Assessing above ground biomass and carbon stocks among vegetation types In the Borneo Tropical Rainforest

Muhamad Khoiru Zaki[1*] and *Umi* Munawaroh[2]

[1]Department of Agricultural and Biosystem Engineering, Faculty of Agricultural technology, Universitas Gadjah Mada, 55281 Yogyakarta, Indonesia
[2]Department of Soil Sciences, Faculty of Agriculture, Universitas Pembangunan Nasional (UPN) Veteran Yogyakarta, 55283 Yogyakarta, Indonesia

Abstract. Above-ground biomass (AGB) is a fundamental indicator of ecosystem productivity and carbon storage, and plays an important role in climate change mitigation efforts. However, variability in species composition and structural characteristics remains a challenge in producing accurate biomass estimates in tropical forests. This study aims to quantify AGB and carbon storage potential in the dominant vegetation types of Kalimantan's tropical rainforests. We established 20 × 20 m sampling plots and estimated tree volume and biomass using species-specific allometric equations. Vegetation inventory identified rubber, teak, and oil palm as the dominant species, each showing different wood density and biomass expansion factor (BEF) values. Teak had the highest wood density (670 kg m^{-3}) and carbon stock, while oil palm had the highest BEF (3.40), indicating a more uniform distribution of biomass. Total AGB reached 154,942.44 kg, equivalent to 72.82 tonnes of carbon and an annual sequestration potential of 801.05 tonnes of CO_2 equivalent. Carbon accumulation shows a strong correlation with species characteristics such as diameter at breast height (DBH), tree height, and form factor. These findings emphasise the importance of species-specific structural assessments in carbon accounting frameworks and carbon offset programmes in tropical forest landscapes. Further research is recommended to integrate below-ground biomass, long-term monitoring, and remote sensing to improve carbon estimates at the landscape scale.

Keywords: Above ground biomass, carbon stock, vegetation type, tropical rainforest

1 Introduction

Carbon stocks, as a key component of ecosystem services, are widely recognised as an important indicator of global climate change [1]. Increased carbon stocks help reduce CO_2 concentrations in the atmosphere, mitigate the greenhouse effect, and maintain climate

* Corresponding author: muhamad.khoiru@ugm.ac.id

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stability [2]. In terrestrial systems, carbon stocks generally consist of above-ground biomass, below-ground biomass, soil organic matter, and dead organic matter. Forest ecosystems are major contributors to the global carbon cycle, functioning as carbon sources when disturbed and as carbon sinks when well-maintained [3]. Carbon stock estimates typically distinguish between above-ground and below-ground biomass [4], where above-ground biomass includes the total dry weight of vegetation above the soil surface—such as trunks, branches, and leaves—while below-ground biomass consists of root biomass and soil organic carbon. Previous studies have shown that above-ground biomass accounts for approximately 80–82% of total biomass, while below-ground biomass accounts for 12–20% [5].

Changes in land use and land cover influenced by climate change and anthropogenic activities are major factors affecting terrestrial carbon stocks [6], as each type of land use has a different carbon storage capacity, which directly impacts vegetation structure and ecosystem function [7]. Carbon stock assessments are generally conducted through analysis of vegetation dominance, wood density, and estimates of species-specific biomass [8]. However, although much research has been conducted on carbon dynamics in tropical forests, studies in Borneo/Kalimantan have mostly focused on remote sensing-based carbon mapping, with few field-based studies quantifying biomass and carbon storage in dominant vegetation types. This creates a research gap in understanding the species-level structural variation that influences carbon accumulation in highly heterogeneous tropical rainforest ecosystems.

The novelty of this research lies in the detailed assessment of above-ground biomass and field-based carbon stocks using a species-specific allometric approach for key vegetation types in Kalimantan rainforests. By integrating wood density, vegetation dominance, and structural characteristics, this study produces more precise plot-level carbon estimates to improve the accuracy of carbon calculations—as well as providing important insights for the implementation of REDD+, reforestation initiatives, and sustainable forest management. Therefore, this study aims to analyse above-ground biomass and carbon stocks in dominant vegetation types in Kalimantan's tropical rainforests.

2 Material and Methods

This study was conducted in Paser Regency and North Penajam Paser Regency, East Kalimantan. The field data collection locations or pools in the study area can be seen in **Fig. 1.** The research stages were divided into three stages, namely (1) above-ground biomass data collection, (2) satellite image analysis, (3) carbon stock tabulation.

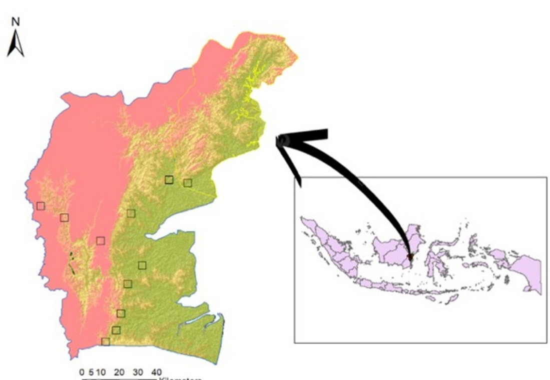

Fig. 1. Study site

Field measurement procedures are similar to those specified in SNI 7724:2011. Each sample location measures 20 m × 20 m. In each plot, we record all tree vegetation indicators, including species, number, canopy density, living/dead status, and height. Trees with a stem diameter >5 cm are measured using the basal stem diameter (Do)/diameter at breast height (DBH, at a height of 1.4 m) or buttress roots above a height of 30 cm. The unit of measurement is standardised to tonnes of carbon per hectare (t C ha−1).

The analysis of contained biomass refers to the measurement and calculation of carbon stocks – field measurements for estimating forest carbon stocks [9]. If allometric equations are not available in the study area, calculations using geometric formulas are used. If the specific gravity of vegetation and biomass expansion factor (BEF) are available, the biomass formula is used to determine above-ground biomass (kg) [10]. Carbon stock analysis refers to the measurement and calculation of carbon stocks – field measurements for estimating forest carbon stocks using available biomass value input data [11] as shown in the following flow chart (**Fig. 2**).

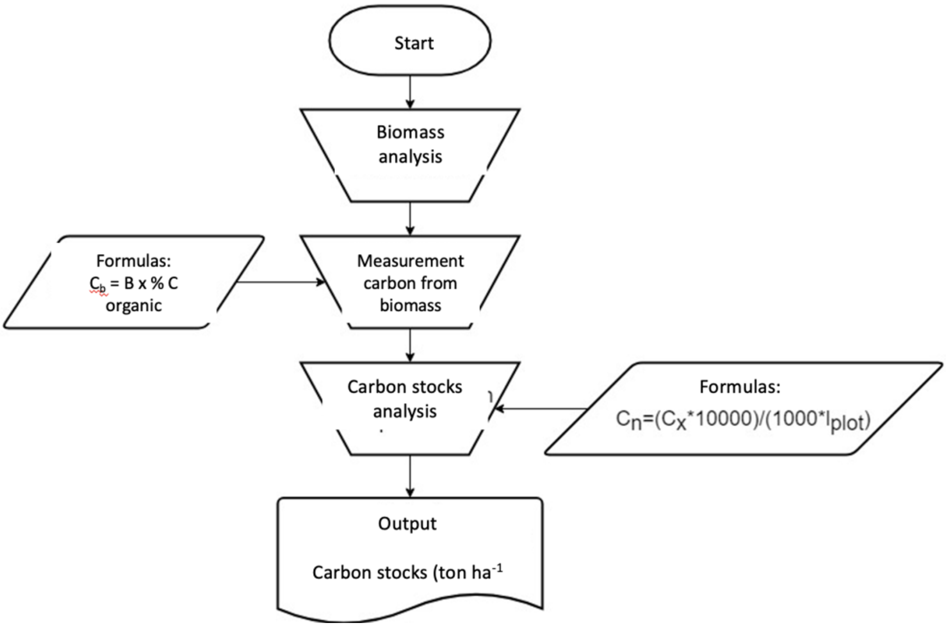

Fig. 2. Framework of this study

3 Results and Discussions

3.1 Vegetation analysis

Vegetation inventory was conducted at several research sites with different types of vegetation in order to obtain biomass values derived from the dominant vegetation in Paser Regency and North Penajam Paser Regency. Oil palm and rubber plantations are the dominant vegetation types, covering 1.4 million hectares and 1,180 hectares, respectively. Several types of vegetation analysed are shown in Table 1.

Table 1. Vegetation dominance and tree BEF

No.	Species	Amount vegetation	Wood Density	Reference	Tree BEF
1	Oil Palm	68	310 kg/m³	Ministry of Environment and Forestry, 2020	3.4
2	Teak	84	670 kg/m³	Ministry of Environment and Forestry, 2020	1.46
3	Rubber	85	580 kg/m³	Ministry of Environment and Forestry, 2020	1.73

An inventory was conducted to determine the variety of vegetation found at the research site, as each type of vegetation has different wood density (WD) and BEF values, which are parameters in determining carbon stock values [8]. The results of the study show that there are three dominant types of vegetation used in this study with a total of 23 vegetation types, namely rubber (85), teak (84), and oil palm (68).

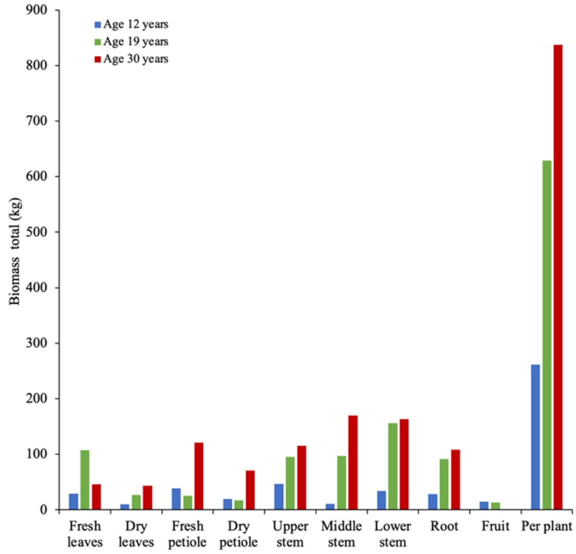

Fig. 3. Distribution of biomass total in oil palm vegetation

One of the most important and practical applications for determining the structure of living biomass is by assessing the following fractions of forest tree biomass: wood and bark, branches, foliage, and roots [9]. BEF is defined as the ratio of oven-dry biomass above ground level (AGB). As can be seen in **Table 1**, the highest BEF value is found in oil palm vegetation. This may be because the weight of oil palm vegetation biomass is distributed almost evenly across all fractions, resulting in a higher BEF value than other vegetation. The quantification of oil palm vegetation biomass weight can be seen in **Fig. 3.** The difference in biomass weight values for each fraction distribution is not very significant and tends to increase with the age of the vegetation. The biomass weight of young plants aged 12 years, 19 years and 30 years does increase, respectively, to 927.18 kg, 2,222.15 kg and 2,945.20 kg.

3.2 Biomass analysis

Tree biomass content is the sum of all biomass fractions resulting from photosynthesis [12]. Through photosynthesis, CO_2 in the atmosphere is absorbed by plants with the help of sunlight and converted into carbohydrates, which are then distributed throughout the plant and stored in the leaves, stems, branches, fruits and flowers [13]. The results of the study show that the amount of biomass at each sampling location varies, with the highest being sampling point 9 at 25,357.5 kg and the lowest being location 1 at 5,227.6 kg, as shown in **Fig.4** below.

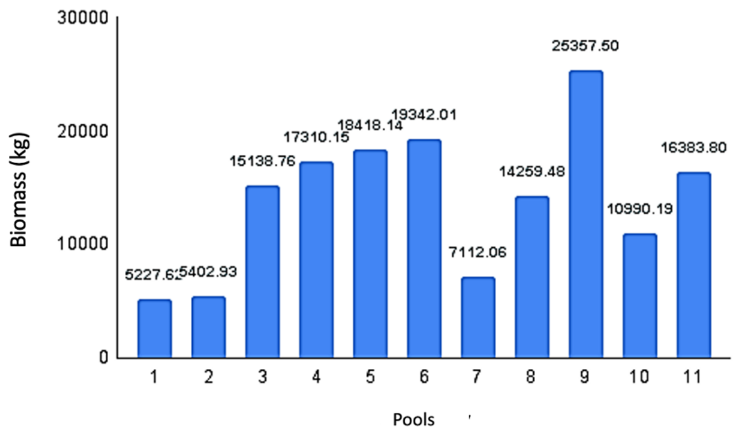

Fig. 4. The above-ground biomass in each pool

The amount of biomass contained in vegetation indirectly influences the rate of photosynthesis [14]. Photosynthesis absorbs CO_2 from the atmosphere, converts it into carbohydrates, and then stores it in various fractions of biomass in vegetation. This is why biomass is important as a carbon sink [15]. In addition, photosynthetic activity also influences the growth process of vegetation, so that the vegetation will continuously grow, as indicated by an increase in volume (as seen from the diameter and height of the vegetation).

3.3 Carbon stock analysis

Table 2. Shows the results of the analysis of total AGB, carbon reserves, and annual carbon sequestration at 11 research locations covering an area of 4400 m^2. The highest carbon reserve value for each biomass pool was found at study location 9, with a value of 297.95 tonnes/ha. Meanwhile, the lowest value was found at study location 1 with a Cx value of 61.42 tonnes/ha. This difference was due to the vegetation at the study locations. The parameters in determining the carbon reserves of each biomass pool were the biomass content in each pool (Fig. 5) and the percentage of carbon content in each biomass pool, which was stated as 0.47 based on the SNI carbon measurement results.

Table 2. Above-ground biomass, carbon stock, annual carbon sequestration at the study Site

No.	Variable	Amount (per ha)	Area (ha)	Total
1	Biomass (tons)	352.14	0.44	154.94
2	Carbon stock (tons)	32.04	0.44	72.82

The carbon sequestration rate in **Fig. 5** represents the carbon capacity that can be absorbed by biomass in a particular box. The sequestration rate is greatly influenced by the type of vegetation and the volume of vegetation in the box. The total absorption rate from a total of 11 study locations was 1,770.92 tonnes/ha, which is the carbon absorption is the annual capacity of carbon dioxide that can be absorbed by trees.

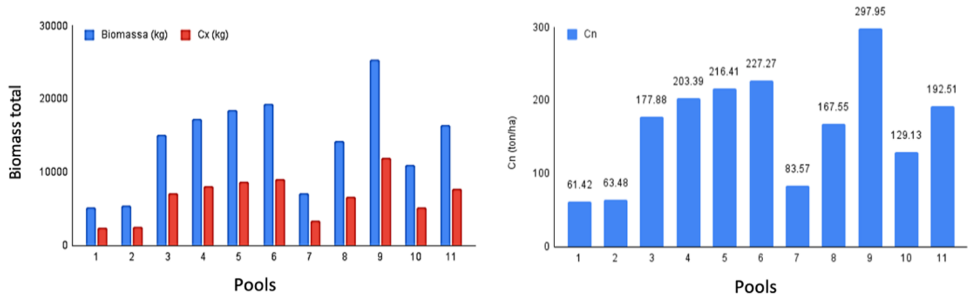

Fig. 5. The Carbon stocks (C_x) and annual carbon sequestrations (C_n) in each pool

4 Conclusions

Based on the objectives of the research conducted, several key conclusions can be drawn. First, the amount of biomass present on the soil surface is strongly influenced by the type of vegetation growing within the area. Different plant species produce varying quantities and qualities of organic material, which directly affect overall biomass accumulation. Second, the carbon reserve stored on the soil surface is closely related to the amount of above-ground biomass (AGB). Higher AGB values indicate greater vegetation density and productivity, which subsequently contribute to increased carbon storage. These findings highlight the essential role of vegetation composition in regulating surface biomass and carbon dynamics.

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