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RESEARCH ARTICLE

# Species Composition and Stand Structure of Puspa (*Schima wallichii* (DC.) Korth.) in Mount Halimun Salak National Park, Sukabumi

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**Abstract**

Puspa is a type of vegetation that can be used to restore forests, and grows in M Halimun Salak National Park. This study aims to analyze the species composition, stand structure and biophysical aspects of *Schima wallichii* (DC.) Korth. The research method used was vegetation analysis with purposive sampling of 5 plots measuring 50 x 50 meters based on the height of the research location. The results showed that puspa dominated the study site with high density at the seedling level and low at the tree level. The horizontal structure of puspa at the study site shows an inverted "J", indicating that natural succession is well underway. The distribution of puspa in the plot shows a clustered distribution. The temperature and humidity of the study site were relatively uniform, the slope was in the steep and very steep class, while the thickness of litter and residual organic matter was relatively uniform, except in plot 2.

Keywords: puspa, regeneration, vegetation analysis

## 1. Introduction

Mount Halimun Salak National Park is a protected conservation area located in West Java, Indonesia. It encompasses diverse ecosystems, including lowland rainforests, lower montane forests, and upper montane forests, making it rich in biodiversity [1]. The park also plays a vital role in hydrological protection, supporting life systems in the region. It spans across three districts: Bogor, Lebak, and Sukabumi [2].

The area is managed with a zonation system used for certain purposes, including core, rehabilitation, wilderness, and utilization zones. The core zone is part of the national park with protected biota and physical conditions to maintain intact and natural biodiversity. The rehabilitation zone is part of the national park that has been damaged; therefore, ecosystem recovery is needed. The wilderness zone is part of the national park that functions to preserve native and migratory animals, and the ecosystem can support the sustainability of the core and utilization zones. The utilization zone is part of a national park whose natural conditions and potential are utilized for environmental services [3].

Some places in the area have experienced ecological disturbances due to human intervention; therefore, secondary forest vegetation types dominate some areas, while primary species are increasingly rare. One of the primary species in the area is puspa (*Schima wallichii* (DC.) Korth.). The classification of plant conservation status is based on the IUCN Red List, CITES, and the Ministry of Environment and Forestry Regulation Number P.106 of 2018 concerning Protected Plants and Wildlife. The International Union for Conservation of Nature and Natural Resources (IUCN) is an international organization dedicated to conserving natural resources. The IUCN updates and evaluates the status of each species every five years, if possible, or at least every ten years. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international treaty on trade in flora and wildlife species that has been in effect since 1975. Conservation status is an indicator used to show the threat to a species' level of extinction. Conservation efforts by the government to protect the existence of plants and wildlife are outlined in the Ministry of Environment and Forestry Regulation Number P.106/MENLHK/SETJEN/KUM.1/12/2018 concerning the types of protected plants and animals. The conservation status of *S. wallichii* according to the IUCN is Least Concern (LC); according to CITES, it is non-appended (not listed in any Appendix), and it is Not Protected [4].

Puspa belongs to the Theaceae family and is an upland plant capable of growing on degraded land; therefore, it can be used to restore damaged mountain forest areas [5]. The selection of puspa (*S. wallichii*) as the object of research is because it is a species that grows at high altitudes, such as in Mount Halimun Salak National Park, in addition to being adaptive to critical land, so that it can be used for land restoration. This tree can live up to 1000 m above sea level, is not picky about soil texture and fertility conditions, and is classified as a fast-growing plant. In addition, the Puspa Plant (*Schima wallichii* (DC.) Korth) has a high survivability with thick bark, so it is fire resistant, but when it collapses, the saplings grow quickly when the tree is destroyed, the saplings grow quickly when rain falls on the forest floor, so it is good for reforestation [6].

Species composition and stand structure are important factors or components in studying the regeneration process of a vegetation type, with many factors. The ecological process or natural regeneration is a very important consideration in the future management of Gunung Halimun Salak National Park. One of the stand types that needs to be studied for its composition and structure is *S. wallichii,* considering its various benefits. Based on this, research related to the species composition and stand structure of S. wallichii is needed.

## 2. Materials and Methods

### 2.1. Study Area

The research was conducted from July to August 2023 in the core zone of Cikaniki Resort, Mount Halimun Salak National Park, Sukabumi Regency, West Java. The land condition of the area has an altitude of 500 – 2,211 m above sea level and has a wet tropical rainforest climate with an annual rainfall of 4.000 – 6.000 mm/year. The average monthly temperature is 31.5°C, with a low temperature of 19.7°C, a high temperature of 31.8°C, and an average air humidity of 88%. The soil types in the area consist of podzolic and latosol material [7]. Figure 1.


**Figure 1.** Research location map of the core zone at Cikaniki Resort, Mount Halimun Salak National Park, West Java. (Balai TNGHS 2020)

### 2.2. Data Collection

Data collection involved establishing research plots, measuring species composition and stand structure, and gathering biophysical data. Relevant information was obtained from the literature review. These methods provide comprehensive data on the vegetation characteristics and environmental conditions. The collected data were then analyzed to understand the species distribution and forest structure.

#### 2.2.1. Construction of research sample plots and measurement of species composition

Vegetation analysis was conducted using a purposive sampling method, with five plots measuring 50 m × 50 m. The plots were purposively selected to ensure that they represented the vegetation characteristics of the core zone in Mount Halimun Salak National Park, focusing on areas dominated by *Schima wallichii* (puspa) stands. The creation of five plots was based on a minimum area for vegetation analysis of 0.25 ha [8]. Each plot was built with subplots measuring 6 m x 6 m for seedling and understory level, 12.5 m x 12.5 m for sapling level, poles level (25 × 25 m), and tree level (50 × 50 m). Data were collected at the seedling and sapling levels in the form of species and number of individuals, and at the pole and tree levels in the form of diameter, total height, free branch height, coordinate points (x and y), crown curve, crown depth, and crown radius.

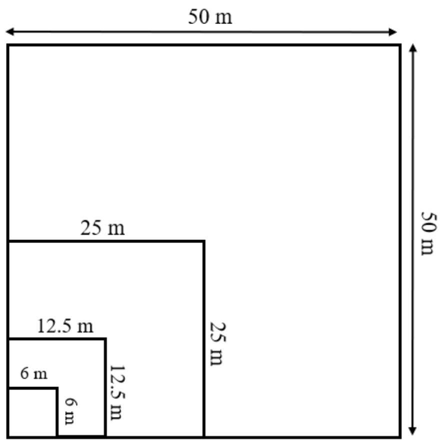



**Figure 2.** Layout of sample plots used in the study [9].

#### 2.2.2. Biophysical data collection

Biophysical data collected around the puspa-growing areas included temperature, humidity, slope, elevation, litter thickness, and residual organic matter. The temperature and humidity data were collected from the plots. Slope was measured using an inclinometer. The elevation was measured using GPS. Litter thickness and residual organic matter content were measured using a ruler. Litter thickness and residual organic matter were sampled at three points around the *S. wallichii* within the 2.5 m x 2.5 m subplots in each plot.

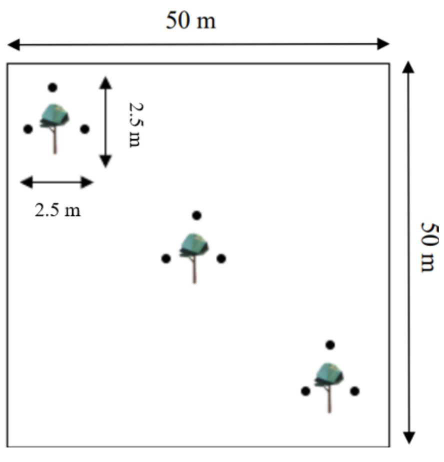



**Figure 3.** Sample plot layout for litter and organic matter [9].

### 2.3. Data Analysis

#### 2.3.1. Vegetation analysis

The Importance Value Index (IVI) was used to assess the dominance of species within a specific community [10]. It was calculated based on three ecological parameters: relative density, relative frequency, and relative dominance. A higher IVI indicates that a species plays a more significant role in the community structure. This index helps researchers to understand species composition and ecosystem balance.

Density = $\frac{\boldsymbol{number\ of\ individuals\ of\ a\ species\ (N)}}{\boldsymbol{sample\ plot\ area\ (ha)}}$

Relative density = $\frac{\boldsymbol{density\ of\ a\ species\ (N/ha)}}{\boldsymbol{density\ of\ all\ species\ (N/ha)}} \times \mathbf{100}\%$

Frequency = $\frac{\boldsymbol{number\ of\ plots\ where\ a\ species\ was\ found}}{\boldsymbol{total\ number\ of\ plots}}$

Relative frequency = $\frac{\boldsymbol{frequency\ of\ a\ species}}{\boldsymbol{frequency\ of\ all\ species}} \times \mathbf{100}\%$

Dominance = $\frac{\boldsymbol{number\ of\ base\ fields\ of\ a\ species\ (m)^2}}{\boldsymbol{sample\ plot\ area\ (ha)}}$

Relative dominance = $\frac{\boldsymbol{dominance\ of\ a\ species\ (m^2/ha)}}{\boldsymbol{dominance\ of\ all\ species(m^2/ha)}}$

Ivi (%) = Relative density + Relative frequency (for seedlings and saplings)

IVI (%) = Relative density + Relative frequency + Relative dominance (for poles and trees)

#### 2.3.2. Shannon-Wiener Diversity Index (H’)

Species diversity index (H’), Shannon diversity formula [11].

$$H' = -\sum_{l=1}^{s} p_i \,.\ln.p\ ; p = \frac{n_i}{N}$$

where ni is the number of individuals of a particular species and N is the total number of individuals of all species. Criteria: H' < 1 low, 1 < H' < 3 Moderate, H' > 3 high.

#### 2.3.3. Evenness Index (E)

Evenness Index is used to measure the distribution of individuals within a community in terms of frequency and abundance

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

where $H'$ = Shannon-Wiener diversity index and S = number of species. Criteria: E < 0.31 low, suppressed community; 0.31 < E ≤ 1 moderate, labile community; E > 1 high, stable community.

#### 2.3.4. Simpson Index (C)

This index is used to show the dominance of a species in an area [12].

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

where ni is the number of individuals of a particular species and N is the total number of individuals of all species.

#### 2.3.5. Richness Index (Dmg)

The richness of different species present in a given area was calculated using the Margalef index formula.

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

where S is the number of species, and N is the total number of individuals of a particular species.

2.3.6. Morisita Index

Morisita Index (Iδ) is used to see the distribution of species that are clustered or not. The distribution pattern of puspa (*S. wallichii*) was determined using the following formula:

a. Morisita Index (Iδ) [13]:

$$I\delta = n\frac{(\sum xi^2 - \sum xi)}{(\sum xi)^2 - \sum xi}$$

where Iδ = Morisita Index, Σxi = number of individuals in each plot, and n is the number of observation plots.

b. Mu, and Mc [14].

$Mu = \frac{(X^2_{0,975} - n + \sum xi)}{(\sum xi) - 1}$ $Mc = \frac{(X^2_{0,025} - n + \sum xi)}{(\sum xi) - 1}$

Keterangan:

Mu = Morisita dispersion index for uniform distribution pattern

$X^2_{0,975}$ = chisquare value of n-1 degrees of freedom and 97.5% confidence interval

Mc = Morisita dispersion index for clustered distribution pattern

$X^2_{0,975}$ = chi-square value index of n-1 degrees of freedom and 2.5% confidence interval

c. Calculation of the standardized Morisita [13]

$Ip = 0{,}5 + 0{,}5\left(\frac{I\delta - Mc}{n - Mc}\right)$ : if Iδ ≥ Mc > 1,0

$Ip = 0{,}5\left(\frac{I\delta - 1}{Mc - 1}\right)$ : if Mc > δ ≥ 1,0

$Ip = -0{,}5\left(\frac{I\delta - 1}{Mu - 1}\right)$ : if 1,0 > Iδ ≥ Mu

$Ip = -0{,}5 + 0{,}5\left(\frac{I\delta - Mu}{Mu}\right)$ : if 1,0 > Mu ≥ Iδ

Criteria: Ip < 0, uniform distribution pattern; Ip = 0, random distribution pattern; and Ip > 0, clustered distribution pattern.

2.3.7. Stand Structure Analysis

a. Horizontal Structure

The horizontal structure was analyzed based on the relationship between diameter class at breast height (cm) and tree density (trees per hectare). Tree density is represented on the y-axis, whereas the diameter class is shown on the x-axis. This analysis helps understand the distribution of tree sizes within the study area.

b. Vertical Structure

Vertical structure or canopy stratification is obtained using stand profile diagrams that visualize crown projections from the top side (crown projection on the forest floor) and stand projections from the side. Stand profile diagrams were created using the SExI-FS 2.1.0 application. The data used were the diameter, total height, free branch height, tree coordinates (x and y), crown curve, crown depth, and crown radius.

## 3. Results and Discussion

### 3.1. Results

3.1.1. Species Composition

The species composition of an area can be determined by measuring the density of individual stands at each growth level, and is used to determine the presence of the main species and new species found in the research plot to analyze the natural regeneration of a species [15]. Seedlings dominated the highest total density of individual stands at 123.334 ind/ha, saplings at 14.270 ind/ha, poles at 1.123 ind/ha, and trees at 672 ind/ha (Table 1).

**Table 1.** Density in each research plot in the core zone of the Cikaniki Resort.

| Plot | Density (ind/ha) | | | |
|---|---|---|---|---|
| | Seedlings | Saplings | Poles | Trees |
| 1 | 14,167 | 2,880 | 224 | 124 |
| 2 | 32,778 | 1,024 | 67 | 116 |
| 3 | 17,778 | 1,856 | 144 | 156 |
| 4 | 28,611 | 4,095 | 272 | 148 |
| 5 | 30,000 | 4,415 | 416 | 132 |
| Total | 123,334 | 14,270 | 1,123 | 672 |

#### 3.1.2. Tree-Level Composition of Puspa and Non-Puspa Species

Trees represent the final stage of the natural regeneration process of a species. The highest total tree density was 156 in plot 3, and the lowest was 116 in plot 2 (Table 2). The total individual trees in plot 2 decreased by 25.64% from the highest total trees. The percentage of Puspa species at the tree level was low in all research plots, except for plot 1.

**Table 2.** Tree-level composition of puspa and non-puspa species.

| Plot | Diameter (cm) | | | | | | Total | % Puspa | % Non puspa |
|---|---|---|---|---|---|---|---|---|---|
| | 20-29 | 30-39 | 40-49 | 50-59 | 60-69 | ≥70 | | | |
| 1 | 52 | 16 | 24 | 16 | 8 | 8 | 124 | 58.06 | 41.94 |
| 2 | 48 | 16 | 24 | 8 | 8 | 12 | 116 | 48.28 | 51.72 |
| 3 | 80 | 24 | 24 | 16 | 4 | 8 | 156 | 39.47 | 60.53 |
| 4 | 40 | 43 | 37 | 16 | 12 | 0 | 148 | 40.54 | 59.46 |
| 5 | 32 | 34 | 38 | 16 | 12 | 0 | 132 | 24.24 | 75.76 |

#### 3.1.3. Seedling-Level Composition of Puspa and Non-Puspa Species

Seedling density showed significant variation among plots, with Plot 2 having the highest density at 32,778 ind/ha and Plot 1 having the lowest at 14,167 ind/ha. The minimal contribution of Puspa species suggests strong competition with other species during the early growth stage. This could also indicate that environmental factors limit the establishment and survival of Puspa. Such conditions may influence species composition and regeneration dynamics in the study area.

**Table 3.** Seedling-level composition of puspa and non-puspa species.

| Plot | Puspa | Non Puspa | Total | % Puspa | % Non Puspa |
|---|---|---|---|---|---|
| 1 | 0 | 14,167 | 14,167 | 0 | 100 |
| 2 | 833 | 31,944 | 32,778 | 2.54 | 97.46 |
| 3 | 4,167 | 13,611 | 17,778 | 23.44 | 76.56 |
| 4 | 1,389 | 27,222 | 28,611 | 4.85 | 95.15 |
| 5 | 2,222 | 27,778 | 30,000 | 7.41 | 92.59 |

#### 3.1.4. Sapling-Level Composition of Puspa and Non-Puspa Species

The sapling density was highest in plot 5 (4,415 ind/ha) and lowest in plot 2 (1,024 ind/ha). Puspa showed a low representation, with the highest percentage in Plot 3 (31.03%). Plot 2 had no Puspa saplings, likely due to unfavorable conditions, such as steep slopes of 18% [16]. The lack of saplings due to competition with other species also affects regeneration [17].

**Table 4.** Sapling-level composition of puspa and non-puspa species.

| Plot | Puspa | Non Puspa | Total | % Puspa | % Non Puspa |
|---|---|---|---|---|---|
| 1 | 576 | 2,304 | 2,880 | 20 | 80 |
| 2 | 0 | 1,024 | 1,024 | 0 | 100 |
| 3 | 576 | 1,280 | 1,856 | 31.03 | 68.97 |
| 4 | 1,152 | 2,943 | 4,095 | 28.13 | 71.88 |
| 5 | 512 | 3,903 | 4,415 | 11.59 | 88.41 |

3.1.5. Pole-Level Composition of Puspa and Non-Puspa Species

The pole-level density was highest in plot 5 (416 ind/ha) and lowest in plot 2 (67 ind/ha). The presence of Puspa was inconsistent, with Plot 3 showing the highest percentage (55.56%). In contrast, plot 1 had no puspa at this stage, suggesting intense competition with non-puspa species.

**Table 5.** Pole-level composition of puspa and non-puspa species.

| Plot | Puspa | Non Puspa | Total | % Puspa | % Non Puspa |
|---|---|---|---|---|---|
| 1 | 0 | 224 | 224 | 0 | 100 |
| 2 | 32 | 35 | 67 | 40 | 60 |
| 3 | 80 | 64 | 144 | 55.56 | 44.44 |
| 4 | 48 | 224 | 272 | 17.65 | 82.35 |
| 5 | 64 | 352 | 416 | 15.38 | 84.62 |

3.1.6. Importance Value Index

The Importance Value Index (IVI) is used to determine the dominance of a species, where the higher the IVI value of a species, the higher the dominance of that species in its community [18]. The IVI values for each plot are presented in Table 6, Table 7, Table 8, and Table 9. *C. acuminatissima* dominated the IVI values in all the plots in ranks 1 and 2 (Table 6). The highest IVI value was observed for *C. acuminatissima* in plot 1 (55.07 %), while the lowest IVI value was observed for *A. excelsa* in plot 5 (5.22 %). *C. acuminatissima* is a native plant species that characterizes the mountain forests of West Java [19].

**Table 6.** Recapitulation of IVI seedling level.

| Species | IVI value (%) at plot- | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| *Schima wallichii* | - | - | 40.10 (1) | - | 17.16 (4) |
| *Castanopsis acuminatissima* | 55.07 (1) | 29.93 (2) | 33.65 (2) | 29.48 (1) | 26.08 (2) |
| *Syzigium antisepticum* | 23.96 (4) | - | - | 18.16 (5) | - |
| *Ficus montana* | 31.54 (3) | - | - | - | - |
| *Lithocarpus daphnoides* | - | 34.34 (1) | 30.73 (3) | 25.60 (2) | 17.75 (5) |
| *Litsea cassiaefolia* | 41.35 (2) | - | - | - | - |
| *Acer laurinum* | - | - | - | - | - |
| *Glochidion macrocarcum* | - | 20.79 (5) | - | - | 26.42 (1) |
| *Ficus recurvua* | - | 21.45 (4) | 28.96 (4) | 18.80 (4) | - |
| *Trycasia singularis* | - | - | 24.06 (5) | - | 20.28 (3) |
| *Eurea javanica* | - | - | - | - | - |
| *Piper majusculum* | 29.16 (5) | 27.48 (3) | - | - | - |
| *Actinodaphne glomerata* | - | - | - | - | - |
| *Altingia excelsa* | - | - | - | 23.01 (3) | - |

( ): A number indicating the 5th highest ranking.

**Table 7.** Recapitulation of IVI sapling level.

| Species | IVI value (%) at plot- | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| *Schima wallichii* | 46.32 (1) | - | 54.56 (2) | 47.36 (1) | 30.64 (3) |
| *Castanopsis acuminatissima* | 41.05 (2) | 91.67 (1) | 57 (1) | 20.07 (4) | 39.75 (1) |
| *Syzigium antisepticum* | - | - | - | - | - |
| *Ficus montana* | 35.79 (3) | 43.75 (3) | 24.54 (5) | - | - |
| *Lithocarpus daphnoides* | 21.64 (5) | - | - | - | - |
| *Litsea cassiaefolia* | - | 64.58 (2) | - | 16.23 (5) | 24.02 (5) |
| *Acer laurinum* | - | - | 32.45 (3) | - | - |
| *Glochidion macrocarcum* | 33.57 (4) | - | - | 22.48 (3) | 24.43 (4) |
| *Trycasia singularis* | - | - | 31.44 (4) | 34.98 (2) | 33.13 (2) |
| *Eurea javanica* | - | - | - | - | - |
| *Piper majusculum* | 21.64 (5) | - | - | - | - |
| *Altingia excelsa* | - | - | - | - | - |
| *Ostodes paniculata* | - | - | - | - | - |
| *Syzigium lineatum* | - | - | - | - | - |
| *Helicia robusta* | - | - | - | - | - |
| *Syzigium pycnanthum* | - | - | - | - | - |

( ): A number indicating the 5th highest ranking.

*C. acuminatissima* also dominated the sapling level, ranked 1, 2, and 4 in all plots (**Table 7**). The highest IVI value was observed for *C. acuminatissima* at 57% in plot 3, whereas the lowest IVI value was observed for A. excelsa at 6.97% in plot 4. The highest IVI value for *S. wallichii* was observed in plot 3 (54.56 %). Plot 2 did not find *S. wallichii* because it experienced growth resistance due to its inability to compete with *C. acuminatissima*, which had an IVI of 91.67%. The IVI of *S. wallichii* species at this level was still in the high category, except for plot 5, which was in the medium category, and plot 2, where no *S. wallichii* species were found. IVI values > 42.66% were included in the high category, IVI 21.96 - 42.66% in the moderate category, and < 21.96% in the low category [20].

**Table 8.** Recapitulation of IVI pole level.

| Species | IVI value (%) at plot- | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| *Schima wallichii* | - | 111.65 (1) | 138.50 (1) | 50.92 (2) | 51.47 (2) |
| *Castanopsis acuminatissima* | - | 50.16 (4) | - | 75.84 (1) | 41.76 (3) |
| *Syzigium antisepticum* | - | - | - | - | 34.14 (4) |
| *Lithocarpus daphnoides* | - | - | 41.77 (4) | - | - |
| *Litsea cassiaefolia* | 110.16 (1) | 76.12 (2) | 63.77 (2) | 36.10 (3) | 69.40 (1) |
| *Acer laurinum* | 46.67 (2) | 62.07 (3) | - | - | - |
| *Glochidion macrocarcum* | - | - | - | 24.55 (5) | - |
| *Trycasia singularis* | - | - | - | - | 31.60 (5) |
| *Eurea javanica* | - | - | - | - | - |
| *Piper majusculum* | - | - | - | - | - |
| *Altingia excelsa* | - | - | - | 27.53 (4) | - |
| *Lithocarpus elegans* | 60.64 (4) | - | - | - | - |
| *Decapermum paniculatum* | 39.05 (3) | - | - | - | - |
| *Plantago mayor* | 21.74 (5) | - | - | - | - |
| *Turpinia sphaerocarpa* | - | - | 55.96 (3) | - | - |
| *Helicia robusta* | - | - | - | - | - |

( ): A number indicating the 5th highest ranking.

Table 8 shows that the pole level was dominated by *L. cassiaefolia*, which was ranked 1, 2, and 3 in all plots. The highest IVI value was observed for the *S*. wallichii species at 138.50% in plot 3, whereas the lowest IVI value was observed for *P. imbricatus* at 13.50% in plot 5. The

*S. wallichii* species was not found in plot 1 but was included in the five highest IVI rankings in plots 2, 3, 4, and 5.

**Table 9.** Recapitulation of IVI tree level.

| Species | IVI value (%) at plot- | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| *Schima wallichii* | 72.74 (1) | 120.99 (1) | 77.31 (1) | 256.94 (1) | 56.56 (1) |
| *Castanopsis acuminatissima* | - | 18.77 (5) | 58.34 (2) | 79.20 (2) | 48.59 (2) |
| *Syzigium antisepticum* | 20.36 (4) | - | - | 74.13 (3) | 30.66 (3) |
| *Lithocarpus daphnoides* | 20.40 (2) | 31.65 (3) | 36.41 (3) | - | - |
| *Litsea cassiaefolia* | - | - | 19.14 (5) | 55.23 (4) | - |
| *Acer laurinum* | - | - | - | - | - |
| *Glochidion macrocarcum* | - | - | - | - | - |
| *Trycasia singularis* | - | - | - | - | - |
| *Eurea javanica* | 20.38 (3) | 19.62 (4) | 19.36 (4) | 41.84 (5) | 30.55 (4) |
| *Piper majusculum* | - | - | - | - | - |
| *Altingia excelsa* | - | 49.18 (2) | - | - | 31.30 (5) |
| *Syzigium lineatum* | - | - | - | - | - |
| *Lithocarpus elegans* | - | - | - | - | - |
| *Helicia robusta* | 17.60 (5) | - | - | - | - |
| *Podocarpus imbricatus* | - | - | - | - | - |
| *Turpinia sphaerocarpa* | - | - | - | - | - |
| *Micromelum minutum* | - | - | - | - | - |
| *Castanopsis tungurrut* | - | - | - | - | - |
| *Quercus sp.* | - | - | - | - | 6.68 |

( ): A number indicating the 5th highest ranking.

### 3.1.7. Biodiversity

Table 10 shows that the species diversity index (H') is in the low to high category at all growth stages. At the seedling level, the highest diversity index values were in plots 4 and 5 at 3.28 and 3.38, respectively. At the sapling to tree level, the highest diversity index values were in plot 5 at 2.12; 2.78; and 2.30, respectively.

**Table 10.** Shannon-Wiener Diversity Index.

| Plot | Growth Level | | | |
|---|---|---|---|---|
| | Seedling | Sapling | Pole | Tree |
| 1 | 1.65 (L) | 1.76 (L) | 1.65 (L) | 1.53 (L) |
| 2 | 2.04 (M) | 1.02 (L) | 1.33 (L) | 1.62 (L) |
| 3 | 1.90 (L) | 1.50 (L) | 1.15 (L) | 2.02 (M) |
| 4 | 3.28 (H) | 2.08 (M) | 2.00 (M) | 1.94 (L) |
| 5 | 3.38 (H) | 2.12 (M) | 2.78 (M) | 2.30 (M) |

L: Low, M: Moderate, H: High.

The value of the species diversity index (H') at the seedling level in plots 4 and 5 is high, while plots 1 to 3 are in the medium to low class (Table 10). The sapling level in plots 1 to 3 shows the value (H') in the low class, while plots 4 and 5 show a medium class. The pole level in plots 1 to 3 showed (H') values in the low class, while plots 4 and 5 showed a medium class. The tree level in plots 1, 2, and 4 showed (H') values in the low class, while plots 3 and 5 showed a medium class. The species diversity index illustrates the level of stability of a standing community.

Table 11 shows that overall, the species evenness index value obtained is high because it is at the value of E > 0.6. The highest species evenness index value was found in plot 5 at the seedling level. The study area in plots 1, 2, and 3 has low species diversity conditions, indicating that species diversity conditions are less stable.

**Table 11.** Evenness Index.

| Plot | Growth Level | | | |
|---|---|---|---|---|
| | Seedling | Sapling | Pole | Tree |
| 1 | 0.92 (H) | 0.98 (H) | 0.92 (H) | 0.70 (H) |
| 2 | 0.88 (H) | 0.93 (H) | 0.96 (H) | 0.74 (H) |
| 3 | 0.91 (H) | 0.93 (H) | 0.83 (H) | 0.79 (H) |
| 4 | 1.32 (H) | 0.87 (H) | 0.91 (H) | 0.81 (H) |
| 5 | 1.36 (H) | 0.97 (H) | 1.27 (H) | 0.90 (H) |

H: High.

The species evenness index (E) had high values in all plots at all growth stages. The evenness index describes the even distribution of individuals of the types of organisms that make up the community and illustrates the stability of a community shown in Table 11. The higher the value of E, the more stable the diversity of species in the community, and the lower the value of E, the lower the stability of species diversity in the community. [21].

Table 12 shows that the richness index value (Dmg) obtained is low (<3.5). The highest species richness index was at the tree level of plot 5 with a Dmg value of 3.43. The value of the species richness index (Dmg) in various observation plots shows low values, as shown in Table 12.

**Table 12.** Richness Index.

| Plot | Growth Level | | | |
|---|---|---|---|---|
| | Seedling | Sapling | Pole | Tree |
| 1 | 1.27 (L) | 1.31 (L) | 1.89 (L) | 2.33 (L) |
| 2 | 1.89 (L) | 0.72 (L) | 1.86 (L) | 2.38 (L) |
| 3 | 1.68 (L) | 1.19 (L) | 1.37 (L) | 3.28 (L) |
| 4 | 2.81 (L) | 2.4 (L) | 2.82 (L) | 2.77 (L) |
| 5 | 2.78 (L) | 1.89 (L) | 2.46 (L) | 3.43 (L) |

L: Low.

Species richness refers to the quantity of species in a community. The number of species in the field determines the size of the richness index. Margalef's richness index divides the number of species by the natural logarithm function, which means that the increase in the quantity of species is inversely proportional to the increase in the quantity of individuals.

Based on Table 13, the species dominance index value for each growth level in all plots is low because the species dominance index value is close to 0. This shows that all plant species found dominate as a whole. Generally, communities or ecosystems with an abundant number of species will have a small quantity of individuals in each of these species.

**Table 13.** Simpson Index.

| Plot | Growth Level | | | |
|---|---|---|---|---|
| | Seedling | Sapling | Pole | Tree |
| 1 | 0.21 | 0.18 | 0.21 | 0.36 |
| 2 | 0.15 | 0.38 | 0.28 | 0.28 |
| 3 | 0.17 | 0.24 | 0.38 | 0.20 |
| 4 | 0.49 | 0.16 | 0.16 | 0.21 |
| 5 | 0.45 | 0.13 | 0.15 | 0.13 |

The highest C value is one that indicates that the dominance pattern is centered on one stand type. Most natural communities contain few species with a larger number of individuals (dominant) and conversely many species are each represented by a few individuals, with a small number of control over growth is greater, thus the pattern of concentration of dominant species will be evenly distributed because the few types allow the number of individuals to grow and develop properly.

The distribution pattern of a species can be known with various distribution indices, one of which is using the Morisita Index. This index is the best method for measuring the distribution pattern of an individual because it does not depend on population density and sample size. Based on the results of the distribution pattern analysis in Table 14, puspa species have a value of Ip> 0, so the distribution pattern is clustered.

**Table 14.** Distribution pattern of puspa (*S. wallichii*) in the study site.

| Species | Morisita Index | Mu | Mc | Ip | Dsitribution Pattern |
|---|---|---|---|---|---|
| Puspa | 1.16 | 795.72 | 5.05 | 0.02 | Clustered |

The distribution pattern of a species can be determined using various distribution indices, one of which is the Morisita Index [22]. This index is the best method for measuring the distribution pattern of an individual because it does not depend on the population density or sample size. Based on the results of the distribution pattern analysis in Table 14, the puspa species had a value of Ip> 0, so the distribution pattern was clustered. Research on the distribution pattern of puspa based on the altitude of the place on the Cetho Temple hiking trail, Mount Lawu, puspa is well planted up to an altitude of 1,950 meters above sea level [23]. Puspa at the research site is at an altitude of 985 - 1,350 meters above sea level, so puspa should develop well according to its characteristics. However, the growth of puspa plants was inhibited at the seedling level in plot 1, the sapling level in plot 2, and the pole level in plot 1. The existence of clustered puspa species indicates good growth of saplings from the surrounding parent trees [24]. The seeds of each plant in a clustered pattern fall, and new saplings occur around the parent tree [25]. This indicates that the natural regeneration of puspa in the core zone of the Cikaniki Resort can occur well.

3.1.8. Stand Structure of *Schima wallichii* (DC.) Korth.

The results of the vegetation analysis of the observation plots showed a distribution of the number of *S. wallichii* stands based on diameter. Forest stand structure is the distribution of individual plants in the crown layer or the distribution of trees per unit area in various diameter classes that assess the relationship between the number of trees and diameter, the distribution of trees by diameter is divided into diameter classes 10-19 cm, 20-29 cm, 30-39 cm, 40-49 cm, 50-59 cm, 60-69 cm, and > 70 cm.

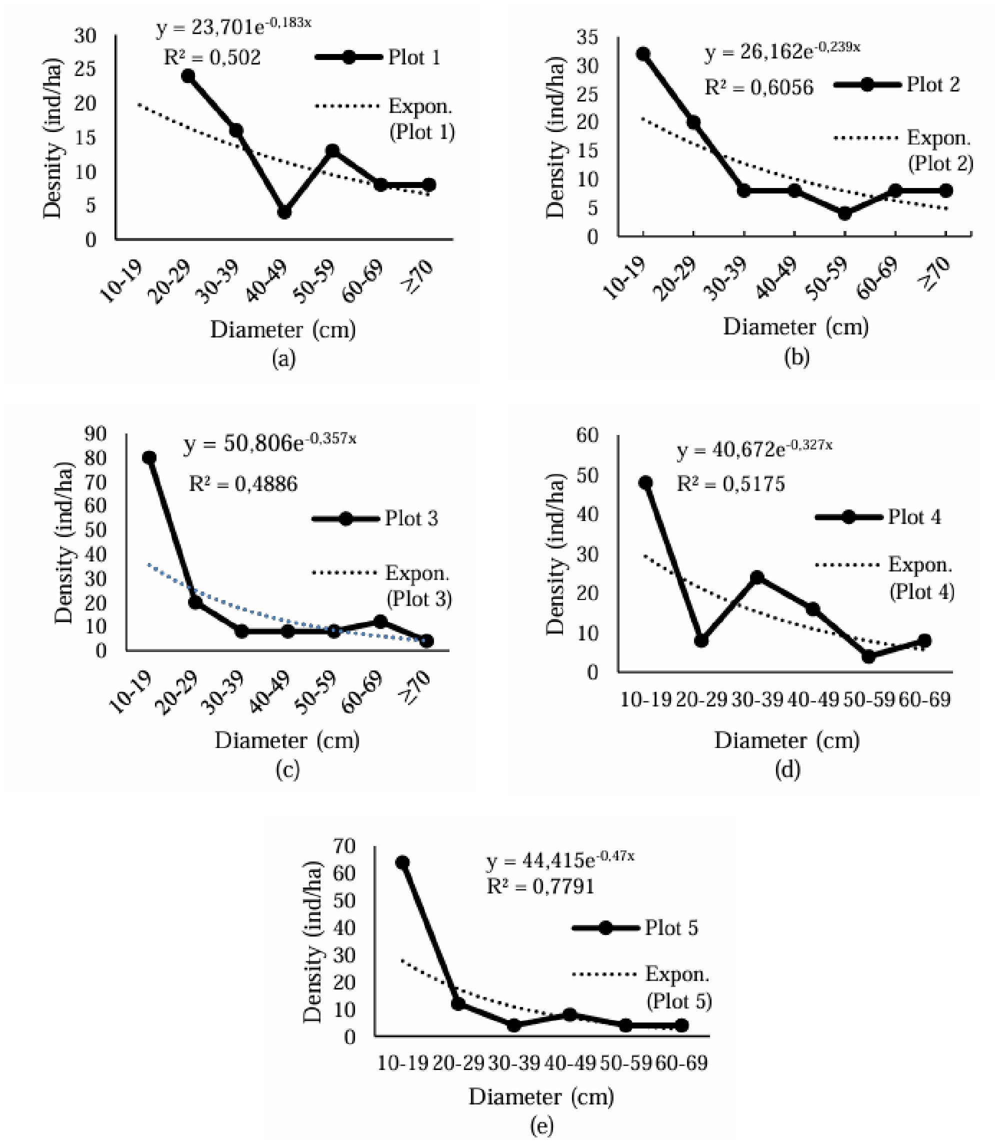
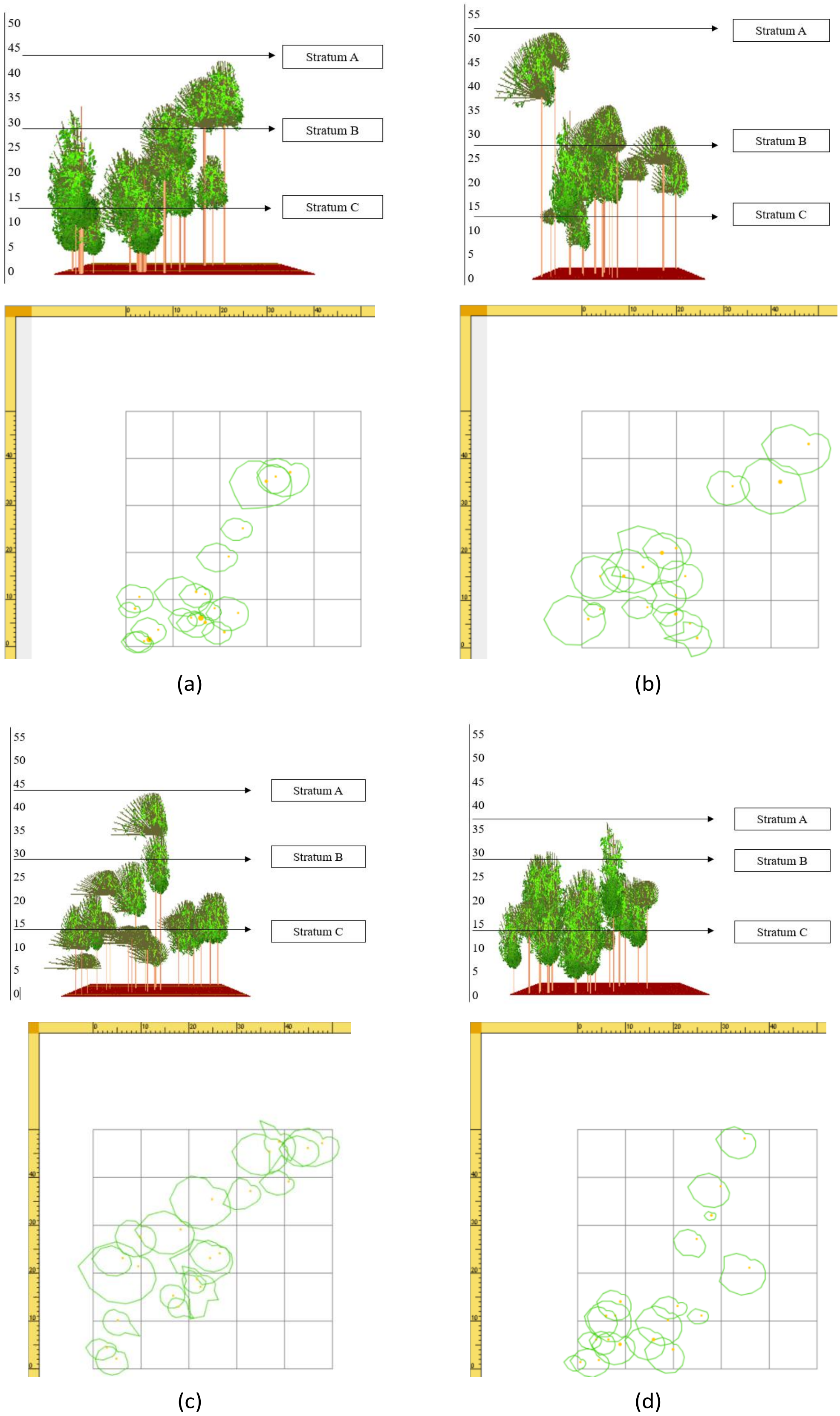
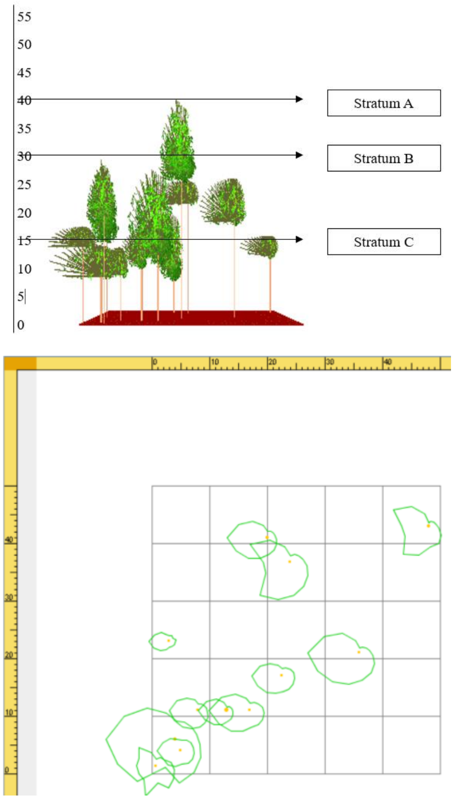



**Figure 4.** Diameter distribution of *S. wallichii* at various plots. (a) = plot 1, (b) = plot 2, (c) = plot 3, (d) = plot 4, (e) = plot 5.


Stratum A
Stratum B
Stratum C
(a)
(b)
(c)
(d)




(e)

**Figure 5.** Crown profile of *S. wallichii* at various plots. (a) = plot 1, (b) = plot 2, (c) = plot 3, (d) = plot 4, (e) = plot 5.

3.1.9. Biophysical Aspects of Research Plots

Information related to biophysical conditions in the core zone of the Resort Cikaniki TNGHS in the observation plot to support the growth of *S. wallichii* (DC.). Table 15 shows that *S. wallichii* is suitable for growing on slightly steep to steep slopes and elevations ranging from 985 to 1,350 meters above sea level [24]. Table 15 shows the study site's biophysical aspects, which consist of temperature, humidity, slope, altitude, litter thickness, and residual organic matter thickness. Temperature and humidity are relatively uniform, and the slope is steep or very steep.

**Table 15.** Biophysical aspect of each plot.

| Plot | Temperature (°C) | Humidity (%) | Slope (%) | Elevation (msl) |
|---|---|---|---|---|
| 1 | 21 | 92 | 16 (S) | 985 |
| 2 | 22 | 88 | 18 (VS) | 1232 |
| 3 | 21 | 92 | 15 (S) | 1336 |
| 4 | 21 | 94 | 12 (S) | 1340 |
| 5 | 21 | 93 | 10 (S) | 1350 |

S: Steep, VS: Very Steep [15] [1].

Table 16 shows that the litter measured in the plant plots ranged from 6.5 to 8.5 cm, with the thickness of organic matter ranging from 4 to 6.8 cm. This supports the regeneration of *S. wallichi*i species as evidenced by the dominance index value of species at various growth stages, which is close to 1, and for the evenness of *S. wallichii* and other species, with moderate to high index values. Furthermore, plot 2 had low values of litter thickness and organic matter due to continuous erosion on very steep slopes. Hence, the soil was shallow, with low organic matter content, high soil density, and low soil porosity. The availability of litter and organic matter as materials and active weathering processes in the soil cycle support sustainable plant growth [24]. The average thickness of litter and organic matter in each plot are shown in Table 16.

**Table 16.** Average thickness of litter and organic matter in each plot.

| Plot | Litter thickness (cm) | Thickness of residual organic matter (cm) |
|---|---|---|
| 1 | 8.3 | 5.5 |
| 2 | 6.5 | 4 |
| 3 | 8.4 | 5.7 |
| 4 | 8.5 | 6.5 |
| 5 | 8 | 6.8 |

### 3.2. Discussion

The dominance of *Schima wallichii* at the tree level suggests that it successfully reached maturity, despite competition at earlier growth stages. However, their low presence at the seedling and sapling levels indicates regeneration challenges. Factors such as competition with *Castanopsis acuminatissima*, steep slopes, and canopy cover may limit puspa recruitment. The variability in density decreased by 56.78% compared to the highest total seedling density. The growing conditions in plot 1, such as elevation and slope, were less favorable for puspa growth at the seedling level. The elevation of the research plot shows that it is at an altitude of 985 m above sea level and the slope is in the steep class of 16%. Puspa can grow optimally at 1,000 meters above sea level [26]. The contribution of puspa species to species composition was low because all research plots were dominated by non-puspa species. Density is related to competition for growing space, light intensity, water, and nutrients required by plants [27]. The higher the density, the higher the competition, which causes puspa to be unable to compete. Regeneration of the *S. wallichii* species at the pole level is still ongoing, as indicated by the IVI value, which is included in the high category. The IVI value at the pole level indicates a change in the composition of the dominant tree species that can occur because of the opening of the forest canopy. Research at Gunung Salak 1 resort shows that the species that dominate the highest IVI at the sapling level include S. wallichii, E. javanicus, and M. alba, which experienced a change in dominance at the pole level, which was replaced by the species *M. triloba*, *S. javanica*, and *S. wallichii* [28]. The opening of the forest canopy is critical for the natural emergence of many plant species that make up the forest canopy. Direct sunlight penetrating the forest floor can affect the growth of plant species, especially low-level plants [29].

Stand structure analysis supports the notion of a well-balanced natural forest with a sustainable regeneration process. The inverted J-curve suggests a dynamic community, in which younger trees continuously replace older individuals. This aligns with the findings in other tropical forests, where regeneration follows similar patterns. The curve of the vegetation analysis results was in the form of an inverted "J" letter, which was also indicated by the negative exponent results (Figure 4). This shows that the forest is in a normal or balanced condition, where the number of individuals at the seedling > sapling > pole > tree level, so that the regeneration process can occur because sufficient young individuals are available. Research in area III, Kuala Penet WKNP, shows the distribution of the graph forming an inverted J curve, indicating the availability of sufficient saplings to support regeneration [30]. The structure or distribution of the number of trees with an inverted J-curve is generally found in tropical rainforests that describe dynamic forest communities [31]. Figure 5 shows that the five plots were dominated by stands with diameter of 10-19 cm, except for plot 1. These results indicate that the natural regeneration process is going well because there are no obstacles to the growth of small trees due to the presence of mature trees caused by crown cover [32]. The canopy cover conditions in the five observation plots showed differences in the canopy strata in some plots. Uniform canopy strata were not observed in any the of plots. Stratification of stands was divided into five stratum classes: stratum A is the highest layer of trees with a total height of more than 30 m, stratum B with a total height of 15–30 m, stratum C with a total height of 4–20 m, stratum D with a total height of 1–4 m, and stratum E below 1 m, which is the lowest layer [33]. *S. wallichii* dominates stratum B (Figure 5). Nonuniform canopy conditions indicate changes due to environmental factors in relation to the light intensity received by the stand.

The biophysical conditions in the study area generally support puspa growth, particularly at higher elevations. However, erosion on steep slopes (as seen in Plot 2) may reduce soil fertility and hinder regeneration. The presence of adequate litter and organic matter in most plots positively contributed to soil health and nutrient availability. The natural distribution of the puspa species in Indonesia is on the island of Java, especially West Java, at an altitude of 1,000 -1,500 meters above sea level [26]. The temperature at the research site in the tropics is 25-30 °C, with relative air humidity in areas in the equatorial region always above 80%. The temperature range is close to the results of Ibadurohmah et al. [18], who reported that puspa plants grow in 89–90% humidity areas. *S. wallichii* is a semi-tolerant species that causes the seedling to transition to the sapling phase and requires considerable sunlight. The variability in density decreased by 56.78% compared to the highest total seedling density. The growing conditions in plot 1, such as elevation and slope, were less favorable for puspa growth during seedling growth. The elevation of the research plot shows that it is at an altitude of 985 m above sea level, and the slope is in the steep class of 16%. Puspa can grow optimally at 1,000 meters above sea level [26]. The contribution of Puspa species to species composition was low because all research plots were dominated by non-Puspa species. Density is related to competition for growing space, light intensity, water, and nutrients required by plants [26]. The higher the density, the higher the competition, which causes Puspa to be unable to compete. While *Schima wallichii* remains dominant at the mature tree stage, conservation strategies should focus on enhancing its regeneration, particularly by improving seedling establishment conditions and reducing competition from other species.

## 4. Conclusions

The composition of the stand species had high to low densities from the seedling to tree level, respectively. All plots in the study location showed a low percentage of *Schima wallichii* species. The IVI value of *Schima wallichii* species at the tree level dominated rank 1, whereas at the sapling level, it was dominated by *Castanopsis acuminatissima*. The structure of forest stands in all plots shows normal natural forest formation and growth as seen from the results of the curve forming an inverted "J." This had a significant impact on the natural regeneration process.

## Author Contributions

**DNA**: Writing - Original Draft Preparation, Writing - Review & Editing, Visualization, Investigation; **PP**: Conceptualization, Writing - Review & Editing, Supervision; **BW**: Conceptualization, Writing – Review & Editing, Supervision

## Conflicts of interest

There are no conflicts to declare

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