillia has the largest capacity to increase its biomass, which is 317.78 tons/ha, followed by macadamia 277.43 tons/ha and gophasa 170.63 tons/ha.

The results showed that the three endemic species can store carbon well. At the age of 5 years, the standing biomass was only 1.99 tons/ha for Macadamia, 2.68 tons/ha for Elmerillia, and 2.45 tons/ha for Gofasa. Until the age of 20 years, each species experienced a significant increase in carbon storage capacity, which increased to 130.39 tons/ha for Macadamia, 149.36 tons/ha for Elmerillia, and 80.20 tons/ha for Gofasa. Diameter data and carbon storage of each species are in Table 2.

Table 2. The estimated amount of biomass and carbon stored according to the increase in stand age

| Stand Age (year) | Average Diameter (cm) | Biomass (ton/ha) | Carbon (ton/ha) |
|------------------|-----------------------|-----------------|-----------------|
| **Macadamia**    |                       |                 |                 |
| 5                | 4.86                  | 4.24            | 1.99            |
| 20               | 32.71                 | 281.67          | 132.38          |
| **Elmerillia**   |                       |                 |                 |
| 5                | 5.86                  | 5.71            | 2.68            |
| 20               | 34.92                 | 323.49          | 152.04          |
To illustrate the differences in the ability to form biomass and store carbon, see Figure 4.

| Gofasa | 5   | 4.45 | 5.22 | 2.45 |
|--------|-----|------|------|------|
|        | 20  | 18.59| 175.85| 82.65|

To illustrate the differences in the ability to form biomass and store carbon, see Figure 4.

**Figure 4.** Ability to generate biomass and store carbon for the three Sulawesi endemic species at the age of 20 years old stand.

### 3.3. Carbon sequestration

When converted to the ability to absorb equivalent CO₂ from the air, the three species at the age of 20 years can absorb 485.83 tons of CO₂/ha for macadamia, 557.99 tons of CO₂/ha for elmerillia, and 303.33 tons of CO₂/ha for gophase.

In Figure 5 it can be seen that the carbon uptake ability of macadamia and elmerillia is higher than that of gophase species but all three are reliable.

**Figure 5.** Comparison of CO₂ absorption capabilities from the air for the three types
4. Discussion
Tree diameter is an appropriate parameter used to estimate tree biomass because diameter growth is a growth dimension that describes stand density. While the Total Basal Area (TBA) as information is used as a description of the land cover capability of the stand [4,13]. The ability and speed of trees to form biomass are used as a measure of the tree's ability to absorb CO₂ from the atmosphere so that it can be relied upon as an effort to reduce the impact of climate change. In general, it can be explained that the increase in the age of a stand is followed by an increase in tree diameter [13,14].

While the growth and density of understorey and litter are determined by the density of the stand and the level of canopy cover. Undergrowth depends on the amount of sunlight that passes through the tree canopy above [3].

The larger the diameter of a tree which is affected by the density of the stand will affect the formation of a larger total canopy surface so that it has a significant effect on the ability to absorb CO₂ from the air through the photosynthesis process [3,17].

However, the ability of trees to store carbon is linearly proportional to the age of the stand, although it is also determined by many other variables such as stand density, quality of the growing site, physiographic factors, and the silvicultural treatment given [3].

5. Conclusions
From the results of tree diameter measurements, it is known that the three potential endemic species of Sulawesi have different diameter growth speeds, namely: macadamia and elmerillia species showing a fairly fast increase in trunk diameter or classified as medium growing stands, while the gophasa species are classified as slow-growing species. Based on the results of this study, it appears that Sulawesi endemic species that are widely developed in community forests can be managed sustainably to absorb and store potential carbon.

Acknowledgment
We would like to thank the Rector of Hasanuddin University for the research funding provided through The Research and Community Service Institute (LP2M Universitas Hasanuddin) with research contract number No. 915/UN4.22/PT.01.03/2021, to support the implementation of this research.

References
[1] Brown S 1999 Guidelines for Inventoring and Monitoring Carbon Offsets in Forest-Based Projects (Winrock International)
[2] Hairiah K and Rahayu S 2007 Petunjuk Praktis Pengukuran Karbon Tersimpan di Berbagai Macam Penggunaan Lahan (Malang: World Agroforestry Centre-ICRAF, SEA Regional Office, University of Brawijaya)
[3] Paembonan S A Hutan Tanaman dan Serapan Karbon (Makassar: Masagena Press.)
[4] Kusmana C, Sabiham S and Watanabe S 1992 An Estimation Of Above Ground Tree Biomass Of A Mangrove Forest In East Sumatera, Indonesia Tropic 4 143–57
[5] N Mangili, B Nurkin, S A Paembonan, S Millang M R and L S H 2019 The potential of carbon deposits to residual stand in Tongkonan lembang Buri ’ garden of Tana Toraja The potential of carbon deposits to residual stand in Tongkonan lembang Buri ’ garden of Tana Toraja IOP Conf. Ser. Earth Environ. Sci. 343 012061 343 1–9
[6] Asdar M 2011 Anatomi kayu Macadamia hildebrandii van Slooten Prosiding Seminar Nasional Masyarakat Peneliti Kayu Indonesia (MAPEKI) XIV (Bogor: Masyarakat Peneliti Kayu Indonesia)
[7] Ginoga B, Seran D, Lempang M and Allo M K 1987 Pertumbuhan dan sifat kayu tomaku (Macadamia hildebrandii V.St.) J. Penelit. Kehutan. 1 1–8
[8] Burley A L, Engriht N J and Mayfield M . 2011 Demographic Response and Life History Of
Traditional Forest Resource Tree Species In A Tropical Mosaic Landscape In Papua New Guinea J. For. Ecol. Manag. 262 750–8

[9] Kinho J and Mahfudz 2011 Prospek Pengembangan Cempaka di Sulawesi Utara

[10] Orwa S 2009 Vitex cofassus 4

[11] Kettering Q M, Coe R, Van Noordwijk M, Ambagau Y and Palm C A 2001 Reducing Uncertainty in the use of Allometric Biomass Equation for Predicting Above-ground Tree Biomass in Mixed Secondary Forest J. For. Ecol. Manag. 199–205

[12] Dharmawan I W S and Siregar C H 2008 Karbon Tanah dan Pendugaan Karbon Tegakan Avicennia marina (Forsk) Vierh. di Ciasem, Purwakarta J. Penelit. Hutan dan Konserv. Alam 5 317–28

[13] Adinugroho C and S K 2001 Model Pendugaan Biomassa Pohon Mahoni (Swietenia macrophylla King) di atas Permukaan Tanah J. Penelit. Hutan dan Konserv. Alam 3 103–17

[14] Krisnawati H and Harbagung 1996 Kajian angka bentuk batang untuk pendugaan volume jenis-jenis hutan alam Prosiding Diskusi Hasil-Hasil Penelitian dalam Menunjang Pemanfaatan Hutan yang Lestari (Bogor) pp 177–91

[15] Wiarta R, Dwi A, Yuliati I and Fairus M 2017 Pendugaan Jumlah Karbon Tersimpan pada Tegakan Jenis Bakau (Rhizophora apiculata BL) di IUPHHK PT. Bina Ovivipari Semesta Kabupaten Kubu Raya J. Hutan Lestari 5 356–64

[16] Uthbah Z, Sudiana E and Yani E 2017 Analisis Biomassa dan Cadangan Karbon pada Berbagai Umur Tegakan Damar (Agathis dammara (Lamb.) Rich.) di KPH Banyumas Timur Scr. Biol. 4 119–24

[17] Krisnawati H, Adinugroho W C and Imanuddin R 2012 Monograph allometric models for estimating tree biomass at various forest ecosystem types in Indonesia