Estimation of above ground biomass *Shorea* spp (Dipterocarpaceae) using allometric models

S Latifah* and M Zahrah

Forestry Study Program, Faculty of Agriculture, University of North Sumatera, Jalan Tri Darma Ujung No. 1 Campus USU, Medan 20155, Indonesia

*Corresponding email: sitilatifah164@yahoo.com

**Abstract.** Forests play an important role in the global carbon cycle. Understanding numerous ecological processes, such as nutrient cycling and carbon sequestration, necessitates the estimation of forest biomass. This study was conducted primarily to estimate the above-ground biomass of *Shorea* spp (Dipterocarpaceae) using an allometric model in the Forest Management Unit Mandailing Natal, North Sumatera-Indonesia. To estimate tree biomass in forests, allometric regression models are frequently utilized. These are mathematical functions that link a tree's dry mass to one or more tree dimensions, like height, diameter, and wood density. The results showed that the average above-ground biomass of *Shorea* spp was 726.42 kg/tree. *Intsia bijuga*, with average biomass of 269.83 kg/tree, contributed to the smallest biomass. While the largest contribution to the amount of biomass is *Shorea platyclados*, with average biomass of 1564 kg/tree and for carbon storage of 735,2761 kg/tree.

1. Introduction

Forests play an important part in climate change mitigation by taking carbon from the atmosphere and storing it in their roots, branches, leaves, stems, and roots through the process of photosynthesis [1]. Live tree biomass estimates are critical for carbon accounting, bioenergy feasibility studies, and other analyses, according to [2].

Stabilizing CO$_2$ levels in the atmosphere is one of the measures being taken to mitigate the effects of climate change. This has to do with a forest's ability to absorb CO$_2$ from the sky and store it in the form of organic matter or plant biomass in the forest. Because half of the plant biomass contains carbon, the potency of the forest in carbon absorption may be evaluated by calculating plant biomass.

Aboveground biomass, defined as the number of organic producers in live and dead plant material, is an important component of the carbon cycle in forest ecosystems, providing both short and long-term carbon sequestration [3]. According to Marra et al. [4], 90 percent of the total aboveground biomass in the tropical forest is estimated to be precise tree biomass.

The plant family Dipterocarpaceae dominates Indonesia's lowland rainforest and has the opportunity to produce carbon. They consist of 350 species found in Indonesia, which are divided into nine genera: *Shorea*, *Dipterocarpus*, *Dryobalanops*, *Hopea*, *Anisoptera*, *Vatica*, *Cotylelobium*, *Parashorea*, and *Upuna*. Many of the members of this group work in the commercial wood industry. *Meranti*, *keruing*, *merawan*, *mersawa*, *kamper*, and *resak* are some of the market names for these plants [5].

When considering the forest's role as a carbon-sequestering medium, knowledge of the amount of carbon stored by a forest region (carbon stock) becomes critical. For applications such as wood...
extraction, tracking changes in forest carbon stocks, and the global carbon cycle, accurate estimation of expected forest biomass is critical [6,7].

Biomass research on species of the family Dipterocarpaceae is important because it will be useful for forest management plans and one of the keys to supporting the success of sustainable forest development in Indonesia in the future. Sustainable forests will have the potential for environmental services to absorb carbon in increasing amounts and durations according to the specified harvesting period.

Field measurements, geographic information systems, and remote sensing can be used to estimate forest biomass values [5]. Allometric regression models are frequently employed to estimate tree biomass in forests [8,9]. These are mathematical functions that link a tree's dry mass to one or more tree dimensions, like height, diameter, and wood density. The allometric equation model was frequently employed to estimate forest biomass [10-13].

Accurate estimation of forest carbon storage and changes in storage capacity is essential to assess the impact of forest management on the role of forests in carbon sequestration. This study aims to estimate the aboveground biomass of Shorea spp (Dipterocarpaceae) using allometric models.

2. Methods
2.1 Time and Location
The study was conducted at the Mandailing Natal-North Sumatera Production Forest Management Unit. The Mandailing Natal area is located between 1 and 1000 meters above sea level, with temperatures ranging from 23°C-32°C and humidity levels of 80 to 85%. Coordinate site location is 98° 52' 22" to 99° 31' 57" East Longitude, 0° 19' 16" to 1° 18' 8" North Longitude. Data was collected in May-June 2021 from various literature sources and online interviews to gain information about Dipterocarpaceae species groups. While the diameter and height statistics for Shorea sp were obtained from secondary data processing [14].

2.2 Tools and Materials
The tools used in this research were compass, machete, tally sheets, axe, Global Positioning System (GPS), diameter tape, camera, tent, recorder, work map, identification card, laptop, and stationery. The material used was Dipterocarpaceae species found in natural forest.

2.3 Data Collection and Analysis
This study used both primary and secondary data. Primary data was collected through in-depth interviews. A deep interview is a dialogue between a researcher and a research informant. The questionnaire used to ask structured questions and to minimize the number of unnecessary questions in the study. The data was analyzed and descriptively evaluated.

In this study, we used a non-destructive method. A non-destructive method is a sample technique that involves measuring rather than harvesting. The parameters used were height, and diameter of trees. Then, we calculated biomass using allometric equations [8]. The biomass estimation equation, also known as the allometric equation of regression model. It can be used to estimate the biomass or volume of tree components above-ground. This equation was calculated using diameter and height of trees, as well as tree weight measurements [9-10]. In this study, we used a total of 2030 trees from 12 species of Dipterocarpaceae.

Above-ground biomass was estimated using diameter, tree height, and wood density as independent variables [9]. Data analysis was carried out by calculating the actual biomass in the field using tree diameter variables based on allometric equations (Table 1). Allometric equations are specific to certain species and locations, so that allometric equations can not be compared across different species and locations [9].
Table 1. Tree Biomass Estimation with Allometric Equation

| No. | Tree type          | Model allometric equation | References |
|-----|--------------------|----------------------------|------------|
| 1.  | Branched tree      | $BK = 0.11pD^{2.62}$       | [11]       |
| 2.  | *Dipterocarpus*    | $lnBBA = -1.232+2.178lnD$  | [12]       |
| 3.  | *Palaquium sp.*    | $lnBBA = 1.098+2.142lnD$   | [12]       |
| 4.  | *Shorea sp.*       | $lnBBA = -2.193+2.37lnD$   | [12]       |
| 5.  | *Shorea leprosula* | $BBA = 0.059D^{2.390}$     | [12]       |

Note: $BK = $ dry weight, $D =$ tree diameter (cm), $H =$ tree height (cm), $p =$ specific gravity $(g/cm^3)$, $BBA =$ top biomass

When the biomass allometric model for the same tree species or ecosystem type was available from other locations, then further checking was carried out to determine whether the distribution of tree diameters from the inventory was within the range of the sample trees used to construct the tree biomass allometric model. If the inventory trees fall within the range of the sample trees, the biomass allometric model developed on other sites can be used to estimate the inventory tree biomass directly [13]. Forest biomass can be used to estimate predictable carbon storage with the formula

$$C = B \times 0.47$$ (1)

Where: $C =$ total carbon stock (tonnes C/ha), $B =$ biomass (tonnes/ha), $0.47 =$ carbon content [14].

3. Result and Discussion

3.1 Statistical Description of *Dipterocarpaceae* Species

The Meranti group or *Shorea* genus is one of the *Dipterocarpaceae* tribe's genera that grow in the lowlands. In the realm of trade, the Meranti group is divided into four basic groups, namely Red Meranti, Yellow Meranti, White Meranti, and Balau Meranti. Several ecological restrictions limit the growth and spread of *Dipterocarpaceae*. The statistical description of *Dipterocarpaceae* species tree diameter is presented in Figure 1, while the description of the tree height is in Figure 2. The most essential factors are soil, climate, and altitude. The taxonomic taxonomy of Meranti is as follows [16,17]:

- **Kingdom**: Plantae
- **Division**: Magnoliophyta
- **Class**: Magnoliopsida
- **Order**: Malvales
- **Family**: Dipterocarpaceae
- **Genus**: Shorea, Dipterocarpus, *Vatica*, *Cotylelobium*, *Anisoptera*, *Dryobalanops*, Hopea

![Figure 1. Dipterocarpaceae species tree diameter](image-url)
The Dipterocarpaceae family has an average diameter of 44.5 cm and height of 20.5 m. The largest tree species is the *Shorea johorensis* Foxw, which has a maximum diameter of 150 cm and an average diameter of 62 cm. The smallest of the species, *Palaquium sp.*, has a diameter of 30 cm. The *Agathis dammara* (star resin) species has the highest average total height of 26 meters, while *Palaquium sp.* has the lowest average total height of 17 meters. At the research site, the *Vatica sp.* tree reaches a maximum height of 47 meters.

In terms of developing mathematical models or functions, measurable variables such as height and diameter are one of the best ways to estimate tree and stand biomass, and they have played a large role in forest inventory, management, and silvicultural research [9,12,13].

![Figure 2. Dipterocarpaceae species tree height](image)

### 3.2 Above-ground Biomass

Tree biomass allometric models that have been developed in Indonesia are above-ground biomass models, both the total aboveground biomass and the sum of the aboveground biomass of individual tree components. By using the allometric model and the conversion value of biomass to carbon, the carbon content of individual trees can be known. The common conversion rate is 50%. To estimate the biomass, we use an allometric model as presented in Table 1. Above-ground biomass of *Shorea spp* and *Dipterocarpaceae* are presented in Table 2.

Based on diameter at breast height (DBH) and tree height data, the biomass estimation equation, also known as the allometric equation of regression model, can be used to estimate the biomass or volume of tree components above ground. This equation is calculated using DBH and sample tree height as well as tree weight measurements [6,15]. The use of allometric equations to estimate the biomass of tree species in forests or plantations is common and inexpensive [7]. According to [18], the parameter for estimating models suitable across species and a wide range of compositional and structural variation associated with species sorting into height layers and frequent natural disturbances.

Table 2 shows the species that contributed the smallest biomass and carbon storage was *Intsia bijuga* with average biomass of 0.27 tons/tree and for carbon storage 0.13 tons/tree. The largest contribution to the total biomass and carbon storage of the Meranti group was *Shorea platyclados* with a total of 48 individuals and resulted in average biomass of 1.56 tons/tree and for carbon storage 0.73 tons/tree. This tree species has a major contribution in storing biomass content, because it has many individuals and has a large diameter. Tree diameter, specific gravity and the number of individual trees determine the amount of biomass [19]. The greater the diameter and density of the tree will result in the higher the biomass content of a tree stand. In any forestry operation or climate change mitigation attempt, biomass calculation is a critical stage that must be recognized and performed [19,6].
Table 2. Above-ground biomass

| No | Species                  | Number of trees | Above-ground biomass Kg/tree | Carbon storage Kg/tree | Carbon storage Ton/tree |
|----|--------------------------|----------------|-------------------------------|------------------------|-------------------------|
| 1  | Shorea platyclados       | 48             | 1564.42                       | 735.2761               | 0.7353                  |
| 2  | Neobalanocarpus heimii   | 68             | 1203.94                       | 565.8508               | 0.5659                  |
| 3  | Agathis dammara          | 2              | 324.57                        | 152.5498               | 0.1525                  |
| 4  | Dryobalanops aromatica   | 432            | 415.62                        | 195.3416               | 0.1953                  |
| 5  | Dipterocarpus hasseltii  | 88             | 396.22                        | 186.2239               | 0.1862                  |
| 6  | Palaquium sp             | 274            | 372.71                        | 175.1743               | 0.1752                  |
| 7  | Shorea sp                | 834            | 532.39                        | 250.2223               | 0.2502                  |
| 8  | Shorea johorensis Foxw   | 35             | 1426.00                       | 670.2182               | 0.6702                  |
| 9  | Shorea sp                | 1              | 927.67                        | 436.0043               | 0.4360                  |
| 10 | Intsia bijuga            | 1              | 269.83                        | 126.8190               | 0.1268                  |
| 11 | Alstonia scholaris       | 2              | 678.25                        | 318.7779               | 0.3188                  |
| 12 | Vatica sp                | 245            | 605.45                        | 284.5593               | 0.2846                  |
|    | **Total**                | **2030**       | **8717.06**                   | **4097.0176**          | **4.097**               |
|    | **Average**              |                | **726.42**                    | **341.4181**           | **0.3414**              |

4. Conclusion

Biomass calculation is a vital stage that must be identified and completed in any forestry activity or climate change mitigation effort. Diameter, tree height, and wood density are common independent variables used to estimate aboveground biomass. *Shorea platyclados* contributed the largest biomass and carbon storage at the study site. Species in the dipterocarpaceae family make a significant contribution to forest biomass and carbon storage.

Acknowledgments

We gratefully acknowledge the support of University of Sumatera Utara Research Institute for granting permission to conduct research and providing finance for publications. The authors are also thankful to all technical personnel who collect data in the field.

Reference

[1] Baishya, R.; Barik, S.K. 2011. Estimation of tree biomass, carbon pool, and net primary production of an old-growth *Pinus kesiya* Royle ex. Gordon forest in north-eastern India. Ann. For. Sci., 68, 727–736.
[2] Nath, S.; Nath, A.J.; Sileshi, G.W.; Das, A.K. 2019. Biomass stocks and carbon storage in *Barringtonia acutangula* floodplain forests in North East India. *Biomass Bioenergy* 98, 37–42.
[3] UNFCCC. 2010b. Greenhouse Gas Inventory Data. Bonn, Germany: UNFCCC.
[4] Marra, D.M.; Higuchi, N.; Trumbore, S.E; Ribeiro, G.H.P.M.; dos Santos, J.; Carneiro, V.M.C.; Lima, A.J.N. 2016. Predicting biomass of hyperdiverse and structurally complex central Amazonian forests – a virtual approach using extensive field data. *Biogeosciences*, 13, 1553–1570, 2016.
[5] Rachmat H H, Pamoengkas P, Rahmatullah R K, and Susilowat A. 2021. Valuation of a man-made dipterocarp forest as a seed source for Shorea red meranti (Dipterocarpaceae). *IOP Conf. Ser.: Earth Environ. Sci.* 713 012031
[6] Kebede B & Teshome Soromessa. 2018. Allometric equations for aboveground biomass estimation of *Olea europaea L.* subsp. cuspidate in Mana Angetu Forest. ECOSYSTEM HEALTH AND SUSTAINABILITY, 2018 VOL. 4, NO. 1, 1–12. https://doi.org/10.1080/20964129.2018.1433951

[7] Nam VT, Van Kuijk M, Anten NP (2016). Allometric equations for aboveground and belowground biomass estimations in an evergreen forest in Vietnam. *PloS One* 11 (6), pp: 1-19. -DOI: 10.1371/journal.pone.0156827

[8] Lisboa S.N, Benard Soares Guedes, Natasha Ribeiro, Almeida Sitoe. 2018. Biomass allometric equation and expansion factor for a mountain moist evergreen forest in Mozambique. *Carbon Balance Manag.*, 13 (1): 23. DOI: 10.1186/s13021-018-0111-7.

[9] Latifah, S dan Nurdin Sulistiyono. 2013. Carbon Sequestration Potential in Aboveground Biomass of Hybrid *Eucalyptus* Plantation Forest. *Journal of Tropical Forest Management*, 9(1)pp: 54-62. ISSN: 2087-0469. http://journal.ipb.ac.id

[10] Latifah, S, Muhand, Agus Purwoko, Etika Tanjung. 2018. Estimation of aboveground tree biomass of *Toona sureni* and *Coffea arabica* in the agroforestry system of Simalungun, North Sumatra, Indonesia. *Journal BIODIVERSITAS*, 9(2): SCOPUS, pp: 590-595. ISSN: 1412-033X

[11] Ketterings, Q.M., Coe, R., Noordwijk, v.M., Ambagau, Y., and Palm, C.A. 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. *Forest Ecology and Management* 146: 199–209.

[12] Krisnawati, H, Wahyu Catur Adiningroho, and Rinaldi Imanuddin. 2012. Monograph Allometric Models for Estimating Tree Biomass in Various Ecosystem Types in Indonesia. Ministry of Forestry. Research and Development agency for conservation and rehabilitation, p. 141.

[13] Krisnawati, H., Wahjono, D., and Imanuddin, R. (2012). The dynamics of species composition, stand structure, and aboveground biomass of undisturbed forest in East Kalimantan. *Indonesian Biology Journal*, 8(1): 9-22. ISSN: 0854-4425.

[14] National Standardization Agency [BSN]. 2011. Indonesian National Standard (SNI) 7724:2011, Measurement and Calculation of Carbon Stocks–Field Measurements for the Assessment of Forest Carbon Stocks (Ground Based Forest Carbon Accounting). National Standardization Agency, Jakarta

[15] Production Forest Utilization Monitoring Center (BP2HP) Region II Medan. 2015. Report on the Results of the Inventory of Timber Forest Products for the Mandailing Natal KPHP Model

[16] Ngatiman dan Amiril Saridan. 2012. Exploration of Dipterocarp Species in Paser Regency, East Kalimantan. *Journal Penelitian Dipterokarpa*, 6(1)

[17] Saridan, A. and S. Soegiharto. 2012. Stand structure remains during trial harvesting in the Labanan Research Forest, East Kalimantan, Indonesian Center for Dipterocarp Research. Samarinda. *Journal of Research and Nature Conservation*. Vol.9 No.3. The Research and Development Center for Conservation and Rehabilitation. Bogor-Indonesia

[18] Marra, D.M.; Higuchi, N.; Trumbore, S.E.; Ribeiro, G.H.P.M.; dos Santos, J.; Carneiro, V.M.C.; Lima, A.J.N. 2016. Predicting biomass of hyperdiverse and structurally complex central Amazonian forests – a virtual approach using extensive field data. *Biogeosciences*, 13, 1553–1570, 2016.

[19] Latifah, S. 2013. Potential Of Biomass And Spatial Distribution Of Forest Plantation Of Hybrid *Eucalyptus* Prosiding The 3rd International Symposium for Sustainable Humanosphere (ISSH) ISSN: 2088-9127, pp: 149-155 https://www.researchgate.net