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Above Ground Biomass and Carbon Stock at Pesanggrahan Preserve Area, Malang, East Java, Indonesia

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Abstract. Tropical forests have known ecosystem services, including sequestering atmospheric carbon and fixing it into biomass. Since the revolutionary industrial changes, the atmospheric carbon level has risen during the recent decades, while the global temperature has increased compared to the pre-industrial levels. Furthermore, reducing atmospheric carbon can mitigate global warming and climate change. This study aims to estimate the aboveground biomass and carbon stock in the Pesanggrahan Forest, Malang Regency, East Java, Indonesia, and contribute local information to the vast global literature. This study was conducted in August 2023 and measured all tree species with a diameter >20 cm in a 5-ha area. The results found 208 individuals and 39 species of trees, the aboveground biomass and carbon stock of which were calculated. The total aboveground biomass (AGB) and carbon stock were 4,486 and 2,248 tons C/ha, respectively. Meanwhile, the total forest AGB and carbon stock in the 5-ha sampling area were 224.77 tons/ha and 112.39 tons C/ha, respectively. These findings highlight the cruciality of tropical forest vegetation in carbon storage and their overall role in regional and global ecosystem management in light of climate change.

Keywords: Aboveground Biomass; Carbon Stock; Climate Change Mitigation; Tropical Forest

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INTRODUCTION

Tropical forests have significantly benefited ecosystem services, including their role in sequestering CO_2 through photosynthesis (Chanlabut & Nahok, 2022). Carbon (C) is stored in the form of biomass. Tropical forests sequester more carbon than any other biome on Earth (Phillips et al., 2019). Forests are regarded as effective natural means of carbon sequestration with vast potential and storage capacity (Dalmonech et al., 2022; Gai et al., 2023). Carbon is stored in the roots, stems, leaves, and branches of trees. Plants continuously absorb atmospheric CO_2 through photosynthesis and then fix it in their biomass and soil via a series of chemical and biophysical reactions for long-term storage (Keenan & Williams, 2018; Ruehr et al., 2023), a process called carbon sequestration. Such carbon accounts for ~50% of the carbon stock (Hairiah et al., 2011).

However, tropical forests are most directly impacted by anthropogenic factors such as deforestation and forest degradation (Zaki et al., 2018) and land use and cover change (Barati et al., 2023; Liu et al., 2020). The carbon primarily produced by humans accumulates in the Earth's atmosphere (Wiegand et al., 2021). Deforestation and forest degradation have contributed the most to pressing global environmental concerns, such as biodiversity loss and climate change. This change directly impacts the carbon pool in the atmosphere. The declining land vegetation impacts greenhouse gas emissions, including carbon, leading to global warming and climate crisis (Cheng et al., 2022.

The Indonesian region has a high plant biodiversity index (Fathoni et al., 2021; Rohman et al., 2020), especially in the tropical forest ecosystem (Fardhani et al., 2020). Plants have a role as a habitat for the fauna, medicine (Rohman et al., 2019), and storing carbon in their biomass (Malik et al., 2020). Although the area of tropical forests has declined, places that have been declared protected remain sustainable. One such area is South Malang Pesanggrahan, East Java, Indonesia. It extends west to east along the south coast and has varied vegetation density characteristics (Rohman et al., 2023). Therefore, assessing biomass and carbon stock in forest areas is crucial to evaluating the sustainability and biodiversity productivity changes of forests (Sunarno et al., 2022). With the complex structure of the tropical forest, there is enormous uncertainty regarding carbon stock estimation (Zaki et al., 2018). As the carbon stock in a region is influenced by vegetation biodiversity (Gebrewahid & Meressa, 2020), managing forest vegetation diversity could be critical for forest conservation.

Carbon stock assessment of tropical forests has been done at Afrika, i.e., the Gura-Ferda District of Southwestern Ethiopia (Betemariyam et al., 2023); Kimbi-Fungom National Park, Cameroon (Sainge et al., 2020); the Banja Forest, northwest of Ethiopia (Abere et al., 2017); and the Tozi tropical dry forest, Sinnar State, Sudan (Yasin & Mulyana, 2022). It has also been performed in certain regions of Asia, i.e., the Bromo Education Forest, Indonesia (Darmawan et al., 2022); the Suan Phueng Nature Education Park, Ratchaburi Province, Western Thailand (Chanlabut & Nahok, 2022); the Sabal Forest Reserve and the Balai Ringin Protected Forest, Borneo, Malaysia (Kenzo et al., 2015); and Colombia (Usuga et al., 2010). Assessing carbon stock is essential and is the initial stage of evaluating the solution for natural climate change mitigation. The Pesanggrahan Forest is one of the tropical forests located in East Java, Indonesia, and has never been analyzed for carbon sequestered capacity. Therefore, ascertaining the aboveground biomass, carbon stock, and carbon sequestration at Pesanggrahan Preserve Area is crucial.

This research aims to determine the amount of biomass and carbon stock in the Pesanggrahan tropical forest. Measuring carbon stock in tropical forests has numerous significant benefits for science and society. The Pesanggrahan Protected Forest Area in South Malang has varying vegetation density characteristics, which can provide insights into the carbon storage potential and health of this forest ecosystem (Rohman et al., 2023). This information benefits local conservation efforts and contributes valuable data to global studies on the role of tropical forests in climate change mitigation. In addition, measuring the carbon stored in tropical forest areas can be a basis for conserving nature, considering carbon trade, and tackling climate change.

METHODS

Study area

This study was carried out in the Pesanggrahan Natural Preserve Area, East Java, Indonesia (8°23'34"S - 8° 24' 15" S and 112° 32'58" E-112°33'42" E). The total area is 90,360.80 ha, divided into preserved area (44,164.90 ha) and productivity forest (46,195.90 ha). A plot of 5 ha was sampled for the study. The Indian Ocean borders the Pesanggrahan Natural Preserve geographical area to the south, the South Cross Road, the western protected forest, and the eastern Berek River, part of Tumpakrejo Village, Gedangan District. This forest has a tropical climate, characterized by rainy and dry seasons that alternate throughout the year, which is very suitable for planting teak and jungle stands. The average temperature is 31°C and the average rainfall is 1226.4 mm/year.

Data Collecting Procedure

The data collection procedure was divided into two parts. First, the sampling was done using the path method, which is most effective for studying changes in vegetation state based on the soil conditions, topography, and elevation. The path taken was 20 m from the left and right of the main line and straight for 50 m. Thus, the total sampled area was 5 ha. Second, diameter at breast height (*dbh*) measurements are carried out on trees with a diameter ≤20 cm. Tree species such as *Vitex glabrata* are more accessible because they do not have buttress roots; hence, *dbh* measurements were carried out at a height of 1.3 m (Figure 1a). However, species such as *Arthocarpus elasticus* have buttress roots so the *dbh* was measured 0.5 m above the end of the buttress (Figure 1b). This process requires caution to ensure the safety of the research team. The species names were validated by appraisal by an expert from BRIN Indonesia, who accompanied the team during the exploration. Meanwhile, to estimate tree biomass, the diameter at breast height (DBH) and the height of each sampling tree were measured. The circumference of the tree determined its diameter.

Data Analysis

Allometric correlations from tree diameter were used to estimate the biomass of the woody plants. The allometric equations were used to calculate the biomass following Brown (1997). The Brown formula was specifically developed for measuring mature plants and had less Mean Prediction Error and Root Mean Square Error compared with other allometric equations (Pati et al., 2022).

$$\text{Aboveground biomass (AGB)} = 42.69 + 12.800\,(\text{DBH}) + 1.242\,(\text{DBH}^2)$$

The AGB obtained from the equation was converted to the carbon stock of single trees using a conversion factor of 50% of the dry biomass, which is 0.5, as suggested by Hairiah et al. (2011), expected to be the carbon of all tree segments as a default value. The equation employed for ascertaining the carbon stock was:

$$\text{Total Carbon Stock (MgCh}^{-1}\text{)} = \text{Total AGB x 0.5}$$

RESULTS AND DISCUSSION

The primary inclusion parameter for this research was tree dbh >20 cm measured with a rolling meter (Figure 1). Trees with larger diameters are assumed to have greater biomass and carbon reserves, but this also depends on the wood density. Species such as *A. elasticus* (Figure 1b) have a larger stem diameter than other species.

A total of 39 tree species were found, and 208 individuals were recorded. Biomass and carbon stock were calculated for all individuals in the area. Information regarding the average diameter and the number of individuals in each species employed to estimate biomass using the allometric formula is provided in Table 1. A formula that considers wood density was not used because collecting them in tropical forests is challenging.

Figure 1 (a) measurement of the *dbh* of a tree without buttresses, (b) with buttresses, namely by measuring 0.5 m above the end of the buttresses, (c) sample tree, (d) measuring the *dbh* of a tree

Table 1. Average of Tree Diameter and Total Tree Species at Pesanggrahan Forest

No.	Species	Average of Tree Diameter (cm)	Total Tree Species
1	*Vitex glabrata*	33.78	44
2	*Corypha utan*	42.40	27
3	*Garuga floribunda*	39.04	23
4	*Ficus variegata*	89.17	17
5	*Pterocymbium tinctorium* var. *javanicum*	34.71	9
6	*Pterospermum diversifolium* Blume	35.99	8
7	*Alstonia spectabilis*	30.89	8
8	*Garcinia celebica*	26.33	8
9	*Microcos tomentosa*	38.06	7
10	*Sterculia cordata*	31.85	7
11	*Terminalia subspathulata*	30.36	6
12	*Adenanthera pavonina*	43.63	6
13	*Ficus benjamina*	56.13	5
14	*Streblus asper*	24.43	5
15	*Terminalia bellirica*	34.39	3
16	*Peltophorum pterocarpum*	29.35	3
17	*Guioa diplopetala*	32.80	2
18	*Canarium hirsutum*	29.27	2
19	*Litsea glutinosa*	31.92	2
20	*Dysoxylum acutangulum*	31.85	2
21	*Ficus drupacea*	29.24	2
22	*Ficus retusa*	30.68	2
23	*Pterygota thwaitesii*	30.57	2
24	*Arytera litoralis*	37.87	1
25	*Actinodaphne glomerata*	27.07	1
26	*Senna multijuga*	26.43	1
27	*Callicarpa pentandra*	25.82	1
28	*Psydrax dicoccos*	24.93	1
29	*Ficus hispida*	24.52	1
30	*Artocarpus elasticus*	30.31	1
31	*Heritiera javanica*	23.89	1
32	*Monoon lateriflorum*	23.41	1
33	*Dracontomelon dao*	23.25	1
34	*Dehaasia caesia*	22.77	1
35	*Suregada glomerulata*	22.29	1
36	*Melicope latifolia*	21.97	1
37	*Harpullia arborea*	21.76	1
38	*Sterculia lanceolata* var. *coccinea*	20.06	1
39	*Mallotus peltatus*	20.00	1
	Total		208

The most common tree species was *Vitex glabrata* (smooth chaste tree) with 44 individuals. *V. glabrata* is distributed in the tropical forests of Asia (Chakravarthy & Ratnam, 2015). *Corypa utan* had 27 individuals. Meanwhile, the tree with the largest average diameter was *Ficus variegata*, at ~89.17 cm. It is a native species of tropical forests and not an introduced one, as this tropical forest has been designated as protected. Next, we calculated the total AGB in each species using the allometric formula (Brown, 1997). The total ABG (Table 2) was calculated for each tree species using an allometric equation.

Table 2. Above Ground Biomass at Pesanggrahan Forest

No.	**Species**	**AGB (ton/ha)**	**Carbon stock (ton C/ha)**
1	*Vitex glabrata*	10.18	5.09
2	*Corypha utan*	9.77	4.88
3	*Garuga floribunda*	1.55	0.77
4	*Ficus variegata*	1.76	0.88
5	*Pterocymbium tinctorium* var. *javanicum*	1.75	0.88
6	*Pterospermum diversifolium*	1.62	0.81
7	*Alstonia spectabilis*	1.06	0.53
8	*Garcinia celebica*	0.93	0.47
9	*Microcos tomentosa*	1.83	0.92
10	*Sterculia cordata*	1.83	0.91
11	*Terminalia subspathulata*	1.05	0.52
12	*Adenanthera pavonina*	0.74	0.37
13	*Ficus benjamina*	1.30	0.65
14	*Streblus asper*	1.71	0.85
15	*Terminalia bellirica*	0.62	0.31
16	*Peltophorum pterocarpum*	0.89	0.45
17	*Guioa diplopetala*	0.71	0.35
18	*Canarium hirsutum*	0.52	0.26
19	*Litsea glutinosa*	0.75	0.37
20	*Dysoxylum acutangulum*	0.43	0.21
21	*Ficus drupacea*	0.95	0.47
22	*Ficus retusa*	0.28	0.14
23	*Pterygota thwaitesii*	0.35	0.18
24	*Arytera litoralis*	0.11	0.06
25	*Actinodaphne glomerata*	0.19	0.10
26	*Senna multijuga*	0.21	0.11
27	*Callicarpa pentandra*	0.27	0.14
28	*Psydrax dicoccos*	0.16	0.08
29	*Ficus hispida*	0.55	0.27
30	*Artocarpus elasticus*	0.09	0.04
31	*Heritiera javanica*	0.16	0.08
32	*Monoon lateriflorum*	0.12	0.06
33	*Dracontomelon dao*	0.10	0.05
34	*Dehaasia caesia*	0.07	0.04
35	*Suregada glomerulata*	0.05	0.03
36	*Melicope latifolia*	0.07	0.04
37	*Harpullia arborea*	0.08	0.04
38	*Sterculia lanceolata*	0.07	0.03
39	*Mallotus peltatus*	0.06	0.03

V. glabrata has the highest total AGB and carbon stock at 10.18 ton/ha and 5.09 ton C/ha, respectively (Table 2), indicating that this species had the largest aboveground biomass, contributing remarkably to carbon storage. A wide range of aboveground biomass (AGB) and carbon stock values across the species listed reflects diversity in biomass and carbon sequestration potential among them. The relationship between AGB and carbon stock was direct, with carbon stock generally being half the AGB value for each species. This trend suggests a consistent conversion factor used to estimate carbon stock from biomass. *Ficus* spp. showed varied AGB and carbon stock values, highlighting the differences in biomass accumulation even within the same genus. The total AGB, carbon stock, and carbon uptake throughout the sampling area and per hectare are presented in Figure 2.

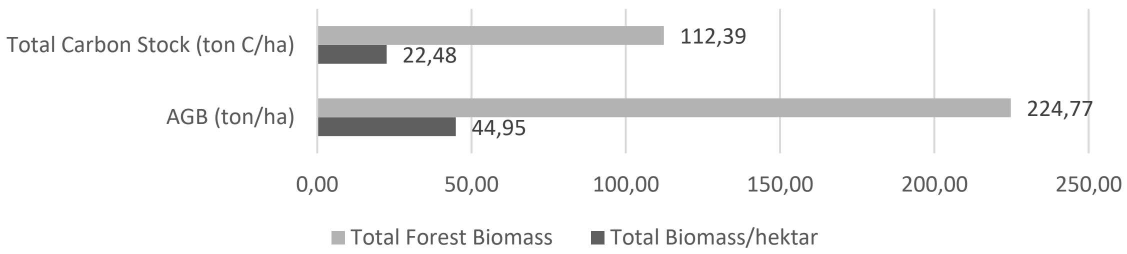

Figure 2. Total aboveground biomass (AGB) and carbon stock throughout the sampling area and per hectare

Figure 1 shows that the total aboveground biomass (AGB) and carbon stock were 44.86 tons/ha and 22.48 tons C/ha, respectively. Meanwhile, the total forest AGB and carbon stock in the 5-ha sampling plot were 224.77 tons/ha and 112.39 tons C/ha, respectively. The AGB of forest ecosystems depends on the density and diversity of the vegetation species (Siarudin et al., 2021). Environmental variation also becomes a limiting factor for certain species; thus, it could inhibit some from growing to full potential (Wang et al., 2019). Consequently, the regeneration capacity of each species in this ecosystem was highly dynamic depending on their adaptability to environmental conditions. Therefore, tree biomass can be accurately measured only by calculating biomass destructively or employing harvesting methods. Thus, the allometric formula is a non-destructive alternative for estimating biomass stress. Brown's formula (1977) is widely used to estimate AGB in tropical forest ecosystems due to the frequent application of allometric equations. Due to the numerous allometric equations used in calculating AGB estimates, this research tried to compare our findings with those from the existing literature.

Biomass and Carbon Stock Comparison with the Other Tropical Forest

This research comparing the total biomass and carbon stock obtained in our study with those in several reported tropical forests. Although the biomass estimation in each study varied, this comparison will describe the amount of biomass stored in tropical forest ecosystems. The difference in tropical forest biomass per hectare is influenced by many factors, such as vegetation community structure, land cover structure, and allometric equations used in calculating biomass estimates. Table 3 presents some literature on biomass in various tropical forests.

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Table 3. A comparative review between biomass and carbon stock estimates in similar forest types reported by previous investigations and the present study

No.	Countries Region	Comment	AGB (ton/ha)	References
1.	Phrae Province, Thailand	Deciduous species such as *Shorea obtusa*	Range between 90-545 ton/ha	(Asanok et al., 2021)
2.	Phayao Province, Thailand	Dry dipterocarp forest	72.69	(Sanwangsri et al., 2016)
3.	Savannakhet Province, Lao PDR	The dominant species in the included *Lithocarpus polystachyus (Wall.) Rehd.*, *Cananga odorata*, *Shorea obtusa. Wall. ex Blume*, *Pterocarpus macrocarpus Kurz*	22.33	(Vicharnakorn et al., 2014)
4.	Ecuadorian Andes	N/A	70.64	(Cuesta et al., 2023)
5.	Diaoluo Mountain, China	N/A	22.55	(Wang et al., 2023)
6.	Chiapas, México: Villaflores and Villa Corzo, both in the Frailesca region	*Quercus peduncularis* Dominant tree	41.96	(López-Cruz et al., 2022)
7.	Mamit District, Mizoram, north-east India.	*Gmelina arborea* dominant tree	Range between 66-108	(Hauchhum, 2017)
8.	Present study	*Vitex glabrata* dominant tree	44.95	Kundariati *et al.*

Table 3 highlights the differences in carbon stocks in various tropical forests. The AGB estimated in the present study was ~44.96 ton/ha, which was higher than that at Diaoluo Mountain (22.55 ton/ha) and Savannakhet Province Lao PDR (22.33 ton/ha). However, it was lower compared to the Phrae area, Thailand (90–545 ton/ha); Phayao, Thailand (72.69 ton/ha); Ecuadorian Andes (70.64 ton/ha); Chapes, México (41.96 ton/ha); and Mamit, India (66–108 ton/ha). The variation in AGB was due to the sampling area, its biogeographical conditions, the method used, and the tree diversity. Asanok et al. (2021) revealed that the diversity index influences carbon stocks. Sanwangsri et al. (2016) also obtained greater carbon stocks on similar vegetation types. This research was conducted in dry dipterocarp forests. The results of previous carbon stock measurements are lower than those of this research, namely Wang et al. (2023); Vicharnakorn et al. (2014). Both employed different methods to estimate carbon stored in the area, namely L-Band polarimetric observations (Wang et al., 2023) and remote sensing methods (Vicharnakorn et al., 2014).

The Pesanggrahan Preserve Area had a higher biomass than those from several studies (Table 3). Several factors influence the biomass of tropical forests and trees. Climate plays a crucial role, as temperature, precipitation, and humidity levels directly affect tree growth and forest density (Ma et al., 2023). Soil fertility and composition also markedly impact tree biomass, with nutrient-rich soils supporting more vigorous growth. Species diversity and composition are essential, as different species have varying growth rates and biomass accumulation potentials (Haro-Carrión et al., 2021). Human activities, such as deforestation, logging, and land-use changes, can reduce forest biomass by removing trees and disrupting ecosystems. Deforestation can thus impact rainfall for seasons beyond its immediate impacts on precipitable water. The combination of warming and altered rainfall patterns due to climate change can lead to feedback effects on the remaining vegetation and reduce biomass accumulation (Brienen et al., 2015). Thus, understanding these factors is vital for managing and conserving tropical forests, ensuring they continue to serve as excellent carbon sinks and biodiversity hotspots.

Besides the differences in the carbon stocks among forests, tropical forests consistently provide ecosystem services by storing large amounts of biomass and carbon. They have a high diversity and density of flora, which is directly proportional to biomass storage (Enríquez-de-Salamanca, 2022). Aboveground biomass can be calculated by applying the allometric equation, using the diameter data of stands, as it is directly proportional to the biomass and carbon stored. It enables foresters to take simple tree stand measurements such as diameter, height, biomass, and carbon (Ruslim et al., 2021). Forests have the potential to contribute up to 50% of total global natural sequestration, particularly in the tropics, by improving carbon stocks in terrestrial ecosystems (Ruehr et al., 2023) and storing the carbon in their biomass (Pradhan et al., 2019), deadwood, litter, and soil (Pukkala, 2020). Carbon as a greenhouse gas (GHG) contributes to global warming and climate change. Tropical forests comprise various tree species growing for decades or even millennia. In this case, Pesanggrahan Forest has been a preserve for decades. Therefore, its trees are estimated to have a considerable amount of biomass and carbon stocks. Most tree biomass assessments are performed on AGB because it represents the most extensive fraction of total living biomass in a forest and does not pose significant logistical problems during field measurements (Zeng et al., 2022). This ecosystem also contributes to the carbon neutrality agenda.

An international panel has recommended carbon neutrality in response to the global climate crisis. Carbon neutrality also known as a zero carbon footprint is reached when the same amount of CO_2 is released into the atmosphere as it is removed by various means, leaving a zero balance. Achieving carbon neutrality depends on carbon emission reduction and sequestration (Chen et al., 2022). Carbon is sequestered and stored in the biomass (Enríquez-de-Salamanca, 2022). This process acts as a natural solution for climate change mitigation (Jin et al., 2020). Therefore, tropical forests should be one of the strategic goals for climate change mitigation by sequestering the atmospheric carbon. However, deforestation, degradation, and poor forest management reduce their ability to store carbon (Withaningsih et al., 2024). Nevertheless, sustainable forest management, planting, and rehabilitation can improve carbon sequestration.

For years, conserving tropical forests has been an essential battleground for development policy. The ever-increasing awareness about the relevance of tropical forests for biological evolution, the functionality of global ecosystems, and the well-being of billions of people and projects tackling the manifold facets of tropical deforestation (Ibisch & Schmidt, 2009). Over 50%

of the plant species are known to grow in tropical forests (Mayaux et al., 2005). Biodiversity has led to the ecosystems' balance and functions as a climate change regulator. Some strategies such as REDD+ have been implemented to address climate change through conserving tropical forests. This program positively incentivizes those countries that reduce emissions, deforestation, and forest degradation, preserve carbon stocks, enhance forest carbon stocks, and sustain forest management (Nugroho et al., 2023).

Another achievable target is carbon trading, which is economically beneficial for the country and society. Carbon trade, tax, and pricing are some climate change mitigation strategies whose primary efforts are forest land conservation (Dominioni, 2022; Rakatama et al., 2023; Vorster et al., 2011). Programs such as the Folu Net Sink Indonesia 2030 framework aim to reduce deforestation and LULC while accelerating forest reforestation rates (Nugroho et al., 2023). This work reflects tropical forest conservation efforts, which are natural solutions for mitigating climate change and reducing the amount of atmospheric CO_2 through carbon sequestration by vegetation.

Measuring the carbon stock enriches our understanding of scientific carbon storage processes and their role in the global carbon cycle. This helps researchers understand the mechanism by which tropical forests reduce atmospheric CO_2 concentrations through photosynthesis and carbon storage in biomass (Chanlabut & Nahok, 2022; Keenan & Williams, 2018). Tropical forests store more carbon than any other biome on Earth (Phillips et al., 2019). Measuring carbon stock allows the assessment of the actual carbon storage capacity of specific areas, which is crucial for determining the effectiveness of a forest in sequestering and storing carbon. Carbon stock measurements provide a foundation for forest conservation and management efforts. Knowing the amount of carbon stored in a forest can facilitate designing more effective conservation strategies and ensuring that they function as vital carbon sinks (Gebrewahid & Meressa, 2020; Lestari et al., 2024). One of the main benefits of ascertaining carbon stock is climate change mitigation. By identifying forested areas with robust carbon storage capacity, we can focus on protecting and restoring them to reduce greenhouse gas emissions and combat the ongoing global climate crisis (Cheng et al., 2022).

This research specifically focused on an understudied area, conducted detailed species-specific analysis, employed a simplified yet effective biomass estimation method, integrated the results with broader ecosystem services and climate strategies, and suggested a comprehensive approach to addressing both challenges and solutions in tropical forest conservation. Information on carbon stock can support the formulation of environmental and economic policies, such as carbon trading schemes and providing financial incentives for forest conservation (Hairiah et al., 2011). Measuring carbon stock is also crucial for education and raising public awareness about the critical role of tropical forests in climate change mitigation. This can encourage community involvement in conservation efforts and help build broader public support for sustainable environmental policies (Fardhani et al., 2020). Measuring biomass and carbon stock helps assess the sustainability and productivity of the forest biodiversity and is essential for ensuring that forests remain healthy and productive, thereby supporting diverse flora and fauna (Sunarno et al., 2022).

CONCLUSION

This research found 39 plant species and 208 individuals in a 5-ha area. *V. glabrata* had the highest total AGB and carbon stock, at 10.18 ton/ha and 5.09 ton C/ha, respectively. This observation indicates that this species has the largest aboveground biomass, contributing significantly to carbon storage. A wide range of AGB and carbon stock values across the tree species studied reflects their diversity in biomass and carbon sequestration potential. The aboveground biomass and carbon stock were 44.86 tons/ha and 22.48 tons C/ha, respectively. Meanwhile, the total forest AGB and carbon stock in the 5-ha sampling area were 224.77 tons/ha and 112.39 tons C/ha, respectively. Tropical forests have enormous amounts of carbon stored in the tree biomass. Since tropical forests play a crucial role in reducing carbon concentration and tackling climate change, we suggest that protected forests must be maintained by controlling deforestation and LULC to protect the climate. This study included only stand and did not assess the deadwood or litter. Further studies are required to estimate the above and belowground biomasses and carbon stock in areas, including the Pesanggrahan Forest, to provide in-depth information and estimation. Lastly, this forest is a valuable area that stores carbon effectively, which could also contribute to climate change mitigation and adaptation.

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