Stand structure and carbon stock of tree vegetation in Deleng Macik Taman Hutan Raya Bukit Barisan Karo District, North Sumatra, Indonesia

T A Aththorick¹, N Pasaribu¹ and E Eyckman²
¹ Biology Department of Faculty of Mathematics and Natural Sciences of Universitas Sumatera Utara Jl. Bioteknologi No.1 Kampus USU Medan, Indonesia.
² Graduated Student of Biology Department of Faculty of Mathematics and Natural Sciences of Universitas Sumatera Utara Jl. Bioteknologi No.1 Kampus USU Medan, Indonesia.

E-mail: t.alief@usu.ac.id

Abstract. Stand structure and carbon stock of tree vegetation have been studied in Deleng Macik Taman Hutan Raya Bukit Barisan Karo district of North Sumatra Province, Indonesia. This study aims to determine the stand structure and carbon stock in the forest of Deleng Macik. The placement plot is determined by purposive sampling method based on 1 km transect line which contains 100 plots area, each plot has size 10x10 m and were placed in zigzag. Observations were made using squares method. The results showed that the tree composition consists of 70 species belong to 23 families. The highest DBH was family of Lauraceae 7.54 m²/ha while the lowest was family of Theaceae 0.02 m²/ha. The vertical structure was dominated by stratum C with 417 individuals. The carbon stored in the research location was 20.76 tons/ha.

1. Introduction
Forest resources are vulnerable to changes either naturally or as a result of human activities, so that forest functions may become inadequate [1,2]. Currently, Indonesia's forests are being massively exploited in various forms of forest conversion such as illegal logging, settlement development, shifting cultivation, plantations, road clearing and other forest functions [2]. Forest exploitation and forest conversion have threatened biodiversity that is essential for sustainability of life [1]. Knowledge of the structure and composition of forest stands is necessary for sustainable forest development [4]. Soil fertility and moisture significantly affect the structure and composition of the forest. This is illustrated by the basal value of the area in different types and groups of tree species [1]. The diversity of forest structures depicted in vertical and horizontal profiles is a good indicator of forest management [5]. Information on forest characteristics especially vegetation conditions is important to support the planning and implementation of a model of forest management. One of the successes of forest management can be seen from the aspects of stored carbon or carbon stock. Forests that have high species diversity and abundant litter play an important role in absorbing and storing carbon as biomass. Forests absorb carbon dioxide from the atmosphere through the process of photosynthesis and convert it into organic carbon and then store it in their body's biomass such as in stems, leaves, roots, fruit tubers and others. Forests can store about 76-78% of the organic carbon from the total terrestrial organic carbon in the form of biomass [6]. Understanding of the factors that affect Carbon storage of...
forests and their presence in various ecosystem components is important for estimating carbon balance on climate change and forest management [7]. Deleng Macik forest in Forest Park (Tahura) Bukit Barisan in addition to functioning as a carbon store also plays an important role as a water catchment area that supports the water needs for residents of Medan City and surrounding areas. The high intensity of human activities around the Deleng Macik forest feared threatening the existence of natural forest vegetation. This is exacerbated by a lack of ecological data and forest inventory information. Therefore, a study was conducted to obtain information on the structure and composition of tree vegetation in the Deleng Macik forest. The purpose of this research is to know the structure and composition of tree vegetation and carbon stored in the Deleng Macik forest, Tahura Bukit Barisan, Karo Regency, North Sumatera.

2. Materials and Methods

2.1. Study area
The forest area of Deleng Macik is geographically located at N 3°14'28.51 "-3 ° 14'30.1" E 98°31'37.2 "-98 ° 31'38" belonging to the territory of the Tahura Bukit Barisan. Administratively located within the area of Doulu Village, Subdistrict Berastagi, Karo Regency, North Sumatra (Fig.1).

![Study site at the Deleng Macik forest Tahura Bukit Barisan](image)

Figure 1. Study site at the Deleng Macik forest Tahura Bukit Barisan
2.2. Collecting data
Determination of study site was done by using purposive sampling method, a method of determination of research location considered representative. Data collection was done by using Quadratic Method. At the study site, a transect was 1000 m long. Along the transects made plots with 10x10 m sizes were placed zigzag so that along the transect there were 100 plots. In each plot the data was collected on stands >10cm in diameter. Individual tree parameters recorded included measurement of circumference of stems at 1.3 m, branch free height and total height. Abiotic factors measured include air temperature, air humidity, soil pH, Soil temperature, light intensity, coordinate point and altitude.

2.3. Data analysis
The structure of the tree vegetation was horizontally analyzed based on the DBH (diameter at breast height, 1.3 m). The vertical tree vegetation structure or tree stratification was obtained from measuring the total height of each individual tree and grouped by height category; Stratum A (> 30 m), Stratum B (20-30 m), Stratum C (4-20m), and Stratum D (1-4m). The composition of tree vegetation was done by comparing the number of individuals of each species from the largest to the smallest [8].

2.4. Biomass and carbon sink measurement
Estimation of tree biomass using allometric equations according to Hairiah et al.[9] and Ketterings [10] as follows:

\[ \text{a. Trees have no branches: } BK = \pi \rho H D^2/40 \]
\[ \text{b. Tree have branches: } BK = 0.11 \rho D^2.62 \]
\[ \text{c. Total Biomass = } BK1 + BK2 + ... + BKn \]

Note:
- \( BK \) = dry weight
- \( D \) = tree diameter (cm)
- \( H \) = tree height (cm)
- \( \rho \) = Heavy type wood, g cm-3

Carbon stored = Biomass x 0.46

3. Result and Discussion
3.1. Diversity of tree
Based on the research conducted in the Deleng Macik forest of Tahura Bukit Barisan, obtained 70 trees species belongs to 23 families as presented in Table 1.

| Species                  | Family      | Number |
|--------------------------|-------------|--------|
| Actinodaphne borneensis  | Lauraceae   | 8      |
| Actinodaphne macrophylla | Lauraceae   | 4      |
| Actinodaphne montana     | Lauraceae   | 3      |
| Anthocephalus cadamba    | Rubiaceae   | 38     |
| Ardisia lanceolata       | Myrsinaceae | 17     |
| Artocarpus rafa          | Moraceae    | 2      |
| Arytera littoralis       | Sapindaceae | 6      |
| Arytera sp.              | Sapindaceae | 9      |
| Caryota sp.              | Areaceae    | 1      |
| Casearia velutinosa      | Salicaceae  | 5      |
| Cryptocarya acuminata    | Lauraceae   | 4      |
| Cryptocarya ferrea       | Lauraceae   | 1      |
| Cryptocarya saligna      | Lauraceae   | 12     |
|   | Species                  | Family          | Number |
|---|--------------------------|-----------------|--------|
| 14| Cryptocarya sp.          | Lauraceae       | 11     |
| 15| Dehaasia hirsuta         | Lauraceae       | 3      |
| 16| Dillenia grandifolia     | Dilleniaceae    | 4      |
| 17| Dimocarpus dentatus      | Sapindaceae     | 6      |
| 18| Dimocarpus fumatus       | Sapindaceae     | 3      |
| 19| Diplospora wrayi         | Rubiaceae       | 1      |
| 20| Eurya nitida             | Pentaphylaceae  | 3      |
| 21| Ficus ampelas            | Moraceae        | 5      |
| 22| Ficus fistulosa          | Moraceae        | 3      |
| 23| Ficus pubinervis         | Moraceae        | 4      |
| 24| Ficus scortechinii       | Moraceae        | 3      |
| 25| Ficus vrieseana          | Moraceae        | 2      |
| 26| Ganophyllum sp.          | Sapindaceae     | 2      |
| 27| Helicia brachyantha      | Proteaceae      | 3      |
| 28| Knema curtisii           | Myristicaceae   | 3      |
| 29| Knema sp.                | Myristicaceae   | 2      |
| 30| Lindera polyantha        | Lauraceae       | 6      |
| 31| Lindera sp.              | Lauraceae       | 8      |
| 32| Lithocarpus daphnoideus  | Fagaceae        | 4      |
| 33| Lithocarpus eichleri     | Fagaceae        | 9      |
| 34| Lithocarpus gracilis     | Fagaceae        | 11     |
| 35| Lithocarpus hystrix      | Fagaceae        | 1      |
| 36| Lithocarpus sp.          | Fagaceae        | 3      |
| 37| Litsea diversifolia      | Lauraceae       | 3      |
| 38| Litsea lancifolia        | Lauraceae       | 14     |
| 39| Litsea ochracea          | Lauraceae       | 24     |
| 40| Litsea tuberculata       | Lauraceae       | 8      |
| 41| Mallotus brachythyrsus   | Euphorbiaceae   | 3      |
| 42| Mallotus oblongifolius   | Euphorbiaceae   | 2      |
| 43| Mallotus resinosus       | Euphorbiaceae   | 6      |
| 44| Mallotus xylacanthus     | Euphorbiaceae   | 1      |
| 45| Mastixia trichotoma      | Cornaceae       | 1      |
| 46| Microcos hirsuta         | Tiliaceae       | 7      |
| 47| Neolitsea foliosa        | Lauraceae       | 4      |
| 48| Neolitsea triplinervia   | Lauraceae       | 6      |
| 49| Nephelium sp.            | Sapindaceae     | 5      |
| 50| Phaeanthus splendens     | Annonaceae      | 3      |
| 51| Phoebe declinata         | Lauraceae       | 7      |
| 52| Quercus elmeri           | Fagaceae        | 19     |
| 53| Quercus wallichiana      | Fagaceae        | 12     |
| 54| Rinorea sp.              | Violaceae       | 7      |
| 55| Saurauia excavata        | Actinidiaceae   | 4      |
| 56| Schima wallichi          | Theaceae        | 1      |
| 57| Scorodocarpus sp.        | Olacaceae       | 2      |
| Species                          | Family       | Number |
|---------------------------------|--------------|--------|
| 58 Symplocos adenophylla        | Symplocaceae | 5      |
| 59 Symplocos lanceifolia        | Symplocaceae | 10     |
| 60 Syzygium acuminateissinum    | Myrtaceae    | 3      |
| 61 Syzygium antisepticum        | Myrtaceae    | 1      |
| 62 Syzygium confertum           | Myrtaceae    | 6      |
| 63 Syzygium lineatum            | Myrtaceae    | 4      |
| 64 Syzygium malaccense          | Myrtaceae    | 12     |
| 65 Syzygium pyrifolium          | Myrtaceae    | 10     |
| 66 Syzygium sp.                 | Myrtaceae    | 10     |
| 67 Syzygium splendens           | Myrtaceae    | 8      |
| 68 Syzygium subdecussata        | Myrtaceae    | 9      |
| 69 Urophyllum sp.               | Rubiaceae    | 2      |
| 70 Ziziphus sp.                 | Rhamnaceae   | 2      |
| **Total**                       |              | 431    |

Based on Table 1, it was known that the dominant family in the Deleng Macik forest were the family of Lauraceae with 17 species, Myrtaceae with 9 species and Fagaceae with 7 species. *Anthocephalus cadamba* was the most abundant tree species found in 38 individuals/ha. The number of tree species in the Deleng Macik forest had a high number of species compared to similar research in other locations, there were 43 species in the Sicike-cikeh Nature Park [11]; 23 species in 30 years old forest Telagah village Langkat regency [12]; 69 species in the Sibuatan Mountain Forest of Karo Regency [13]. Differences in the number of tree species between the Deleng Macik Forest and other locations are due to the typical environmental conditions and vegetation characteristics of each site. Species diversity of vegetation is the result of a dynamic ecophysiological process and correlation with local climatic conditions, nutrient conditions, tolerance ranges, biogeographic factors or distribution of species and variations in forest conditions [14,15].

Tree species found in almost all plots were *Anthocephalus cadamba*, *Litsea ochracea*, *Ardisia lanceolata* and *Syzygium malaccense*. The tree species found only in one plot were *Ziziphus* sp, *Caryota* sp, *Mallotus xylacanthus*, *Cryptocarya ferrea*, *Actinodaphne montana*, *Lithocarpus hystrix*, *Syzygium antisepticum*, *Diplospora wrayi*, *Knema curtisi*, *Knema* sp, *Mastixia trichotoma*, *Schima wallichi*, *Ficus fistulosa* and *Artocarpus rufa*. The diversity of tree species on each plot was due to the wide and random dispersal pattern, and the ability of each species to adapt to the surrounding environment. Another factor was the compatibility of vegetative and generative characters of each tree species with the surrounding environmental conditions that allow a species of tree to regenerate quickly and dominate a site [14,15].

### 3.2. Horizontal structure of stands

Measurements of trees diameter were done to obtain the DBH to describe vegetation structure horizontally (Fig.2). The total of DBH in Deleng Macik forest was 40.32 m²/ha, ranging from 0.02 - 7.54 m²/ha. The highest DBH was family of Lauraceae 7.54 m²/ha while the lowest was family of Theaceae 0.02 m²/ha. Significant differences in DBH between family indicate different adaptability of trees to the physical and chemical conditions of the surrounding environment. DBH was affected by the size of the diameter of the stem as well as the individual number of each tree present. The tree structure in the forest stand would form a variety of diameter ranges, due to the differences in the ability of trees to utilize solar energy, nutrients, water and competitiveness [14,15,16].
3.3. **Vertical structure of stands**
Stratification of the canopy is a vertical arrangement of plants in the forest ecosystem. The results of the height measurement of trees showed two different stratum categories. Based on Figure 3 it was known that the average tree was in stratum B (height 20-30 m) and C (height 4-20 m). The number of trees that had a lower canopy (417 individuals) was more dominant than the number of trees with high canopy (14 individuals). This was due to the trees found in the average location classified as young. This showed the existence of competition between plants and the nature of tolerance of tree species to solar radiation. In addition, the stratum also showed the age class of each forest constituent vegetation. The higher altitude would have the shorter and less of trees.

![Figure 2. Diameter at breast height (BDH) in all observation plots](image1.png)

![Figure 3. Tree stratification in Deleng Macik forest](image2.png)

3.4. **Composition of tree vegetation**
The composition of tree vegetation could be known by analyzing the density of trees from each family from the largest to smallest. From all observations was known vegetation composition of 23 families (Table 2).
Table 2. Composition of Tree Vegetation in Deleng Macik Forest Tahura Bukit Barisan of Karo District, North Sumatra

| No | Family           | Number | Percentage (%) |
|----|------------------|--------|----------------|
| 1. | Lauraceae        | 126    | 29.23          |
| 2. | Myrtaceae        | 63     | 14.62          |
| 3. | Fagaceae         | 59     | 13.69          |
| 4. | Rubiaceae        | 41     | 9.51           |
| 5. | Sapindaceae      | 31     | 7.19           |
| 6. | Moraceae         | 19     | 4.41           |
| 7. | Myristinaceae    | 17     | 3.94           |
| 8. | Symplocaceae     | 15     | 3.48           |
| 9. | Euphorbiaceae    | 12     | 2.78           |
| 10.| Tiliaceae        | 7      | 1.62           |
| 11.| Violaceae        | 7      | 1.62           |
| 12.| Actinidiaceae    | 5      | 1.16           |
| 13.| Salicaceae       | 5      | 1.16           |
| 14.| Dilleniaceae     | 4      | 0.93           |
| 15.| Myristicaceae    | 4      | 0.93           |
| 16.| Annonaceae       | 3      | 0.7            |
| 17.| Pentaphylacaceae | 3      | 0.7            |
| 18.| Proteaceae       | 3      | 0.7            |
| 19.| Olacaceae        | 2      | 0.46           |
| 20.| Rhamnaceae       | 2      | 0.46           |
| 21.| Arecaceae        | 1      | 0.23           |
| 22.| Cornaceae        | 1      | 0.23           |
| 23.| Theaceae         | 1      | 0.23           |

Based on Table 2 it was known that the composition of trees in Deleng Macik forest consists of 23 families with total species was 70 species and total individuals was 431 ind./ha. Here, ten (10) of trees family were selected with the highest composition value as shown in Figure 4.

The dominant tree in Deleng Macik forest was Lauraceae with 32% and the lowest was Violaceae with 2%. This was based on the large number of individuals and species and the widespread distribution of the Lauraceae family so that it was located almost in all observation plots, then its good adaptability and tolerant of environmental factors supported the Lauraceae family capable to dominate. Mountain forest was characterized by an abundance of Myrtaceae, Fagaceae and Lauraceae. The composition of tree vegetation in Deleng Macik forest was relatively lower when compared with similar research conducted in other locations; in the forest area of Mount Sinabung found 93 trees species belonging to 33 families with 276 individuals/0.6 ha [17]; in the Tangkahan forest area, Gunung Leuser National Park of Langkat Regency found 159 tree species included in 35 families with 437 individuals/ha [18]; in the forest area of Mount Sibuan Karo Regency found 69 trees species belonging to 26 families with 831 individuals/1.6 ha [13]. Differences in the composition of tree vegetation between locations were caused by physical and chemical factors surrounding environment as well as the character and condition of vegetation around different locations [3].

The dominant species was a species that had wide adaptation and tolerance capability to environmental conditions. Differences in the number of species within a forest area were caused by differences in environmental conditions of the habitat affecting the growth of that species.
3.5. *Biomass and carbon sinks*

It was found that biomass and carbon stored at research location were 45.14 ton/ha and 20.76 ton/ha. Forest biomass was determined by diameter, height, density of wood, soil density and soil fertility. This biomass was higher than the forest biomass of Mount Sibuatan at altitude of 1500-1600 m asl of 42.08 ton/ha [13] and lower than tree standing biomass in secondary forest 30 years Telagah Village Langkat District of 318.52 ton/ha [12]. Differences in the number, type and size of constituent trees lead to differences in the value of tree biomass in the forest. The greater the value of forest biomass, the more carbon can be absorbed by it. Natural forests are the highest carbon sink (C) when compared to agricultural land use systems, due to their high tree diversity with under-ground plants and litter on many soil surfaces [19].

4. **Conclusion**

The structure and composition of vegetation trees and carbon stored in the Deleng Macik forest Tahura Bukit Barisan, Karo Regency of North Sumatra could be summarized as follows:

a. Number of trees found 70 species belonging to 23 families with the amount of 431 individuals/ha.

b. Total of DBH was estimated 40.32 m² and the largest DBH belonging to Lauraceae 7.54 m².

c. Stratification trees were grouped into stratum B and C

d. The amount of carbon stored in the Deleng Macik forest was 20.76 tons/ha.

**Acknowledgment**

We would like to appreciate to all those who had contributed to the writing of this manuscript especially to the Biology Students of FMIPA USU who were very eager to assist in the collection of field data.
References

[1] Jaan Liira J, Sepp T, Parreent O 2007 *Forest Ecology and Management* **250** 34
[2] Francis Q, Brearley F Q, Prajadinata S, Kidda P S, Proctor J, Suriantata 2004 *Forest Ecology and Management* **195** 385–397
[3] Toniatoa M T Z, de Oliveirea-Filha A T 2004 *Forest Ecology and Management* **198** 319
[4] Kartawinata K, Purwaningsih, Partomihardjo T, Yusuf R, Abdulhadi R, Riswan S 2008 *Reinwardtia*. **12** 301-323
[5] Miren Onaindia M, Domingueza I, Albizu I, Garbisu C, Amezaga I 2004 *Forest Ecology and Management* **195** 341
[6] Kun Y and Dongsheng G 2008 *Journal of Environmental Science*. **20** 1439
[7] Zhu B, Wang X, Fang J, Piao S, Shen H, Zhao S, and Peng C 2010 *J Plant Res* DOI 10.1007/s10265-009-0301-1
[8] Mueller-Dombois D and Ellenberg H 1974 *Aims and Methods of Vegetation Ecology* (New York: John Wiley and Sons.)
[9] Hairiah K, Van Noordwijk M, Palm C 1999 *Methods for sampling above and below ground organic pools*. Modelling Global Change Impacts on the Soil Environment. IC-SEA Report No.6. SEAMEOBIOTROP-GCTE ICSEA, Bogor
[10] Ketterings Q M, Coe R, Van Noordwijk M, Ambagau Y, Palm C 2001 *Forest Ecology and Management*. **146** 199
[11] Seneng S A 2010 *Structure and Composition of Tree Vegetation and Poles around The Sickeh-Cikeh Natural Park Tourism, Dairi, North Sumatra*. (Medan: Universitas Sumatera Utara)
[12] Simamora J 2013 *Tree and Pole Diversity and Potential of Carbon stock In Secondary Forest Area 30 Years and Coffee Plantation Telagah, Langkat* (Medan: Universitas Sumatera Utara)
[13] Taufik M 2016 *Structure and Composition of Tree Vegetation and Carbon Potential in Forest Area of Gunung Sibuan Karo Regency* (Medan: Universitas Sumatera Utara)
[14] Kenfack D, Chuyong G B, Condit R, Russo S E, Thomas D W 2014 *Forest Ecosystems* **1** 1
[15] Lee H S, Davies S J, La Frankie J V, Tan S, Itoh A, Yamakura T, Okhubo T, Ashton P S 2002 *Journal Tropical Forest Science*. **14** 379
[16] Smith R G B and Nichols J D 2005 *Forest Ecology Management*. **218** 319
[17] Tarigan A 2005 *Structure and Composition of Tree Vegetation in Sinabung Mountain Area of Karo Regency* (Medan: Universitas Sumatera Utara)
[18] Susilo F 2004 *Diversity of Tree Species in Tangkahan Forest Area Gunung Leuser National Park Langkat Regency* (Medan: Universitas Sumatera Utara)
[19] Baishya R, Barik S K, Upadhyay K 2009 *Tropical Ecology* **50** 295