Analysis of vegetation and ecosystem components of Mount Ciremai National Park (MCNP) with key indicators of species, density, frequency, dominance, and calculation of Important Value Index (IVI)

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Abstract
This study aims to analyze the vegetation structure and ecosystem components of Mount Ciremai National Park (MCNP) using the parameters of density, frequency, dominance, and the Important Value Index (IVI). Data were collected across 3 observation stations using the quadrat sampling method with three-tiered plot sizes (1×1 m, 5×5 m, and 10×10 m). A total of 53 vegetation species comprising 847 individuals were identified, predominantly dominated by understory plants such as *Oplismenus hirtellus* and *Homalomena philipinensis*. The IVI analysis revealed distinct key species across different strata: H. philipinensis in the seedling stratum, *Dysoxylum spectabile* and *D. cauliflorum* in the sapling stratum, and *Gurea bullata* in the tree stratum, which exhibited high dominance despite a low individual count. Furthermore, environmental factors, including acidic soil pH (5.6–6.7) and stable temperatures (21–22°C), significantly influenced these distribution patterns. Notably, the stand structure was highly unbalanced, with a massive dominance of seedlings compared to saplings and trees, indicating a severe regeneration bottleneck. These findings imply that while the understory ecosystem remains stable, the forest faces a critical threat to its natural tree succession. Consequently, long term monitoring and targeted conservation strategies such as active seedling protection are urgently needed to ensure the sustainability of the forest structure in MCNP.

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1. Introduction

Mount Ciremai National Park (MCNP) is one of the conservation areas with a high level of biodiversity in West Java. This area has a distinctive ecological gradient from sub-montane to upper montane zones that form a variety of vegetation with complex community structures(Dian Hayati et al., 2021). Tropical mountain forests such as MCNP play an important role as a buffer for hydrological systems, carbon storage, and habitat for various endemic flora and fauna (Malhi & Marthews, 2013). Recent studies have also shown that mountain forest ecosystems in Indonesia are under increasing pressure due to climate change and human activities, making vegetation analysis crucial for understanding current ecological conditions (Sagala, 2019). Vegetation analysis is a basic method in forest ecology used to determine community structure, species dominance, and plant regeneration dynamics (Kuchler et al., 1976). Parameters such as density, frequency, dominance, and Importance Value Index (IVI) are key indicators in assessing the role of a species in the community (Curtis & Mcintosh, 1922). Recent studies in tropical forests show that IVI serves as an integrative indicator to determine key species that influence ecosystem stability and function. Species with high IVI values are often categorized as ecological driver species, that determine ecosystem stability and function (Walker, 1992).

Aiba & Kitayama (2020) reported that evaluating how age and soil (edaphic) properties in the tropical montane forests of Borneo affect community structure and species dominance, showed that species composition and tree growth are strongly influenced by soil conditions, light, and age-related changes in stand structure. This study showed that environmental factors such as air temperature, soil humidity, and elevation significantly affect tree species distribution anad diversity and regeneration in different climate zones; although not Indonesian montane forests, the results demonstrate that temperature & soil humidity can control tree

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distribution and regeneration (Song et al., 2021) In the context of Mount Ciremai National Park (MCNP), environmental factors such as low temperature, acidic soil, and limited light intensity form a distinctive vegetation community dominated by understory plants such as *Homalomena*, *Tectaria*, and various other pakuan species.

On the other hand, ecological pressure on Mount Ciremai National Park (MCNP) has increased in recent years due to increased nature tourism visits and habitat fragmentation in the buffer zone (Pamungkas & Jones, 2021). Human footprint change analysis also confirmed that human activities in and around the park are stressing the condition of conservation ecosystems (Dwiyahreni et al., 2021). In addition, a review of forest fragmentation in Indonesia confirmed that land use change, especially in buffer zones, threatens habitat continuity and reduces natural regeneration (Gunawan et al., 2024). Therefore, research on vegetation structure and environmental factors is needed as a scientific basis for conservation management.

Previous studies have indicated that ecological pressures on montane forest areas stem not only from the intensity of human activities, but also from irregular stand structures that have direct implications for the natural regeneration process. The imbalance in vegetation structure has the potential to reduce the forest's ability to maintain its community dynamics, especially when these conditions persist over the long term. In line with this, a recent study on forest fragmentation in Indonesia showed that the fragmentation of forest areas leads to a decrease in the level of landscape connectivity, which in turn increases the vulnerability of ecosystems to various forms of external disturbances, both in the form of anthropogenic pressures and changes in the bio geophysics environment (Gunawan et al., 2024).

Various studies in montane forest ecosystems show that the instability of regeneration patterns is an important indicator of the decline in forest ecological functions. This condition is usually seen when understory vegetation dominates the forest floor, increasing competition for light, nutrients, and growing space, which in turn inhibits the development of sapling strata to young trees towards mature stands (Rochimi et al., 2021). Such imbalances have the potential to cause structural degradation, especially when recruitment rates are unable to cover tree mortality rates. Similar findings were reported in several mountainous areas in Java, where long-lasting regeneration disruptions were shown to reduce the sustainability of plant communities and weaken the ecological resilience of forest ecosystems (Hilwan & Laijanan, 2024).

In the context of conservation management, studies confirm that structural indicators such as basal area, tree density, and stand composition distribution are necessary to assess forest health and detect early signs of ecological decline. These parameters have proven effective in describing vegetation dynamics and community stability in tropical forests, both in short and long-term observations (Pessoa & de Araujo, 2014). Therefore, conducting comprehensive vegetation analysis in conservation areas such as Mount Ciremai National Park is crucial as a scientific basis for understanding changes in ecosystem structure, identifying ongoing external disturbances, and producing accurate management recommendations for conservation sustainability (Hidayat et al., 2022). In recent years, the community structure of MCNP has faced significant anthropogenic pressures, including the rapid expansion of ecotourism and forest edge fragmentation. Despite these growing external disturbances, there is currently limited empirical data and a lack of continuous monitoring regarding vegetation regeneration in MCNP. Most ecological studies in the region have focused merely on species inventory, overlooking the complex dynamics of how human-induced environmental changes directly affect the multi-strata regeneration process.

Although numerous studies have evaluated vegetation structure in tropical montane forests, most have primarily focused on general fragmentation, broad macro-environmental factors, or specific lowland ecosystems, leaving a critical knowledge gap regarding specific multi-strata regeneration bottlenecks in high-elevation volcanic landscapes. For instance, (Aiba & Kitayama, 2020) focused heavily on edaphic and age-related factors in Borneo's forests, while (Song et al., 2021) analyzed climatic impacts on tree distribution outside Indonesian montane ecosystems. Within Indonesia, recent studies emphasized macro-level forest fragmentation and human footprint indices rather than specific micro-level stand structure imbalances (Dwiyahreni et al., 2021;Gunawan et al., 2024). Furthermore, while (Hilwan & Laijanan, 2024) identified regeneration disruptions in other Javanese mountains, comprehensive studies specifically integrating multi-strata IVI analysis (from seedlings to mature trees) with localized micro-environmental constraints in Mount Ciremai National Park (MCNP) remain largely unexplored. Therefore, the originality (state of the art) of this research lies in its integrative approach to identifying specific 'regeneration bottleneck' phenomena in MCNP by combining tiered plot vegetation analysis with specific localized edaphic (e.g., acidic soil pH) and microclimatic data. This study fills the gap by providing empirical evidence on how understory dominance and micro-environmental pressures uniquely shape the unbalanced stand structure in a heavily visited volcanic conservation area.

This study aims to analyze the vegetation composition and ecosystem structure of Mount Ciremai National Park (MCNP) using indicators of species, density, dominance, frequency, and the Important Value Index (IVI) (Mandarasy & Santhyami, 2025). By utilizing tiered vegetation data ranging from seedlings to mature trees, this study provides a comprehensive picture of plant community conditions in high-elevation zones amidst environmental changes (Tarigan et al., 2016). Additionally, the evaluation of data from the past five years allows for a deeper understanding of vegetation regeneration dynamics and stability in response to shifting ecological factors (Sulistyawati et al., 2018). The results are expected to serve as a foundational basis for habitat management, key species conservation planning, and long-term monitoring in mountainous areas (Handayani & Ahmed, 2022). Furthermore, from a sustainability perspective, the implications of this research extend beyond ecological management. The specific data regarding vegetation structure and regeneration bottlenecks provide a crucial scientific basis for conservation education. By utilizing MCNP as a living laboratory, these findings can be implemented as a contextual resource for environmental learning based on local ecosystems. Ultimately, this approach will equip future educators, students, and the local community with the necessary ecological literacy to support long term forest conservation."

2. Method

2.1. Research time and place

This research was conducted on Saturday, November 8th, 2025. The data collection location was centered in the Situ Sanghyang conservation area or often known as Sangiang Lake, which is administratively located in Banjaran District, Majalengka Regency, West Java Province. This area is an integral part of the Mount Ciremai National Park (MCNP) management zone. Geographically, the research site at Sanghyang Lake is characterized by a mountainous tropical rainforest ecosystem combined with an aquatic ecosystem (natural lake). The selection of this location is based on representative vegetation diversity to represent the structure of plant communities in the foothill region of Mount Ciremai. The administrative location of the study area is shown in Figure 1, while the specific geographical distribution and coordinates of the three-observation station are detailed in Figure 2.

Figure 1. Adminsitrative map of Majalengka Regency and the Location Mount Ciremai National Park (MCNP), West Java, Indonesia

Figure 2. Map of the study area in Mount Ciremai National Park (MCNP), West Java, Indonesia. The red dots indicate the locations of the three observation stations (Map data: ©2026 Google)

2.2. Tools and materials

The tools and materials used in this research are meters, raffia ropes, wooden stakes, compasses, stationery, digital cameras, plant scissors, plant identification applications (Pl@ntNet and iNaturalist), soil testers, lux meters, environmental thermometers, counting tools, and location maps.

2.3. Vegetation Data Collection Technique

Vegetation data collection was carried out using the quadrat sampling method. Initially, the minimum plot area was determined by establishing a 1 × 1 m sampling square and gradually expanding it to 5 × 5 m and 10 × 10 m until no new species were recorded. Based on this preliminary assessment, a tiered (nested) plot design was established using a purposive sampling method. The locations were specifically chosen to represent the most characteristic ecological gradient and microclimatic conditions of the montane ecosystem in MCNP. A total of three nested plots were established, resulting in a total sampling area of 300 m^2 (0.03 ha) for the tree stratum. The tiered plot sizes consisted of 1 × 1 m for seedlings and understory vegetation, 5 × 5 m for saplings, and 10 × 10 m for poles and trees. Within each plot, comprehensive ecological data were recorded, including the types of species found, the number of individuals per species, and the vegetation habitus. Additionally, local climatic and edaphic factors were measured at each observation station. For the pole and tree strata, the stem diameter was measured specifically at breast height (DBH, approximately 1.3 meters above the ground) using a diameter tape. The DBH data were subsequently used to calculate the basal area (BA) of each tree using the Equation (1), which is a prerequisite parameter for determining the relative dominance and the Important Value Index (IVI) of the plant community.

$$BA = \pi \; x \; \frac{D}{2^2} \tag{1}$$

2.4. Vegetation Identification Technique

Vegetation identification is done through several stages:

a. Field identification

Observe major morphological features such as leaf shape and size, branching type, stem texture and color, habitus, and generative organs if available (flowers or fruits). All individuals were photographed from various angles for verification purposes.

b. Use of real-time identification application (Pl@ntNet)

Pl@ntNet was used in the field as an initial identification tool. It helps match photos of plant organs (leaves, flowers, fruits, or bark texture) with botanical databases to generate scientific names and their accuracy. The identification results were recorded in a worksheet to be used for further analysis.

c. Post-field verification (iNaturalist)

Specimens that have not been identified with certainty are uploaded to iNaturalist for vetting by a community of botanists (expert curation). Only species that reached Research Grade status or were expert verified were included in the analysis.

2.5. Data Analysis

Analysis of the structure and composition of the species at the seedling, sapling, pole and tree levels was obtained by calculating the importance value index (IVI), relative density, relative frequency, and relative dominance. The formula follows ((Kuchler et al., 1976); (Solanki et al., 2017)) as follows:

a. Relative Density (RD): RD = (Density of a species / Total density of all species) × 100%

b. Relative Frequency (RF): RF = (Frequency of a species / Total frequency of all species) × 100%

c. Relative Dominance (RD): RD = (Dominance of a species / Total dominance of all species) × 100%

d. Important Value Index (IVI): IVI = RD + RF + RD

Important value index (IVI) of tree, pole, and sapling levels with the formula: IVI = RD (%) + RF (%) + RD (%), and for seedling level with the formula: IVI = RD (%) + RF.

Utilization of Identification Applications in Field Data Collection In the data collection stage at the research site (MCNP), two supporting applications were used including:

Pl@ntNet was used as the main instrument for real-time taxonomic identification in measuring plots (quadrants) or transect lines. Given the forest conditions that have diverse vegetation strata ranging from seedlings to trees, the specific features of Pl@ntNet being able to identify plants based on separate organs such as leaves, flowers, fruits, or bark texture is very crucial. Researchers can take pictures of plant organs found in a plot, and the app will match them with botanical databases to generate a scientific name and its accuracy. The resulting species name is then recorded directly into a tally sheet as the basis for grouping data for the calculation of Density (D) and Frequency (F). The use of offline features in this application is also prioritized to anticipate limited cellular signal in mountainous areas. As a verification step to ensure the validity of scientific data

iNaturalist is used in the post-field stage or during data validation. Photographs of questionable or unidentified plant specimens in the field are uploaded to this platform for taxonomic confirmation from a community of botanists and other researchers (expert curation). This process aims to ensure that each species counted in the Important Value Index (IVI) analysis has an appropriate and globally standardized nomenclature (Research Grade).

3. Results and Discussion

Location and Geographical Conditions Based on the results of spatial verification using Google Earth satellite imagery, the Sanghyang Lake area, Banjaran District, Majalengka Regency, is located at an altitude range of 986 to 1.000 meters above sea level (masl). This geographical position places the study area in the transition zone between lowland forest and sub-montane forest. The topography in this elevation range tends to be undulating with varying slopes, surrounding the Sanghyang Lake as the center of the catchment area. Elevation Correlation with Vegetation Distribution Elevation is the main environmental factor controlling vegetation zones in Mount Ciremai National Park through the Lapse Rate mechanism (decrease in temperature as altitude increases). Climate Zones and Plant Physiology At an altitude of 986-1.000 masl, the average air temperature is recorded to range from 210-220C. These cool and humid microclimate conditions are ideal for the growth of complex tropical rainforest vegetation. This elevation allows high rates of photosynthesis due to less extreme temperatures, thus supporting high vegetation density. Vegetation Structure and Stratification In terms of vegetation distribution, areas at this elevation are generally dominated by Strata A and B large-diameter trees that form a dense canopy. However, as the area approaches the mountainous zone, the species composition begins to show shifts. Ground vegetation (shrubs and herbs) tends to be abundant in areas where there are gaps in the canopy, while epiphytes (such as ferns and orchids) begin to be found more frequently than at lower altitudes due to higher air humidity.

Species Diversity Elevations of 1.000 masl are often ecotone zones with high biodiversity. At this location, researchers could potentially find a mix of cultivated plant species (due to proximity to buffer zones/settlements) and native mountain forest species. This explains why analyzing the vegetation structure in this location is important to map whether the area is still dominated by native species or non-native/invasive species.

Based on the results of vegetation analysis in the Mount Ciremai National Park (MCNP) area, it is known that the Edaphic Climatic Vegetation Analysis measured abiotic environmental factors including climatic factors (temperature and wind) and edaphic factors (soil pH) in three different observation plots in the Mount Ciremai National Park (MCNP) area. Measurement of physical and chemical environmental factors is crucial because ecology aims to understand the reciprocal relationship between organisms and the abiotic environment around them.

Climatic parameters showed typical microclimate conditions in mountainous areas. The ambient temperature was recorded to be relatively stable and cool across the observation plots, with a range of 21°C Plot 1 and Plot 2, and a slight increase to 22°C Plot 3. These measurements were taken using an environmental thermometer in accordance with the procedures for using the device. These cool temperature conditions support the growth of tropical montane forest vegetation. Different from temperature, wind speed showed a wide range of fluctuations in each plot. In Plot 1, winds ranged from 0.9 - 24.5 m/s, while Plots 2 and 3 showed similar patterns with maximum speeds reaching 1.2 - 24.4 m/s. These high variations in wind speed may affect plant transpiration rates and seed dispersal on the forest floor.

The edaphic factor measured using a soil tester was soil acidity (pH), which exhibited notable variation across the study locations. Soil pH values in Plot 1 and Plot 2 were recorded at 6.0 and 6.7, respectively, indicating neutral to slightly acidic conditions that are generally optimal for nutrient uptake by most plant species. In contrast, Plot 3 showed more acidic conditions with a pH value of 5.6. This lower pH may act as a limiting factor, influencing the distinct vegetation composition observed in Plot 3 compared to the other plots. A comprehensive summary of these edaphic parameters, alongside climatic and vegetation data, is presented in Table 1.

Table 1. Analysis of Vegetation, Climate, and Soil

Description	Plot 1	Plot 2	Plot 3
Wind	0.9 - 24.5 m/s	1.2 - 24.0 m/s	1.4 - 24.4 m/s
Soil pH	6.0	6.7	5.6
Temperature	21°C	21°C	22°C

Table 1 describes the climatic and soil conditions of the three research plots, including wind speed, soil pH and temperature. Temperatures across the plots were in a similar range of 21-22°C, which is typical of lower montane forest areas and supports the growth of understory vegetation such as herbs and ferns. Wind speed showed greater variation, ranging from 0.9 to 24.5 m/s in plot 1 and increasing slightly in the larger plots; high wind speeds can affect transpiration rates, seed dispersal and canopy openness. However, the factor that most determined the differences in vegetation across the three plots was soil pH. Plot 1 had a pH of 6.0 and plot 2 had a pH of 6.7, both indicating neutral to slightly acidic soil conditions that favor vegetation diversity, including seedling and sapling growth. In contrast, plot 3 had a more acidic pH of 5.6, so it was more overgrown with understory vegetation that is able to withstand high acidity soil conditions. This variation in pH is what causes the difference in plant composition in each plot, especially the high dominance of understory plants in the more acidic soil.

The soil pH range of 5.6-6.7 at the study site shows that there are variations in edaphic conditions that affect the type of vegetation growing in each plot. At pH 6.0, which falls into the slightly acidic category (Plot 1), the most dominating vegetation was *Homalomena philipinensis*, as this species is well adapted to moist and slightly acidic soils and occupies the seedling layer. In addition, *Tectaria gemmifera*, a fern species that is resistant to shade and slightly acidic soil conditions, was also found in small plots with high humidity levels. Several other seedling species, such as *Peperomia hirta* and *Piper aduncum*, also grew well in the pH range of 5.5-6.5, which favored the development of herbaceous plants on the forest floor. At pH 6.7 (Plot 2), the near-neutral soil conditions provided optimal amounts of nutrients, which increased vegetation diversity. *Homalomena philipinensis* remained one of the dominant species as it is tolerant of a wide pH range. In addition, *Ruellia prostrata* emerged as a ground cover that thrived at near-neutral pH. Other herbaceous species such as *Hydrocotyle javanica* are also abundant in moist areas with pH 6.5-7, especially in sites that receive low light. These neutral soil conditions also support the growth of sapling species such as *Pouteria spicata* and *Dysoxylum cauliflorum*, which generally regenerate better on soils with low acidity. At pH 5.6 (Plot 3), the more acidic soil conditions meant that the vegetation was dominated by species with a high tolerance to acidity. The most abundant species was *Oplismenus hirtellus*, which thrives very well on acidic soils and shady, humidity understory environments. In addition, *Hydrocotyle javanica* also grows optimally on acidic and humidity soils. Ferns such as *Dryopteris cristata* and *Tectaria gemmifera* also dominate because ferns generally prefer acidic and wet soil conditions. Other species such as *Zingiber purpureum* also survived well under low pH and low light. Overall, increasingly acidic soil conditions tended to increase the dominance of understory plants such as herbs and ferns, while a near-neutral pH increased vegetation diversity and sapling growth.

The MCNP area has dynamic abiotic supporting factors. These biotic and abiotic factors support each other in forming a complex ecological system in the area. This data is an important basis for analyzing why certain vegetation types dominate in these plots in the subsequent calculation of the Important Value Index (IVI). The comprehensive results of this vegetation analysis and the importance of each species within the community are detailed in Table 2.

Table 2. Analysis of Vegetation

Type of vegetation	N	Plot	D (ind/m^2)	RD (%)	F	RF	Do	RDo	IVI	Category
Homalomena philippinensis	11	1.5.10	11.0	32.51%	1.00	4.66%	0.02	0.10	37.17	Seedling
Peperomia hirta	1	1	1.0	2.95%	0.33	1.53%	0.00	0.00	4.48	Seedling
Piper aduncum	1	1	1.0	2.95%	0.33	1.53%	0.00	0.00	4.48	Seedling
Pouteria spicata	1	1	1.0	2.95%	0.33	1.53%	1.80	8.99	13.47	Sapling
Tectaria gemmifera	8	1.5	8.0	23.64%	0.66	3.07%	0.00	0.00	26.71	Seedling
Alternanthera philoxeroides	5	5	0.2	0.59%	0.33	1.53%	0.00	0.00	2.12	Seedling
Anonidium mannii	1	5	0.04	0.12%	0.33	1.53%	1.60	7.99	9.64	Sapling
Anthonotha macrophylla	3	5	0.12	0.35%	0.33	1.53%	0.16	0.80	1.88	Seedling
Asimina parviflora	1	5	0.04	0.12%	0.33	1.53%	0.00	0.00	1.65	Seedling
Asplundia rigida	2	5	0.08	0.24%	0.33	1.53%	0.00	0.00	1.77	Seedling
Bischofia javanica	1	5	0.04	0.12%	0.33	1.53%	0.16	0.80	2.45	Sapling
Cinnamomum osmophloeum	2	5	0.08	0.24%	0.33	1.53%	0.16	0.80	2.57	Treelet
Dysoxylum cauliflorum	1	5.10	0.04	0.12%	0.66	3.07%	1.40	6.99	10.18	Sapling
Gallesia integrifolia	1	5	0.04	0.12%	0.33	1.53%	0.10	0.50	2.15	Sapling
Geophila repens	1	5	0.04	0.12%	0.33	1.53%	0.00	0.00	1.65	Seedling
Gironniera parvifolia	1	5	0.04	0.12%	0.33	1.53%	1.40	6.99	8.64	Sapling
Homalomena philipinensis	41	1.5.10	0.56	1.65%	1.00	4.66%	0.01	0.05	6.31	Seedling
Hydrangea anomala	4	5	0.16	0.47%	0.33	1.53%	0.00	0.00	2.00	Seedling
Impatiens grandis	12	5	0.48	1.42%	0.33	1.53%	0.00	0.00	2.95	Seedling
Miconia crenata	1	5	0.04	0.12%	0.33	1.53%	0.01	0.05	1.65	Seedling
Milletia sanagana	1	5	0.04	0.12%	0.33	1.53%	0.10	0.50	2.15	Sapling
Nicotiana rustica	1	5	0.04	0.12%	0.33	1.53%	0.01	0.05	1.65	Seedling
Hydrocotyle javanica	3	5.10	0.12	0.35%	0.66	3.07%	0.01	0.05	3.42	Seedling
Quercus laurifolia	2	5	0.08	0.24%	0.33	1.53%	0.22	1.10	2.87	Treelet
Ruellia prostrata	33	5	1.32	3.90%	0.33	1.53%	0.01	0.05	5.43	Seedling
Scyphocephalium mannii	1	5	0.04	0.12%	0.33	1.53%	0.16	0.80	2.45	Treelet
Tectaria gemmifera	13	1.5	0.52	1.54%	0.66	3.07%	0.01	0.05	4.61	Seedling

Type of vegetation	N	Plot	D (ind/m²)	RD (%)	F	RF	Do	RDo	IVI	Category
Treculia obovoidea	1	5	0.04	0.12%	0.33	1.53%	0.10	0.50	2.15	Treelet
Zingiber purpureum	21	5	0.84	2.48%	0.33	1.53%	0.02	0.10	4.01	Seedling
Asplenium platyneuron	9	10	0.09	0.27%	0.33	1.53%	0.01	0.05	1.80	Seedling
Begonia palamanta	10	10	0.10	0.30%	0.33	1.53%	0.00	0.00	1.83	Seedling
Calanthe discolor	18	10	0.18	0.53%	0.33	1.53%	0.01	0.05	2.06	Seedling
Callicarpa americana	4	10	0.04	0.12%	0.33	1.53%	0.22	1.10	2.75	Treelet
Cleome rutidosperma	4	10	0.04	0.12%	0.33	1.53%	0.00	0.00	1.65	Seedling
Culcasia obliquifolia	3	10	0.03	0.09%	0.33	1.53%	0.01	0.05	1.62	Seedling
Dendrocnide	15	10	0.15	0.44%	0.33	1.53%	0.01	0.05	1.97	Seedling
Diplopterys cabrerana	9	10	0.09	0.27%	0.33	1.53%	0.22	1.10	2.90	Treelet
Dorstenia psilurus	3	10	0.03	0.09%	0.33	1.53%	0.01	0.05	1.62	Seedling
Dryopteris cristata	75	10	0.75	2.22%	0.33	1.53%	0.01	0.05	3.75	Seedling
Dysoxylum spectab	9	10	0.09	0.27%	0.33	1.53%	1.80	8.99	10.79	Sapling
Dysoxylum cauliflorum	5	5.10	0.05	0.15%	0.66	3.07%	1.40	6.99	10.21	Sapling
Guarea bullata	1	10	0.01	0.03%	0.33	1.53%	7.20	35.96	37.52	Tree
Hibiscus tiliaceus	3	10	0.03	0.09%	0.33	1.53%	1.40	6.99	8.61	Sapling
Homalomena philipinensis	16	1.5.10	0.16	0.47%	1.00	4.66%	0.01	0.05	5.13	Seedling
Hydrocotyle javanica	40	5.10	0.40	1.18%	0.66	3.07%	0.01	0.05	4.25	Seedling
Iochroma arborescens	2	10	0.02	0.06%	0.33	1.53%	0.16	0.80	2.39	Treelet
Coffea liberica	22	10	0.22	0.65%	0.33	1.53%	0.10	0.50	2.68	Treelet
Mimosa quadrivalvis	3	10	0.03	0.09%	0.33	1.53%	0.00	0.00	1.62	Seedling
Oplismenus hirtellus	353	10	3.53	10.43%	0.33	1.53%	0.00	0.00	11.96	Seedling
Petivera alliacea	45	10	0.45	1.33%	0.33	1.53%	0.00	0.00	2.86	Seedling
Psychotria rubra	1	10	0.01	0.03%	0.33	1.53%	0.00	0.00	1.56	Seedling
Thelypteris dentata	1	10	0.01	0.03%	0.33	1.53%	0.00	0.00	1.56	Seedling
Antidesma neurocarpum	21	10	0.21	0.62%	0.33	1.53%	0.01	0.05	2.15	Seedling
Total	847	-	33.84	114.67%	21.48	99.72	20.02	100.0	297.9	

Table 2 summarizes the vegetation structure in Mount Ciremai National Park (MCNP) based on density, frequency, dominance, and the Important Value Index (IVI). From observations across three quadrant sizes, 53 vegetation species with a total of 847 individuals were recorded. The majority of the vegetation consists of understory plants, such as herbs and ferns, reflecting the typical character of humid montane forests.

In the seedling stratum, the highest IVI values are held by *Homalomena philippinensis* (37.17), *Tectaria gemmifera* (26.71), and *Oplismenus hirtellus* (11.96). While *Oplismenus hirtellus* shows the highest abundance with 353 individuals, its lower frequency and dominance compared to H. philippinensis result in a lower overall IVI. In the sapling stratum, species such as *Pouteria spicata* (13.47), *Dysoxylum spectabile* (10.79), and *Dysoxylum cauliflorum* (10.21) dominate the biomass and vertical space due to their larger stem sizes. At the pole and tree levels, *Guarea bullata* is the most dominant species with an IVI of 37.52, primarily driven by a high relative dominance of 35.96%, indicating its significant canopy occupancy despite a low number of individuals.

This structural composition reveals critical forest regeneration dynamics, specifically a 'regeneration bottleneck' where the forest floor is heavily dominated by non-tree species. The extraordinary dominance of herbaceous plants like *H. philippinensis* suggests intense competition between vegetation strata. This thick understory layer likely monopolizes space and nutrients, suppressing the transition of tree seedlings into higher strata. Furthermore, the influence of edaphic factors plays a vital role in this distribution. The high soil moisture and acidic volcanic soil typical of MCNP provide an optimal niche for shade-tolerant aroids and ferns to thrive. These conditions create an ecological barrier that prevents many climax tree species from successfully establishing, thereby shaping the unique community stability observed in this research area. The composition of these dominant species across all strata is detailed in Table 3.

Table 3. Dominant Species Composition

Dominant Type	Total individuals	Plot Dominant	Ecological description
Oplismenus hirtellus	353	10×10 m	Dominant herb; indicator of moist understory
Homalomena philipinensis	68 (11+41+16)	1×1 m & 5×5 m	Dominant seedling; tolerant of low light
Hydrocotyle javanica	40	10×10 m	Aquatic herb; prefers moist, acidic soil
Ruellia prostrata	33	10×10 m	Fast-growing ground cover
Tectaria gemmifera	8	1×1 m	Low pH tolerant fern

Table 3 indicates the five most dominant plant species in the research area. *Oplismenus hirtellus* was the species with the highest number of individuals in the 10 × 10 m plot and is a typical herb of the moist forest floor. *Homalomena philipinensis* dominated in small plots as a seedling capable of growing in low light conditions. *Hydrocotyle javanica* and *Ruellia prostrata* were also abundant in the 10×10 m plots, serving as damp-acid soil-loving herbs and fast-growing ground covers, respectively. *Tectaria gemmifera* was prominent in the 1×1 m plot as an acid soil-tolerant fern. Overall, this composition shows that the understory strongly dominates the vegetation of the humid montane forest. The ecological significance and hierarchical ranking of these key species based on their Important Value Index (IVI) are comprehensively presented in Table 4.

Table 4. Important Value Index (IVI) Key Species

Species	IVI	Srata	Factors Contributing to High IVI
Homalomena philipinensis	37.17	Seedling	High density & frequency
Gurea bullata	37.52	Tree	BA very large (907.46 cm^2)
Oplismenus hirtellus	11.96	Seedling	Density is very dominant
Dysoxylum spectabile	10.79	Treelet	Frequency and RDo are normal
Dysoxylum cauliflorum	10.21	Treelet	Even distribution in the plot

Table 4 shows the five-key species with the highest IVI values reflecting the important role of each species in the vegetation community. *Homalomena philipinensis* showed a large IVI at the seedling stratum due to its high density and frequecy of occurrence. In the tree stratum, *Gurea bullata* became the most dominant species thanks to its huge dominance value, indicated by its basal area (BA) of 907.46 cm^2. *Oplismenus hirtellus* obtained a high IVI as a herbaceous seedling due to its very abundant number of individuals. Meanwhile, *Dysoxylum spectabile* and *Dysoxylum cauliflorum* stood out in the sapling stratum, each due to a combination of considerable frequency and dominance as well as even distribution across several plots. Overall, this table illustrates that IVI values are influenced by the density, distribution and size of the vegetation structure in each stratum. The specific environmental conditions that provide the ecological context for these vegetation dynamics are presented in Table 5.

Table 5. Environmental Conditions Plots

Plot	Soil pH	Temperature(°C)	Wind speed (m/s)	Ecological description
1×1	6.0	21	0.9	Slightly acidic soil, herbaceous vegetation dominant
5×5	6.7	21	1.2	The soil is more neutral; supports treelet
10×10	5.6	22	1.4	The soil is very acidic; dominated by understory plants

Table 5 shows the variation in environmental conditions in each plot that affect vegetation composition. The 1×1 m plot had a pH of 6.0 with a temperature of 21°C and very low wind, indicating a slightly acidic soil suitable for herbaceous dominance. The 5×5 m plot had a pH of 6.7 which was closer to neutral, thus favoring the growth of sapling species. Meanwhile, the 10×10 m plot showed a more acidic pH of 5.6, with slightly higher temperatures and stronger winds, so it was dominated by understory plants tolerant of acidic soil conditions. The variation in pH between plots is the main factor that determines the type of vegetation that grows in each area. The resulting patterns of species dominance corresponding to these specific plot sizes and environmental conditions are presented in Table 6.

Table 6. Vegetation Dominance Plots Size

Plot	Dominant Vegetation	Structure Level	Key Ecological Characteristics
1×1 m	*Homalomena philipinensis*, paku	Understory–seedling	Damp, low light
5×5 m	Sowing–Staking (*Dysoxylum*)	Transition	Composition of various types
10×10 m	*Oplismenus hirtellus*, big tree	Tree–Treelet–Seedling	Acidic soil, higher winds

Table 6 shows that each plot size has different dominant vegetation and ecological characteristics. The 1×1 m plot was dominated by *Homalomena philipinensis* and ferns at the understory-seedling level, corresponding to the humid and low-light conditions. In the 5×5 m plot, the dominance shifted to a mixture of seedlings and saplings, including *Dysoxylum*, thus reflecting a transitional area with higher species diversity. Meanwhile, the 10×10 m plot showed a dominance of *Oplismenus hirtellus* and large trees, illustrating the complete vegetation structure from seedlings to trees in the more acidic and windy soil environment. The integrated ecological analysis that explains the core dynamics of this community structure is summarized in Table 7.

Table 7. Ecological Analysis

Ecological Aspects	Results & Interpretation
Regeneration	Seedling very high, sapling a little → *regeneration bottleneck*.
Treelet Structure	Unbalanced: seedlings dominate, few large trees.
Herbal Dominance	Triggered by acidic soil pH and low light.
Dominance of Large Trees	*Gurea bullata* dominates due to its large body length, not the number of individuals.
Key Environmental Factors	Soil pH, low temperature, wind, humidity.
Habitat Conditions	Stable for understory plants, less ideal for tree regeneration.

Table 7 shows that regeneration is not optimal because seedlings are very abundant while saplings are few, resulting in an unbalanced stand structure. Herbaceous dominance is influenced by acidic soil and low light, while large trees such as *Gurea bullata* are superior due to their stem size. Environmental factors, mainly soil pH, low temperature, wind and humidity, are involved in shaping this vegetation pattern. In general, habitat conditions favor understory plants over young tree growth.

The species composition in the forest area of Mount Ciremai National Park (MCNP) shows a strong dominance by the understory group with a total of 847 individuals from 53 species, reflecting the general character of humid mountain forests that have high diversity in the herbaceous and fern strata (Dian Hayati et al., 2021). The dominance of species such as *Oplismenus hirtellus*, *Homalomena philipinensis*, and *Hydrocotyle javanica* in the 10 × 10 m plot indicates that the understory layer is in optimum growth conditions at low light levels and high humidity, typical of the lower montane zone. The high density of seedlings and herbs is also in line with the acidic soil conditions (pH 5.6-6.7), which are known to favor the proliferation of ferns and other understory plants in montane forest ecosystems.

The vegetation structure that was formed showed an imbalance between strata, with the dominance of seedling groups much higher than saplings and trees, indicating a potential regeneration bottleneck from seedling to sapling strata (Isyarah et al., 2019). This condition is reinforced by field data showing that although there are species such as *Dysoxylum cauliflorum* and *Dysoxylum spectabile* in the sapling stratum, the number of individuals is much lower than the seedling group that dominates the forest floor (Hidayat et al., 2022). This indicates that intensive competition in the lower strata can inhibit the growth of high ecological value tree species such as *Dysoxylum*, whose role as the key species is very important in long-term stand structure (Luo et al., 2024).

The Important Value Index (IVI) values show different dominance patterns between strata, where *Homalomena philipinensis* dominates the seedling stratum, *Dysoxylum spectabile* dominates the sapling stratum, and Gurea bullata dominates the tree stratum thanks to the high dominance value of the basic area (BA) parameter (Hendrayana et al., 2022). The dominance of *Gurea bullata* even though the number of individuals is only one shows the influence of stem diameter on the ecological value of a species, in accordance with the concept that basal area is the main determinant of species contribution in forest communities (van Breugel et al., 2012). This difference in dominance between strata confirms the importance of IVI analysis in understanding the ecological hierarchy and function of plant communities, especially in mountain ecosystems that have sharp microclimatic gradients (Sulistyawati et al., 2018).

The variation in composition between plots shows that plot size has a major effect on the representation of vegetation structure, with small plots (1×1 m) dominated by seedlings, medium plots (5×5 m) showing a mixture of seedlings and saplings, while large plots (10×10 m) include all strata including large trees. This pattern is in line with the theory that the complexity of stand structure becomes more apparent as the size of the sampling unit increases, especially in vertically heterogeneous ecosystems such as montane forests (Zhao et al., 2022).

The observed environmental factors also contributed to the vegetation distribution, with temperatures stabilizing at 21-22°C supporting a high presence of seedlings and understory plants (Meng et al., 2023). Differences in soil pH between plots indicate gradations in soil fertility and acidity that may affect the dominance of certain species, especially ferns and herbaceous plants that are more tolerant of low pH ranges (Mantilla-Contreras et al., 2012). In addition, increased wind speed in larger plots indicates a more open canopy structure, which may increase light intensity and dominance of herbaceous species adapted to semi-open conditions (Xiang et al., 2025).

Ecologically, the observed dominance patterns indicate that the MCNP vegetation community is in a stable phase but prone to regeneration stagnation, especially in relation to the low amount of saplings and treelet (Gunawan et al., 2024). This regeneration imbalance has the potential to affect the long-term sustainability of forest structure, especially for high conservation value arboreal species (Dian Hayati et al., 2021). If this condition continues, there could be a shift in community composition due to the over-dominance of understory plants that inhibit the growth of tree kanopy species that direct forest structure (Zuhri & Mutaqien, 2011).

The results of this study have important implications for conservation area management, because information on density, dominance, frequency, and IVI can be used to determine priority species in habitat rehabilitation efforts (Kalima, 2021). In addition, multilevel vegetation analysis as applied in this study is an important basis for monitoring long-term regeneration in national park areas in Indonesia (Purwaningsih & Razali, 2008). As a result, these outputs can assist MCNP managers in formulating strategies for key plant conservation, managing vulnerable areas, and developing a vegetation monitoring system based on scientific data.

4. Conclusion

This study identifies a significant regeneration bottleneck within Mount Ciremai National Park (MCNP), characterized by a structural imbalance where an abundance of understory vegetation primarily *Homalomena philippinensis*, *Tectaria gemmifera*, and *Oplismenus hirtellus* dominates the seedling stratum. Scientifically, this research contributes to the understanding of montane forest dynamics by demonstrating how specific edaphic and microclimatic factors, such as acidic soil pH and stable temperatures, create an ecological niche that favors low-status vegetation while suppressing the transition of climax tree species like *Guarea bullata* and *Dysoxylum spp*. into mature stages. Consequently, these findings provide a crucial baseline for conservation management, suggesting that interventions should prioritize the mitigation of the regeneration barrier to ensure long-term ecosystem sustainability. Furthermore, the results offer a significant contribution to environmental education by positioning MCNP as a 'living laboratory'. Integrating these site-specific ecological data into local curricula can enhance ecological literacy among students and the community, fostering a deeper commitment to the preservation of the Mount Ciremai forest ecosystem.

Author Contributions

Based on these findings, regular monitoring of treelet regeneration is required to ensure continued growth from seedling to sapling and tree strata. Overly high understory dominance should be selectively managed so as not to inhibit the growth of treelet species, including through regulating seedling density and managing light openings in the forest canopy. Rehabilitation efforts are advised to prioritize planting high ecological value species such as *Dysoxylum spectabile*, *Dysoxylum cauliflorum*, and *Gurea bullata* due to their important role in shaping long-term forest structure. In addition, maintaining soil quality and microhabitat conditions is an important step, especially in reducing the effects of soil acidity that can inhibit tree growth. Area management also needs to reduce anthropogenic pressures through limiting tourism activities, educating visitors, and involving local communities in conservation. Further research on the dynamics of understory competition, factors causing the low seedling-stake transition, and the relationship between edaphic conditions and vegetation composition is highly recommended to strengthen conservation strategies and sustainable management of the MCNP area.

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Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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