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# Species Composition, Stand Structure, Biomass, and Carbon Storage in the Lower Montane Forest of Gunung Ciremai National Park

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**Abstract**. Lower montane forests exhibit high biodiversity and perform essential ecological functions. This study aimed to analyze species composition, stand structure, and estimate the potential biomass and carbon stock in the lower montane forest of Mount Ciremai National Park. Vegetation analysis was conducted using a combination of line-transect and nested plot methods. Above-ground biomass and carbon stocks at the pole and tree levels were estimated using allometric equations. The results showed the presence of 11 tree species, including their regeneration stages, and 14 understory species. *Ageratina riparia* was the dominant understory species, while *Calliandra calothyrsus* dominated the seedling, sapling, and pole layers. *Pinus merkusii* was the dominant species at the tree level. The distribution of plant density and regeneration followed a reverse J-shaped curve. Canopy stratification was dominated by trees in stratum C (4–20 m in height). The total estimated biomass and carbon stock were 452.11 tons/ha and 212.49 tons/ha, respectively. These findings highlight the ecological importance of lower montane forests and their role in biodiversity conservation and carbon sequestration.

**Keywords:** biomass estimation, carbon stock, lower montane forest, species composition, stand structure

## Introduction

Indonesia is a tropical country with diverse landscapes, including mountainous regions and extensive tropical rainforests. The country hosts a wide range of forest ecosystem types, which are classified based on climatic, edaphic, and altitudinal conditions (Soerianegara and Indrawan 1988). One of the important forest ecosystem types identified by Van Steenis (1972) is montane forest, typically found at elevations above 1000 m above sea level and further divided into several sub-zones according to altitude. Lower montane forests, a sub-zone of this classification, occur between 1,000–1500 m and are characterized by specific climatic conditions that significantly influence species distribution. Most plant species in this ecosystem are adapted to climate regimes (Aminudin and Ismail 2021). While elevation increase tends to reduce vegetation height and species abundance, lower montane forests are still recognized as biodiversity hotspots (Putri 2015).

Gunung Ciremai National Park or GCNP (Taman Nasional Gunung Ciremai, TNGC) is a conservation area that encompasses a rich montane forest ecosystem. Mount Ciremai, the highest mountain in West Java Province, reaches 3,078 m and spans an area of approximately 15500 hectares. It was designated as a national park under the Decree of the Minister of Forestry No. 422 of 2004. Administratively, the park is located within the Kuningan and Majalengka Regencies. TNGC includes various forest types, such as lowland forests, lower montane forests, and upper montane forests (BTNGC 2007). Each altitudinal zone exhibits distinct environmental conditions that shape the structure and composition of its vegetation (Dewa et al. 2023). The lower montane forest within GCNP serves as a critical habitat for several protected species, including the Javan leopard (*Panthera pardus*), Javan hawk-eagle

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(*Nisaetus bartelsi*), and surili (*Presbytis comata*), and functions as a primary watershed supporting water supply for several regions in West Java, including Majalengka, Kuningan, Cirebon, Indramayu, and Brebes (Noerdjito and Mawardi 2008).

Vegetation within lower montane forest ecosystems plays a crucial ecological role, serving as habitat for fauna and regulating key ecological processes such as the hydrological, carbon, and nutrient cycles. Through photosynthesis, forest vegetation absorbs atmospheric carbon dioxide ($CO_2$) and produces oxygen, thus contributing to climate regulation (Irfan et al. 2021). This function is particularly important in the context of Indonesia's commitment under the *Nationally Determined Contribution* (NDC), where the forestry and other land use (FOLU) sector is expected to contribute nearly 60% of the country's total greenhouse gas emission reduction target. Consequently, the assessment of forest carbon stocks is vital to support sustainable forest governance and climate change mitigation strategies. In line with these considerations, this study aims to analyze species composition and stand structure, as well as to estimate biomass potential and carbon stock in the lower montane forest of Gunung Ciremai National Park.

## Methods

### Time and Place

The research was conducted from December 2024 to January 2025 in the lower montane forest zone, located at elevations ranging from 1000 to 1500 meters above sea level, within SPTN Region I Kuningan, Gunung Ciremai National Park, West Java, Indonesia (Figure 1). The study area encompassed sections of the traditional zone, utilization zone, and rehabilitation zone surrounding the Palutungan hiking trail.

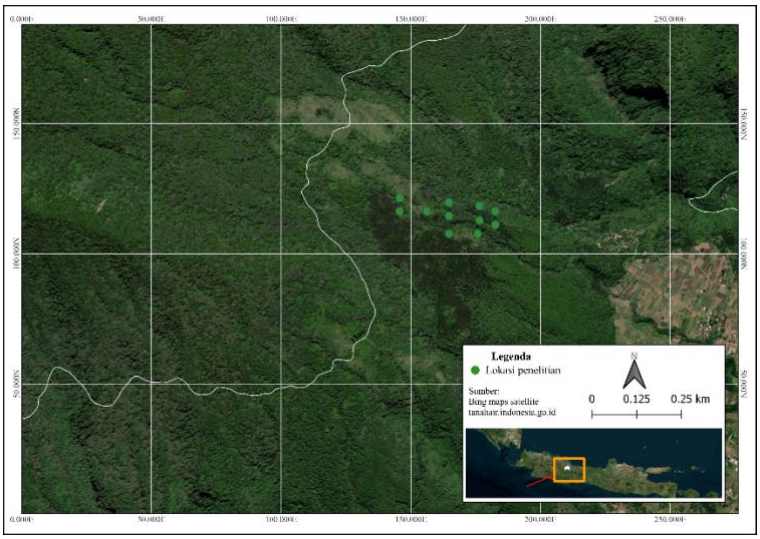



**Figure 1: Research site**

### Data Collection Procedures

The instruments used in this study included a measuring tape, diameter tape, haga hypsometer, Global Positioning System (GPS), Avenza Maps, lux meter, thermohygrometer, rope, compass, machete, camera, and field stationery. Vegetation data collected comprised species names and the number of individuals per species. Additional data were also recorded to construct canopy profile diagrams, including branch-free height, tree position within the plot (x and y coordinates), maximum and minimum crown lengths, and the azimuths corresponding to both crown extents.

Vegetation sampling was conducted using a vegetation analysis method based on a combination of transect and nested plot techniques. A total of ten observation plots, each measuring 20 m × 60 m, were established, resulting in a total sampling area of 1.2 ha (12000 m²). Within each transect, 20 m × 20 m plots were established for tree inventory, in which regeneration surveys were conducted using a nested sampling design. Transects were laid perpendicular to the contour lines, with the spacing between transects adjusted based on field accessibility due to steep and rugged terrain. Vegetation inventory followed the Indonesian National Standard (SNI 2019), with the following plot sizes:

2 × 2 m subplots for seedling layer (height < 10 cm);
5 × 5 m subplots for sapling layer (height ≤ 1.5 m and diameter < 10 cm);
10 × 10 m subplots for pole layer (height > 1.5 m and diameter < 20 cm);
20 × 20 m plots for tree layer (diameter ≥ 20 cm).

Microclimatic variables were measured to assess environmental conditions at the study site. These included air temperature, relative humidity, and light intensity, which were measured directly in the field. Rainfall and wind speed data were obtained from the nearest meteorological station. Environmental parameters were measured at 15 plots along the same transect lines as the vegetation analysis, at three different elevations (1100, 1250, and 1500 m a.s.l.), with five replications per elevation. Horizontal stand structure was analyzed by assessing the relationship between tree density and diameter class distribution. Vertical stand structure was visualized using canopy profile diagrams generated with SeXI-FS (Spatially Explicit Individual-based Forest Simulator) version 2.1.0.

**Data Analysis**

Data were analyzed descriptively based on the calculation of the Important Value Index (IVI), biodiversity indices (including diversity, evenness, richness, and dominance), canopy profile visualization, and the estimation of stand biomass and carbon stock.

*Important Value Index (IVI)*

IVI was calculated using the relative values of density, frequency, and dominance for each species, following the method of Misra (1980). IVI was used to determine species dominance across different vegetation strata (understory, seedling, sapling, pole, and tree levels).

$$\text{Density (D)} = \frac{\sum \text{individual species}}{\text{The total width of plots}}$$

$$\text{Relative density (RD)} = \frac{\text{Density of a species}}{\text{The total number of all species density}} \times 100\%$$

$$\text{Frequency (F)} = \frac{\text{The number of lot which is found a species}}{\text{The total number of plots}}$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{The total frequency of all species}} \times 100\%$$

$$\text{Dominance (C)} = \frac{\text{The total of basal area of a species}}{\text{The total width of plots}} \times 100\%$$

$$\text{Relative Dominance (RC)} = \frac{\text{Dominance of a species}}{\text{The total dominance of all species}} \times 100\%$$

IVI (%) = RD + RF (understory, seedling, and sapling)
IVI (%) = RD + RF + RC (pole and tree)

*Diversity Index (H')*

Species diversity (H') was calculated using the Shannon-Wiener index (Magurran 1988). Diversity levels were categorized as low (H' < 2), moderate (H' 2–3), and high (H' > 3).

$$H' = -\sum_{i=1}^{n} \left( \left( \frac{ni}{N} \right) \ln \left( \frac{ni}{N} \right) \right)$$

Where:
H' : Diversity index
Ni : Number of individuals of species i
N : Number of individuals of all species

*Evenness Index (E)*

Species evenness (E) was determined following Ludwig and Reynolds (1988), with classifications of low (E < 0.3), moderate (E = 0.3–0.6), and high (E > 0.6) based on Magurran (1988).

$$E = \frac{H'}{\ln(S)}$$

Where:
E : Evenness index
H" : Diversity index
S : Number of observed species

*Richness Index (R)*

Species richness (R) was estimated using Margalef's index (Magurran 1988), categorized as low (R < 3.5), moderate (R = 3.5–5), and high (R > 5).

$$R = \frac{S - 1}{\ln(N)}$$

Where:
R : Richness index
N : The total number of individuals
S : Number of observed species

*Dominance Index (C)*

Species dominance (C) was calculated based on Misra (1980), where values range from 0 to 1, with higher values indicating greater species dominance (Kartawinata 2016).

$$C = \sum_{i=1}^{n} \left(\frac{ni}{N}\right)^2$$

Where:
D : Dominance index
Ni : Number of individuals of species i
N : Number of individuals of all species

*Biomass and Carbon Stock Estimation*

Above-ground biomass was estimated using a non-destructive approach based on the allometric equation developed by Chave et al. (2005), which is suitable for moist tropical mixed forests. A mean wood density of 0.68 g/cm³ was applied, following the findings of Rahayu et al. (2006).

$$Y = \rho \times \exp(-1{,}1499) + 2{,}1481\ln(DBH) + 0{,}207(\ln(DBH))^2 + 0{,}0281(\ln(DBH))^3$$

Where:
Y : Biomass (kg)
ρ : wood density (g $cm^{-3}$)
DBH : Diameter at breast hight (cm)

The estimated biomass was then used to calculate carbon stock using a carbon content conversion factor of 47% of the total biomass (IPCC 2006). Carbon stock per hectare was derived by scaling up the per-tree carbon values based on the total plot area, as outlined in BSN (2019).

$$\text{Carbon} = \text{Biomass (kg)} \times 47\%$$

$$\text{Carbon (ton/ha)} = \frac{\text{carbon (kg)}}{1.000} \times \frac{10.000}{\text{Lplot } (m^2)}$$

## Results and Discussion

### Composition of Vegetation

This study recorded 11 tree species along with their regeneration stages and 14 understory plant species, belonging to 8 families and 11 genera. The number of tree species at each regeneration level consisted of 9 species at the tree stage, 8 at the pole stage, 3 at the sapling stage, and 4 at the seedling stage. Both species richness and individual abundance were lower compared to previous studies conducted in similar ecosystem types and locations (Suryana et al. 2018; Purwaningsih and Yusuf 2008). Purwaningsih and Yusuf (2008) reported 57 tree and regeneration species with a total of 1,069 individuals, while this study only identified 11 species with a total of 703 individuals. This discrepancy may be attributed to the dominance of invasive species such as *Calliandra calothyrsus*, which inhibits the natural regeneration of native species. The prevalence of alien invasive species can significantly reduce the ability of native vegetation to access growing space, soil nutrients, and sunlight (Nursanti and Adriadi 2018).

Understory vegetation exhibited the highest species richness and individual abundance, most likely due to the relatively open canopy structure, allowing higher light penetration to the forest floor. According to Rahmawati et al. (2022), excessive sunlight supports the proliferation of light-intolerant species such as grasses and shrubs. However, the presence of invasive species like *C. calothyrsus*, found across nearly all growth stages, is suspected to be a limiting factor for the survival of local plant species. Invasive species possess high reproductive capacity and dispersal potential, enabling them to outcompete endemic species for light, water, and nutrients, while also exhibiting strong adaptability to the local environmental conditions (Tjitrosoedirjo et al. 2016).

### Dominance

Dominant species were identified based on their Importance Value Index (IVI). Understory plant species with an IVI >10% included *Ageratina riparia*, *Clidemia hirta*, *Rubus moluccanus*, ferns, *Lophatherum gracile*, and *Oplismenus hirtellus*. These species were evenly distributed across all observation plots and showed high adaptability to open canopy conditions. *A. riparia* recorded the highest IVI value, consistent with the findings of Sari et al. (2022), which stated that this species is highly adaptive to open and secondary habitats. *A. riparia* is commonly found in secondary montane forest areas with open to semi-open conditions and possesses a high capacity for reproduction and environmental adaptation (Parwati et al. 2019). Ferns were abundant in this study site, aligning with their typical distribution in tropical and montane forests characterized by high humidity and rainfall throughout the year (Yolla et al. 2022). The relatively open canopy allowed greater light penetration to the forest floor, which favored the growth and development of other understory species such as *L. gracile*, *C. hirta*, *R. moluccanus*, and *O. hirtellus*.

**Table 1: Importance Value Index (IVI) of understory.**

| Scientific name | D (ind/ha) | F | IVI (%) |
|---|---|---|---|
| *Ageratina riparia* | 96500.00 | 0.83 | 98.12 |
| *Clidemia hirta* | 5250.00 | 0.33 | 15.62 |
| *Rubus moluccanus* | 9500.00 | 0.23 | 15.06 |
| *Lophatherum gracile* | 10416.70 | 0.23 | 15.71 |
| *Oplismenus hirtellus* | 8666.67 | 0.20 | 13.28 |
| *Leersia virginica* | 2000.00 | 0.07 | 3.79 |
| *Cyperus rotundus* | 1500.00 | 0.10 | 4.63 |
| *Pteridophyta* sp. | 4083.33 | 0.47 | 19.56 |

| Scientific name | D (ind/ha) | F | IVI (%) |
|---|---|---|---|
| *Petiveria alliaceae* | 83.33 | 0.03 | 1.25 |
| *Euphorbia heterophylla* | 416.67 | 0.03 | 1.49 |
| *Elatostema cyrtandrifolium* | 2333.33 | 0.13 | 6.41 |
| *Zingiber roseum* | 83.33 | 0.07 | 2.44 |
| *Molineria capitulata* | 166.67 | 0.03 | 1.31 |
| *Alpinia purpurata* | 166.67 | 0.03 | 1.31 |

At the seedling, sapling, and pole levels, *C. calothyrsus* showed the highest IVI values, with 185.13%, 157.89%, and 87.30%, respectively, indicating strong dominance at these growth stages. Such dominance may suppress native species due to the competitive advantages of *C. calothyrsus* in adaptation, dispersal, and nutrient uptake (Tjitrosoedirjo et al. 2016). *Calliandra* is one of the invasive species that extensively dominates and spreads across the study area. This finding corroborates the study by Nasihin et al. (2024), which reported that *C. calothyrsus* was the most dominant invasive species during the seedling and sapling stages in the Gunung Ciremai National Park (TNGC). In the observation plots, *Calliandra* was primarily found in the sapling stage, forming dense thickets (Figure 6). The widespread distribution of *Calliandra* (Calliandra spp.) may be attributed to the conversion of cultivated lands within the park into fully open areas, contradicting the original concept of Joint Forest Management with communities (Aditya et al. 2023). In TNGC, *C. calothyrsus* occupies an area of 302.62 ha, distributed across elevations ranging from 600 to 1,500 m above sea level, encompassing the utilization, rehabilitation, and wilderness zones (Supartono et al. 2023).

At the tree level, the highest IVI was recorded for *Pinus merkusii*, which dominates elevations between 1,000–1,300 m a.s.l. The Ciremai Mountain area was designated as a production forest in 1978, managed by Perum Perhutani with pine plantation establishment (Aini and Nawiyanto 2021), and was later converted into a national park in 2004. Pine species are known to release allelopathic secondary metabolites, which can inhibit the growth of other plant species in order to secure their own survival (Anwar et al. 2019). As a result, only certain species adapted to such conditions can grow beneath pine stands. Several plant species found under pine canopies in the study area included African wood (*Maesopsis eminii*), *C. calothyrsus*, *Toona sureni*, jackfruit (*Artocarpus heterophyllus*), and bamboo (*Gigantochloa* sp.). These findings are in line with Supartono et al. (2023), who reported that adapted species under pine stands in Mount Ciremai included *M. eminii*, avocado (*Persea americana*), mahogany (*Swietenia macrophylla*), *T. sureni*, *Gmelina arborea*, *A. heterophyllus*, and *Michelia velutina*. *M. eminii* and *P. americana* were observed from the seedling to tree stages; *S. macrophylla*, *T. sureni*, and *G. arborea* at the tree stage; and *A. heterophyllus* at the sapling and tree stages.

**Table 2: Importance Value Index (IVI) at seedling, sapling, pole, and tree**

| Growth stages | Scientific name | RD (%) | RF (%) | FD (%) | IVI (%) |
|---|---|---|---|---|---|
| Seedling | *Calliandra calothyrsus* | 98.17 | 86.96 | - | 185.13 |
| | *Castanopsis tungurrut* | 0.61 | 4.35 | - | 4.96 |
| | *Swietenia macrophylla* | 0.61 | 4.35 | - | 4.96 |
| | *Ficus fistulosa* | 0.61 | 4.35 | - | 4.96 |
| Sapling | *Calliandra calothyrsus* | 97.89 | 60.00 | - | 157.89 |
| | *Ficus fistulosa* | 1.05 | 20.00 | - | 21.05 |
| | *Maesopsis eminii* | 1.05 | 20.00 | - | 21.05 |
| Pole | *Calliandra calothyrsus* | 56.67 | 20.93 | 9.70 | 87.30 |
| | *Pinus merkusii* | 11.67 | 44.19 | 12.69 | 68.54 |

| Growth stages | Scientific name | RD (%) | RF (%) | FD (%) | IVI (%) |
|---|---|---|---|---|---|
| | *Maesopsis eminii* | 6.67 | 13.95 | 12.42 | 33.04 |
| | *Ficus fistulosa* | 11.67 | 9.30 | 10.49 | 31.46 |
| | *Quercus sundaica* | 1.67 | 4.65 | 19.43 | 25.75 |
| | *Persea* sp. | 1.67 | 2.33 | 16.11 | 20.10 |
| | *Castanopsis tungurrut* | 3.33 | 2.33 | 11.44 | 17.10 |
| | *Schima wallichii* | 6.67 | 2.33 | 7.72 | 16.71 |
| Tree | *Pinus merkusii* | 86.46 | 55.88 | 13.07 | 155.41 |
| | *Quercus sundaica* | 3.39 | 14.71 | 21.81 | 39.90 |
| | *Maesopsis eminii* | 5.21 | 8.82 | 10.96 | 25.00 |
| | *Castanopsis tungurrut* | 1.56 | 2.94 | 17.19 | 21.70 |
| | *Ficus fistulosa* | 1.04 | 5.88 | 8.27 | 15.19 |
| | *Artocarpus heterophyllus* | 0.26 | 2.94 | 8.48 | 11.68 |
| | *Calliandra calothyrsus* | 1.30 | 2.94 | 7.27 | 11.51 |
| | *Persea* sp. | 0.52 | 2.94 | 7.54 | 11.00 |
| | *Toona sureni* | 0.26 | 2.94 | 5.41 | 8.62 |

**Diversity, Evenness, Richness, and Dominance Indices**

The species diversity index (H′) across all tree growth stages was categorized as low (<2), with the lowest value observed at the seedling stage (H′ = 0.11). The magnitude of species diversity is influenced by the number of species and individuals recorded in a community (Destaranti et al. 2017). The species richness index (R) was also considered low (<3.5), indicating a limited number of species present in the community. The species evenness index (E) was low at the seedling, sapling, and tree stages, but high at the pole stage, suggesting a more balanced distribution of species at that level. The dominance index for understory vegetation and the pole stage was categorized as low, indicating no single species overwhelmingly dominated those strata. However, high dominance index values were observed at the seedling, sapling, and tree stages, as indicated by C values approaching 1 (Table 6). This pattern reflects the strong dominance of *Calliandra calothyrsus* at the seedling and sapling stages, and *Pinus merkusii* at the tree stage, both of which contributed to the elevated dominance index values in these strata.

**Table 3: Diversity, Evenness, Richness, and Dominance Index**

| Index | Understory | Seedling | Sapling | Pole | Tree |
|---|---|---|---|---|---|
| Diversity (H') | 1.25 | 0.11 | 0.12 | 1.43 | 0.62 |
| Richness (R) | 1.75 | 0.59 | 0.44 | 1.71 | 1.34 |
| Evenness (E) | 0.47 | 0.08 | 0.11 | 0.69 | 0.28 |
| Dominance (C) | 0.48 | 0.96 | 0.96 | 0.36 | 0.75 |

**Stand Structure**

The diagram illustrating the density of each tree growth stage formed an inverted "J" curve, as the number of individuals in the regeneration stages was higher than in the pole and tree stages. However, this condition does not guarantee the sustainability of the forest stand in the future, as the presence of invasive species such as *Calliandra calothyrsus* poses a threat to native species. The horizontal stand structure, represented by a graph of individual tree density across diameter classes, indicated that the highest tree density occurred in the 30–39 cm diameter class. As the diameter class increased, the tree density decreased. This pattern is consistent with the findings of Oladoye et al. (2014), who stated that larger tree diameters tend to be associated with fewer individual trees. This condition may result from competition, both

within and among species, for access to light, water, nutrients, carbon dioxide, and growing space (Soerianegara and Indrawan 2002).

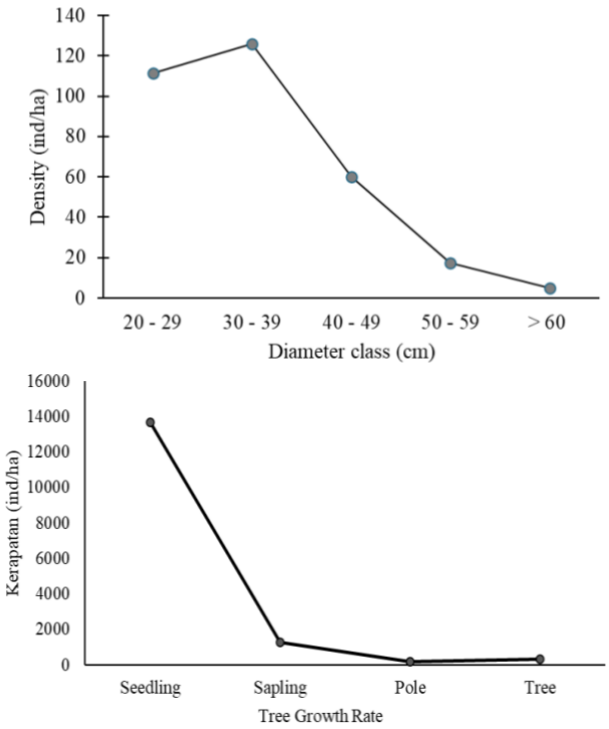



**Figure 2: Horizontal stand structure**

The vertical stand structure showed the highest density in stratum C (tree height class of 4–20 m). The species most frequently observed in this stratum were *C. calothyrsus* and *Pinus merkusii*. Tree density declined with increasing height class. Trees in stratum A were rarely encountered in the study area, suggesting that only individuals with high adaptability to environmental conditions were able to reach this stratum. To attain stratum A, trees must survive extended periods of competition for nutrients, water, soil, and sunlight. This observation aligns with the canopy profile visualization in Figure 10, which shows a higher frequency of trees in strata C and B, while only a few individuals had reached stratum A. Stratification occurs because of interactions among individual trees and between individuals and their environment, as well as plant responses to light intensity through varying degrees of shade tolerance (Indriyanto 2012).

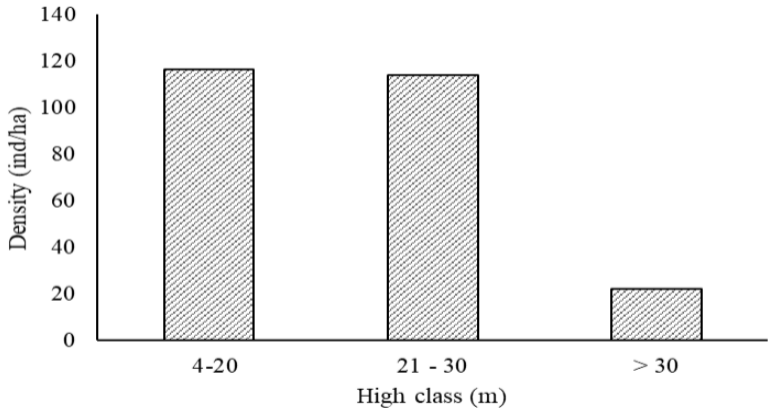



**Figure 3: Vertical stands structure**

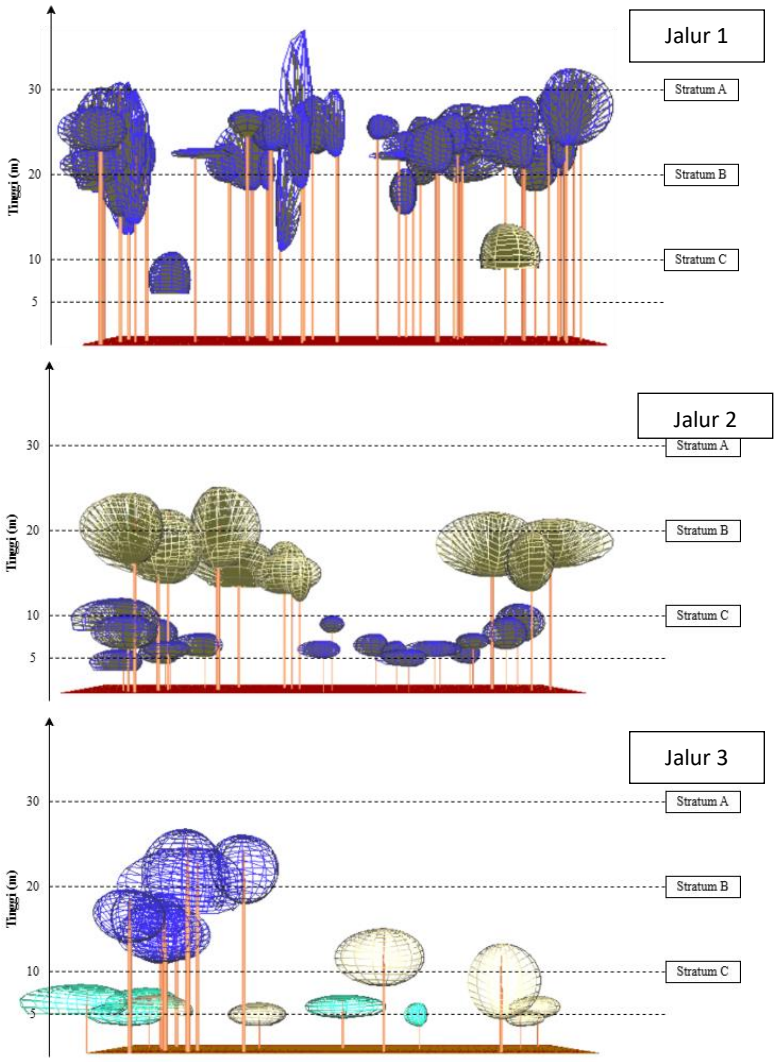



**Figure 4: Canopy profile visualization**

## Biomass and Carbon Stock

Biomass and carbon estimations were conducted at the pole and tree levels using the allometric equation developed by Chave et al. (2005). The total estimated biomass was 452.11 tons/ha, with a corresponding carbon stock of 212.49 tons/ha. According to IPCC (2006) classification, these values are considered high and comparable to those of other tropical conservation areas, although they remain lower than those found in Dipterocarpaceae-dominated stands (Purnawan et al. 2020). The dominance of large-diameter *Pinus merkusii* contributed significantly to the biomass and carbon stock values in the stand. Biomass is closely related to a tree's diameter at breast height (DBH); larger tree diameters generally result in higher biomass accumulation (Nurfansyah et al. 2019). The study site's location within a conservation area with relatively low anthropogenic disturbance has likely allowed for more optimal tree growth and biomass accumulation.

## Environmental Characteristic

The study area has a moderate climate, with annual rainfall ranging from 2000 to 4000 mm and an average temperature of 18–24°C. Temperature decreases and humidity increases with elevation. Sunlight intensity was relatively high due to open canopy conditions, which strongly supports the growth of light-demanding and invasive species such as *Calliandra calothyrsus*. *C. calothyrsus* thrives under full sunlight conditions, is intolerant to deep shade, and moderately tolerant of partial shade. The land cover types in the study area included mixed

pine forest and shrubland. Both land cover types exhibit more open canopy structures compared to primary natural forests, providing suitable habitat for *C. calothyrsus*, which grows well under low to moderate shade conditions.

**Table 4: Average values of environmental parameters**

| Elevation | Parameters | | |
|---|---|---|---|
| | Temperature (ºC) | Relative humidity (%) | Sunlight intensity (luxmeter) |
| 1100 | 26.61 | 67.0 | 1520.3 |
| 1250 | 24.59 | 67.3 | 1164.5 |
| 1500 | 21.26 | 76.2 | 1663.6 |

**Implications for Conservation Management**

The findings of this study highlight critical implications for forest conservation management in the Gunung Ciremai National Park. The dominance of invasive alien species such as *Calliandra calothyrsus* across multiple vegetation strata poses a significant threat to native biodiversity and forest regeneration dynamics. Although the current stand structure indicates a potential for regeneration, the suppression of native species by invasive plants could compromise long-term ecosystem resilience. Effective management should therefore prioritize the control of invasive species, particularly in the utilization and rehabilitation zones, while simultaneously promoting the regeneration of native species through enrichment planting, habitat restoration, and community-based conservation strategies. Furthermore, the relatively high biomass and carbon stock values underscore the importance of preserving these forested areas not only for biodiversity conservation but also for climate change mitigation. A balanced approach that integrates ecological integrity, species diversity, and carbon storage is essential to ensure the sustainability of lower montane forest ecosystems within protected areas like TNGC.

## Conclusion

The composition of the lower montane forest at the study site consists of 11 tree species (including their regeneration stages) and 14 understory plant species. The dominant species across vegetation strata are *Ageratina riparia* (dominant in the understory layer), *Calliandra calothyrsus* (dominant at the seedling, sapling, and pole stages), and *Pinus merkusii* (dominant in the tree layer). Native species such as pasang (*Quercus sundaica*) and saninten (*Castanopsis tungurrut*) were also recorded. The horizontal stand structure tends to follow a reversed J-shaped curve, with the highest tree density found in the 30–39 cm diameter class. However, this condition requires attention since *Calliandra* species were found in almost all regeneration stages, indicating their aggressive establishment. Canopy stratification is dominated by *Calliandra* within stratum C (tree height 4–20 m).

The estimated total biomass and carbon stock within the study plots were 452.11 tons/ha and 212.49 tons/ha, respectively. Air temperature values generally decreased with increasing elevation, while relative humidity showed an upward trend, and light intensity varied across elevations. These environmental factors are suitable for supporting the growth and development of tree stands in lower montane forests.

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