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Research Paper

ECOLOGICAL CHARACTERISTICS OF *Castanopsis tungurrut* (BLUME) A. DC ALONG THE ALTITUDINAL GRADIENT IN CIBODAS BIOSPHERE RESERVE

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ARTICLE HIGLIGHTS

- *Castanopsis tungurrut* prefer mid-altitude forest habitat
- The population show clumped pattern on steep slopes
- Vegetation cluster shift with altitudinal gradient
- Cisarua is the highest density of *Castanopsis tungurrut*

Article Information

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ABSTRACT

Castanopsis tungurrut is an endangered species that has received limited attention in terms of research, with scarce ecological information and description of its native distribution area, the Cibodas Biosphere Reserve. This study aimed to investigate the ecological characteristics, vegetation clusters, population structure, and habitat preferences of *C. tungurrut* along the altitudinal gradient. To assess the vegetation, a total of 41 plots were used, with dimensions of 20 × 20 m for trees, 10 × 10 m for poles, 5 × 5 m for saplings, and 2 × 2 m for wildings. The results revealed that the vegetation in four different locations (Cibodas, Bodogol, Cisarua, and Selabintana) within the altitude range of ca. 750 - 1800 meters above sea level (m asl) could be grouped into three distinct zone clusters based on the dominant species. These clusters were named Zone I (ca. 500 - 1,000 m asl), *Castanopsis-Lithocarpus* and *Schima wallichii* forest characterized by the dominance of *Castanopsis tungurrut*, *Maesopsis eminii*, and *Schima wallichii*; Zone II (ca. 1,000 -1,500 m asl), *Castanopsis* and *Schima wallichii* forest, dominated by *Castanopsis* (Fagaceae forest) and *Schima wallichii*; and Zone III (ca.1,500-2,400 m asl), *Schima wallichii*, *Castanopsis*, and *Altingia excelsa* forest where *Schima wallichii*, *Castanopsis*, and *Altingia excelsa* were prevalent. *C. tungurrut* was found to dominate at elevations between ca. 750 and 1,500 m asl, gradually decreasing in higher elevations or even absent. It exhibited a clumped distribution pattern, favoring steep to highly steep habitats. The highest population density was observed in Cisarua (53.1 individuals/ha), followed by Bodogol (25 individuals/ha), Cibodas (10.7 individuals/ha), and Selabintana (5 individuals/ha). These findings emphasize the species' selective habitat preferences, particularly with regard to altitude and slope factors, which should be taken into consideration when planning conservation efforts.

Keywords: endangered species, habitat preference, population

INTRODUCTION

Most species of *Castanopsis* are adaptable to various habitats, soil types, topography, climate variations, and altitudes, contradicting earlier studies that suggested limited distribution (Cheuk & Fischer 2021; Watanabe *et al.* 2021). *C. tungurrut*, like other *Castanopsis* species, shows similar responses to its surroundings and tends to cluster in specific areas, although its distribution becomes more even at an altitude of 1,300 m asl (Nurcahyani 2017).

C. tungurrut exhibits a wide range of altitude tolerance, but its survival rate decreases at altitudes between 1,550 and 1,560 m asl (Fathia *et al.* 2019; Handayani *et al.* 2019). Additionally, other studies have shown that the distribution of different life stages of *C. tungurrut* significantly varies with altitude (Nurcahyani 2017).

C. tungurrut, despite its wide range of altitude tolerance, struggles to adapt to changing environmental conditions, particularly at higher altitudes. This struggle is evident in the species' declining population at higher altitudes. Factors such as elevation and precipitation rates, as discussed by Harapan *et al.* (2022), contribute to the species' distribution.

However, *C. tungurrut* tends to grow individually and does not compete for resources in its habitat, similar to *C. argentea* (Nurcahyani 2017). These findings are intriguing because studies conducted in the mountain forests of Java observed *C. tungurrut* growing alongside *C. argentea*, *C. javanica*, *Schima wallichii*, and *Macropanax dispermus* at altitudes ranging from 1,400 to 1,600 m asl, mostly without any apparent association. Given that *C. tungurrut* exhibits significant variation in its distribution with altitude, further replication of this study in environments with similar ecological characteristics, such as elevation, will provide deeper insight into its ecological preferences and survival strategies.

The objective of the study was to investigate how the ecological characteristics of the altitudinal gradient affect the vegetation structure, habitat preference, and population structure of *C. tungurrut* in the Cibodas Biosphere Reserve. Investigating whether the patterns observed in the Cibodas Biosphere Reserve are consistent across other location with similar environmental conditions will not only confirm the generality of the findings, but also strengthen the overall validity of the study, providing a more comprehensive understanding of its habitat preferences and population structure.

MATERIALS AND METHODS

Study Area

The Cibodas Biosphere Reserve, situated in West Java Province, Indonesia, is a designated protected area known for its rich biodiversity. It spans across three regencies, namely Cianjur, Bogor, and Sukabumi, and is home to a variety of plant and animal species, including the endangered *Castanopsis tungurrut*. In this study, we focused on four representative locations within the reserve, namely Cibodas (CBS), Bodogol (BDL), Selabintana (SBL), and Cisarua (CSR) (Fig. 1). Cibodas has slopes ranging from 11% to 42%, an elevation 1,346 to 1,830 m asl, and temperatures between 15 °C and 18 °C. Cisarua, with a slightly warmer climate (17 °C to 19 °C), features slopes from 11% to 55% and an altitude 1,157 to 1,500 m asl. Selabintana offers moderate conditions with slopes between 7% and 35%, an elevation of 1,163 to 1,829 m asl, and temperatures ranging from 16 °C to 18 °C. Lastly, Bodogol, at a lower altitude (759 to 1,104 m asl), experiences warmer temperature (20 °C to 21 °C) and steeper slopes ranging from 20% to 69%.

The study encompassed locations spanning an elevation range of ca. 750 to 1,800 m asl, which is a crucial factor for the presence of *C. tungurrut*. Previous research has demonstrated that variations in altitude significantly affect temperature and nutrient availability, which in turn can impact the distribution pattern patterns and population dynamics of the target species (Hilwan & Irfani 2018; Fathia *et al.* 2019).

Methods

The population structure and distribution of the species in all locations were assessed using the plot method. The plot sizes varied depending on the life stage of the species: 20 × 20 m for trees, 10 × 10 m for poles, 5 × 5 m for saplings, and 2 × 2 m for wildings (Fig. 2).

In each plot, the names and numbers of species were recorded for wildings, saplings, poles, and trees. The tree category included woody plants that are over 2 meters tall and have a stem diameter of at least 5 cm. Poles, on the other hand, refer to stands with a diameter greater than 2.5 cm but less than 5 cm (Fathia *et al.* 2019). Saplings are stands with a diameter at breast height (DBH) less than 2.5 cm and a height of at least 130 cm, while wildings are individuals with a height below 130 cm (Frei *et al.* 2022).

The data were analyzed to determine the frequency, density, and basal area. These parameters were then used to calculate the relative values, which were summed up to obtain the Importance Value Index (IVI) for both trees and poles (Pandey & Lodhiyal 2015). Further analysis included the assessment of the dominance index, Margalef's index, Shannon index, Evenness index, and Morisita index (which represents the distribution pattern).

The PAST software was used to generate a dendrogram representing the clustering of vegetation among different locations to identify the cluster of vegetation plots based on the basal area (BA) values of woody species. The clustering was performed based on the basal area and utilized the unweighted pair group method with arithmetic mean (UPGMA) and Euclidean distance as an indicator of similarity among the plots. This approach aimed to identify distinct plant communities within the forest landscape.

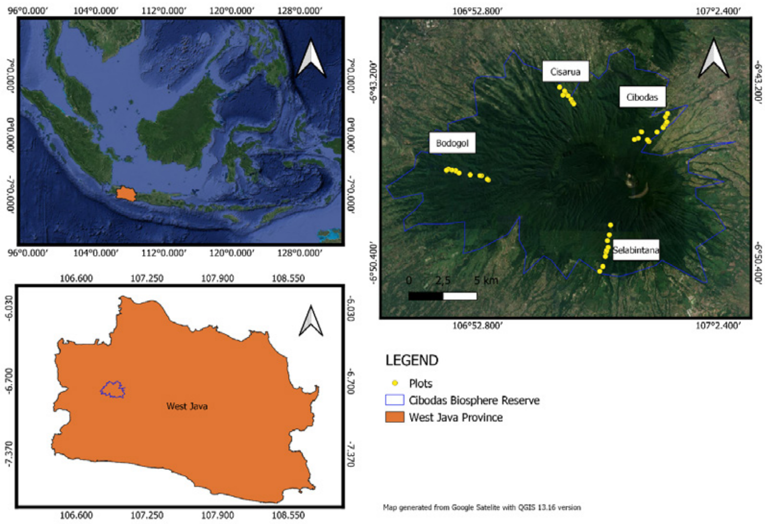

Figure 1 Map displaying locations distribution based on the altitudinal gradient
Notes: CBS = Cibodas; CSR = Cisarua; SBL = Selabintana; BDL = Bodogol.

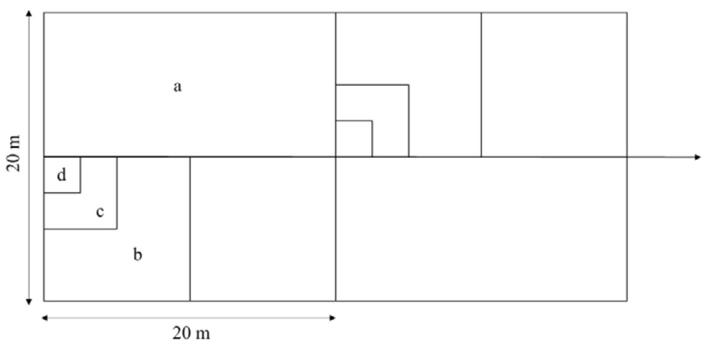

Figure 2 Plot diagram for vegetation analysis
Notes: a = Plots measuring 20 × 20 m for trees; b = 10 × 10 m for poles; c = 5 × 5 m for saplings; d = 2 × 2 m for wildings.

RESULTS AND DISCUSSION

Floristic Composition

The scope of this study, which encompassed 41 plots across various locations with altitudinal gradients, was significant. The distribution of plots was as follows: 14 in Cibodas, 8 in Cisarua, 9 in Selabintana, and 10 in Bodogol (Fig. 1). The variations in plot numbers were due to practical constraints such as accessibility and time. Furthermore, the study was limited to specific elevations in some locations, preventing access to higher or lower elevations.

The floristic composition based on life stages and locations, showing variations in the Importance Value Index (IVI) and the number of species are presented in Tables 1, 2, 3, and 4. Notably, *Schima wallichii* emerged as the dominant species across all locations and life stages, exerting a significant influence on the forest structure. In contrast, *Castanopsis tungurrut* was found to be absent in specific locations and life stages.

Bodogol represents the colline subzone (500 - 1,000 m asl) and the submontane zone (1,000 - 1,500 m asl), as referred to by Sadili *et al.* (2023). The colline zone is a zone characterized by the physiognomy of the vegetation, which is described as follows: a lofty, closed tropical forest, with a canopy height of 40 - 50 m, multistorey with higher emergent trees (Prawiradilaga 2017). The submontane zone is characterized by the physiognomy of high-stemmed, closed, multistorey forests with a canopy height of 30 - 40 m. This location represents the transition zone between the lowland and submontane zones. The most dominant species was *Schima wallichii*, followed by *C. tungurrut*. Several factors affect the dominance of the species, including sporadic regeneration and a long lifespan, which makes it both shade-tolerant and intolerant (Tang *et al.* 2020). In addition, the existence of invasive plants in a location with robust regenerative capacity for the exotic species *Maesopsis eminii* and the presence of the pioneer species Mallotus sp. contribute to the general structure of the forest, including the presence of the native species *C. tungurrut*.

In Bodogol, the *C. tungurrut* distribution and coexistence involve complex interactions between life stages, environmental factors, and species characteristics. There are changes between the number of early stages and the mature tree of *C. tungurrut*. Nguyen *et al.* (2016) revealed that spatial patterns and interspecific associations change with life stages, with aggregation increasing and positive association decreasing as trees mature. In addition, it is probably related with the intense resource competition, which causes changes in species composition as the forest structure as also described by Yu *et al.* (2020), where distinct plant species' relative dominance at distinct stages of development, such as wilding, sapling, pole, and tree, has a substantial impact on the general structure and make-up of forests.

The submontane (1,000 - 1,500 m asl) and montane zone (1,500 - 2,400 m asl) are represented by Cibodas (CBS), a topographical location known for its steep inclination and horizontal slope range of 10 - 42%. Furthermore, Sudarmono (2018) defines the submontane zone as characterized by the physiognomy of high-stemmed, closed, multistorey forest and a canopy of 30 - 40 m. In comparison, montane zone is defined as closed forest canopy 25 - 30 m, storey, many epiphytes but less lianas. In this location, *Schima wallichii* exhibited the highest Importance Value Index (IVI) of 57.6, indicating its dominance over the other four species. Interestingly, this finding aligns with the observed tree growth pattern in Bodogol. Therefore, the dominance of *Schima wallichii* in both locations can be attributed to favorable climatic and ecological conditions that support its growth and development. In contrast, *C. tungurrut* was less dominant in this location, which is probably related to the favorable climatic and ecological conditions or even the presence of invasive species.

In this location, *C. tungurrut*, despite being in its altitude range (1,346 - 1,830 m asl), was not dominant and was rarely found. This is not due to unfavorable conditions, but rather the existence of invasive alien species such as *Chimonobambusa quadrangularis* (Franceschi) Makino and *Cestrum aurantiacum* Lindl. These invasive species can significantly alter the native ecosystem, posing a serious threat to the area's biodiversity.

Table 1 Floristic composition based on the IVI in Bodogol (ca. 750 - 1,104 m asl)

	Tree	Pole	Sapling	Wilding
Species number	83	38	39	33
Family number	40	23	25	21
Shannon Diversity Index	3.86	3.54	3.45	3.31
Margalef's Index	14.3	9.45	9.1	7.72
Evennes Index	0.87	0.97	0.94	0.94
Dominant Species	*Schima wallichii* Choisy (46.1)	*Syzygium rostratum* (Blume)DC. (15.9)	*Casearia coriacea* Vent. (15.2)	*Maesopsis eminii* Engl. (13.7)
	Castanopsis tungurrut (Blume) A.DC. (20.4)	*Aglaia* sp. (12.9)	*Magnolia liliifera* (L.) Baill.(13.7)	*Castanopsis tungurrut* (Blume) A.DC. (12.7)
	Syzygium rostratum (Blume) DC. (18.7)	*Villebrunea rubescens* (Blume)Wedd. (12.3)	*Ficus* sp.(13)	*Homalanthus populneus* (Geiseler) (12.2)
	Lithocarpus pseudomoluccus (Blume) DC. (16.6)	*Ficus sinuata* Thunb. (11.7)	*Sterculia* sp 1 (11.4)	*Calamus reinwardtii* Mart.(11.1)
	Maesopsis eminii Engl. (13.2)	*Mallotus* sp. (11.3)	*Lithocarpus pseudomoluccus* (Blume) Rehder (10.2)	*Clidemia hirta* (L.) D. Don (11.1)

Table 2 Floristic composition based on the IVI in Cibodas (ca. 1,346 - 1,830 m asl)

	Tree	Pole	Sapling	Wilding
Species number	72	56	76	67
Family number	34	31	35	38
Shannon Diversity Index	3.69	3.54	3.75	3.51
Margalef's Index	11.67	10.78	12.83	11.58
Evennes Index	0.86	0.88	0.86	0.84
Dominant Species	*Schima wallichii* Choisy (57.6)	*Cestrum aurantiacum* Lindl. (31.8)	*Cestrum aurantiacum* Lindl. (12.3)	*Lasianthus laevigatus* Blume (17.7)
	Macropanax concinnus Miq (20.8)	*Lasianthus stercorarius* Blume (30.5)	*Lasianthus stercorarius* Blume (11.1)	*Psychotria montana* Blume (10.3)
	Dacrycarpus imbricatus (Blume)de Laub. (18.2)	*Polyalthia subcordata* (Blume) Blume (30)	*Freycinetia insignis* Blume (7.4)	*Cyrtandra picta Blume* (8)
	Castanopsis javanica (Blume)A.DC. (17.9)	*Turpinia sphaerocarpa* Hassk.(25.6)	*Polyalthia subcordata* (Blume) Blume (7.1)	*Strobilanthes cernua* Blume (7.9)
	Villebrunea rubescens (Blume) Wedd. (16.4)	*Macropanax undulatus* (Wall.ex G.Donn) Seem (18.1)	*Bartlettina sordida* (Less.) R.M.King & H.Rob. (6.6)	*Trevesia sundaica* Miq. (7.3)

Cisarua represents the submontane zone, with a slope ranging from 11% to 55%. This slope range is significant as it influences the distribution of tree species and the overall ecological characteristics of the area. In general, Cisarua shares similar characteristics with Bodogol, as both are located at the Pangrango mountain ridge. In terms of vegetation, Cisarua had the lowest diversity of tree species, with only 47 species present. Among these, the dominant species in the tree phase at this location were *Castanopsis tungurrut*, *Villebrunea rubescencs*, *Cinchona pubescens*, *Schima wallichii*, and *Castanopsis javanica*, with Importance Value Index (IVI) values of 77.9, 29.6, 23.9, 12.4, and 11.3, respectively. *Villebrunea rubescens* had the highest density, with 59.3 individuals per hectare (indv/ha), followed by *Cinchona pubescens*, *Castanopsis tungurrut*, and *Schima wallichii*, with densities of 56.2, 53.1, and 21.8 indv/ha, respectively. In comparison to dominant tree species in other locations like Bodogol and Cibodas, *Schima wallichii* remains the dominant species in the tree phase category. However, even though Cisarua is at the ideal altitude for *C. tungurrut* habitat, the existence of wilding (young trees that grow without human intervention) and sapling (a young tree) is rarely found in this location. This rarity of wilding and sapling could be due to the existence of *Cinchona pubescens* plantations which decreases the level of plant diversity and homogenization of forest areas. We can conclude it from the high importance value index in the tree, pole and sapling phases of *Cinchona pubescens*.

The tree vegetation in Selabintana was mainly dominated by *Schima wallichii*, *Macropanax dispermus*, *Villebrunea rubescens*, *Neolitsea javanica*, and *Acronychia pedunculata*. *Lasianthus* sp. dominated the pole, sapling, and wilding stages. The diversity index across different life stages in this location showed no significant differences, with values of 3.46 for trees, 3.18 for poles, 3.12 for saplings, and 2.86 for wildings. These indices demonstrate a decrease in diversity from trees to wildings, as well as a decrease in the Margalef's index (indicating richness). This suggests a need for further investigation into the factors influencing the diversity of tree vegetation in Selabintana.

When compared to the other three locations, Selabintana shares a similarity with Cibodas in terms of the low dominance of *C. tungurrut*, which is only prevalent in the sapling phase. This unique ecological pattern can be attributed to a variety of factors such as forest gaps, topography, anthropogenic impacts, seed dispersal disruption, and global climate change. Previous studies have shown how these factors can limit the regeneration of certain species (Dey *et al.* 2019).

Table 3 Floristic composition based on the IVI in Cisarua (ca. 1,157 - 1,500 m asl)

	Tree	**Pole**	**Sapling**	**Wilding**
Species number	47	30	42	22
Family number	26	21	27	21
Shannon Diversity Index	3.42	3.16	3.43	2.19
Margalef's Index	8.89	7.34	8.77	4.67
Evennes Index	0.89	0.93	0.92	0.71
Dominant Species	*Castanopsis tungurrut* (Blume) A.DC. (77.9)	*Cinchona pubescens* Vahl (64)	*Cinchona pubescens* Vahl (16.6)	*Elatostema strigosum* Hassk. (52,9)
	Villebrunea rubescens (Blume) Wedd. (29.6)	Antidesma tetrandrum Blume (42.4)	*Magnolia liliifera* (L.) Baill. (14.7)	*Pinanga javana* Blume (15.8)
	Cinchona pubescens Vahl (23.9)	*Ficus ribes* Reinw.ex Blume (18)	*Castanopsis tungurrut* (Blume) A.DC. (9)	*Symplocos fasciculata* Zoll. (12,5)
	Schima wallichii Choisy (12.4)	*Macropanax dispermus* (Blume) Kunze (16.6)	*Ficus cuspidata* Reinw. ex Blume (8.2)	*Polyalthia subcordata* (Blume) Blume (11.3)
	Castanopsis javanica (Blume) A.DC (11.3)	*Camellia sinensis* (L.) Kuntze (15.9)	*Dendrocnide stimulans* (L.f.) Chew (8.1)	*Psychotria montana* Blume (10.2)

Table 4 Floristic composition based on the IVI in Selabintana (ca. 1,163 - 1,829 m asl)

	Tree	Pole	Sapling	Wilding
Species number	54	29	35	26
Family number	31	21	26	23
Shannon Diversity Index	3.46	3.18	3.12	2.86
Margalef's Index	9.82	7	7.32	5.73
Evennes Index	0.86	0.94	0.87	0.87
Dominant Species	*Schima wallichii* Choisy (80.2)	*Lasianthus laevigatus* Blume (30.4)	*Lasianthus stercorarius* Blume (28.5)	*Lasianthus laevigatus* Blume (27.9)
	Macropanax dispermus (Blume) Kunze (24.3)	*Macropanax dispermus* (Blume) Kunze (26.2)	*Dysoxylum alliaceum* (Blume) Blume (16.2)	*Symplocos costata* Choisy ex Zoll. (18.5)
	Villebrunea rubescens (Blume) Wedd. (22.7)	*Magnolia liliifera* (L.) Baill. (25.8)	*Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Sweet (12.4)	*Strobilanthes cernua* (15.5)
	Neolitsea javanica (15.6)	*Itea* sp. (24.9)	*Polyalthia subcordata* (Blume) Blume (9.5)	*Helicia serrata* Blume (13.2)
	Acronychia pedunculata (L.) Miq. (15)	*Villebrunea rubescens* (Blume) Wedd. (22.1)	*Castanopsis tungurrut* (Blume) A.DC. (8.5)	*Smilax* sp. (11.9)

Cluster of Vegetation along the Altitudinal Gradient based on Tree Basal Area

The dendrogram (Fig. 3) collates all locations (Cibodas, Selabintana, Cisarua, and Bodogol) into three distinct zones: the colline zone, submontane zone, and montane zone. This clustering was determined by considering the basal area of the tree stage and the altitudinal gradient of the plots. We excluded the Pole, Sapling, and Wilding stages.

An overview of four different locations was analyzed to see the combinations of the species found, based on the results shown in Figure 3. *Castanopsis* species were present in all three distinct zones and dominated in all zones, but their specific composition and dominance varied across the altitudinal gradient. This variation is a clear indication of the significant role that environmental factors play in the distribution of species. It can be inferred that zones I, II, and III serve as ideal habitats for *Castanopsis*, demonstrating the adaptability of these species to diverse environmental conditions along the altitudinal gradient.

Zone I (500 - 1,000 m asl) – *Castanopsis-Lithocarpus* and *Schima wallichii* forest. The clustering analysis revealed that within the colline zone, there are four clusters with a similarity level of around 0.3. Specifically, plot BDL 10 was clustered with BDL 3, while BDL 2 was clustered with dominant species such as *Castanopsis tungurrut*, *Lithocarpus pseudomoluccus*, *Maesopsis eminii*, *Schima wallichii*, and *Aglaia* sp. This zone comprises six plots located in Bodogol (BDL), as it is the only location with vegetation below 1,000 m asl. A total of 64 tree species were recorded in this zone, with dominant species based on Basal Area (BA), including *Castanopsis tungurrut*, *Maesopsis eminii*, *Schima wallichii*, *Lithocarpus pseudomoluccus*, and *Aglaia* sp. The location is primarily situated on a ridge with deep valleys, which limits species dispersion and exposes them directly to wind effects. On the other hand, BDL 1, BDL 9, and BDL 8 represented transition zones from lowland to submontane zones. Dominant species in these transition zones included *Maesopsis eminii*, *Schima wallichii*, *Lindera polyantha*, *Altingia excelsa*, and *Castanopsis javanica*.

Zone II (1,000 - 1,500 m asl) – *Castanopsis* and *Schima wallichii* forest, the submontane cluster zone, known as the big cluster, represented a specific altitude range. Within this range, CBS 13 and SBL1 formed a cluster with a 0.5 similarity and a slope range of 10 - 30%. On the other hand, CBS 12 and CSR3 formed a cluster with a 0.4 similarity and a slope range of 12 - 25%. Overall, this zone was home to 110 species, with ten dominant species including *Castanopsis argentea*, *Castanopsis tungurrut*, *Castanopsis javanica*, *Schima wallichii*, *Altingia excelsa*, *Villebrunea rubescens*, *Castanopsis acuminatissima*, *Ostodes paniculate*, *Helicia serrata*, and *Syzygium rostratum*. These *Castanopsis* species thrive in this altitudinal zone due to favorable environmental conditions that support their growth and regeneration. The temperature gradient and cation exchange capacity (CEC) show a positive correlation, indicating that lower temperatures and higher altitudes promote the distribution and germination capacity of *Castanopsis argentea* (Hilwan & Irfani 2018).

Zone III (1,500 - 2,400 m asl) – *Schima wallichii*, *Castanopsis*, *Altingia excelsa* forest. The montane zone, ranging from 1,500 m asl to 2,400 m asl, is divided into eight clusters with a similarity of 0.2. A total of 69 species were identified in this zone. Within the montane zone, CBS5, CBS6, CBS3, CBS1, and CBS3 formed a large cluster compared to other plots in this altitude range. The dominant species in this zone included *Schima wallichii*, *Castanopsis javanica*, *Dacrycarpus imbricatus*, *Castanopsis argentea*, *Altingia excelsa*, *Castanopsis tungurrut*, *Macropanax dispermus*, *Macropanax concinnus*, *Syzygium rostratum*, and *Acronychia pedunculata*.

Some species overlap in specific locations, indicating a wide distribution and adaptation to different zones. Notably, species such as *Schima wallichii* and *Villebrunea rubescens* were found across the altitudinal gradient from 800 m asl to 1,800 m asl.

Among the three zones being considered, the submontane zone, ranging from 1,000 m asl to 1,500 m asl, stands out with the highest level of diversity. This can be attributed to several factors, including the establishment of a greater number of plots and favorable environmental conditions that provide suitable temperatures, nutrient availability, and water supply, supporting a wide range of species. In contrast, the montane zone has a lower habitat suitability, resulting in reduced species richness in the area. Additional research conducted by Sang (2009) suggested that soil characteristics significantly influence species richness at medium altitudes, while temperature becomes more influential at higher elevations, and water availability plays a critical role at lower elevations. These factors contribute to the higher diversity observed in the submontane zone compared to the other zones.

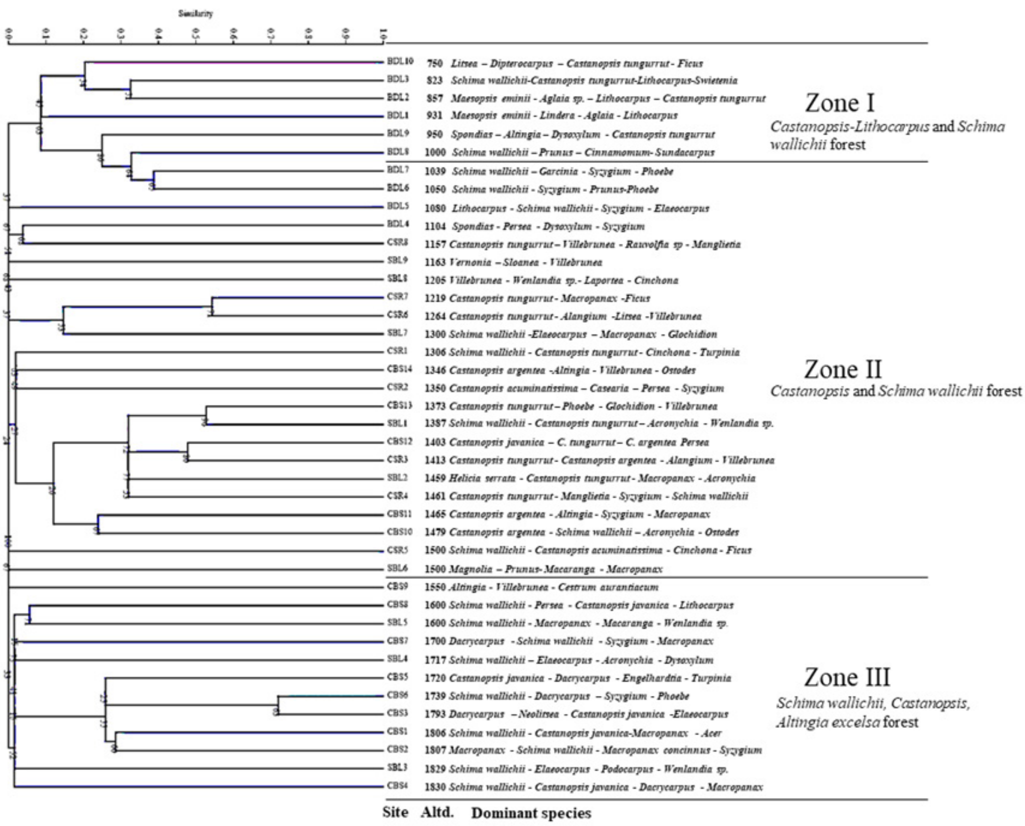

Figure 3 Cluster dendrogram of 41 sampling in Cibodas Biosphere Reserve generated by PAST software based on the basal area of tree species on the location by UPGMA using Bray-Curtis index of similarity, with Copphen correlation of 0.3464

Notes: Three altitudinal tree vegetation zones were identified from 750 - 1,830 m asl. Zone I (500 - 1000 m asl) – *Castanopsis-Lithocarpus* and *Schima wallichii* forest; Zone II (1,000 - 1,500 m asl) – *Castanopsis* and *Schima wallichii* forest; and Zone III (1,500 - 2,400 m asl) – *Schima wallichii*, *Castanopsis*, *Altingia excelsa* forest.

Population Structure and Habitat Preferences of *C. tungurrut*

The population structure of *C. tungurrut* exhibited an interrupted inverted "J" curve (Fig. 4), indicating a reasonably good regeneration of the species. Similar interrupted inverted "J" curves have been observed in studies on plant diversity in Ethiopia by Mekonen *et al.* (2015), indicating successful regeneration in specific areas. However, in this case, the number of poles is lower than that of mature trees, indicating disturbance in this regeneration phase.

C. tungurrut had a limited distribution range within a specific altitude range. The tree was found to occur between 750 and 1,500 m asl, but it was absent at higher altitudes. Out of the 41 plots examined, *C. tungurrut* dominated in 10 plots. These plots included BDL3 (823 m), CSR 7 (1,219 m), CSR 6 (1,264 m), CSR 1 (1,306 m), CBS13 (1,373 m), SBL 1 (1,387 m), CBS 12 (1,403 m), CSR3 (1,413 m), SBL2 (1,459 m), and CSR 4 (1,461 m). The density of *C. tungurrut* varied across different locations, with Bodogol having a density of 25 individuals/ha, Cibodas with 10.7 individuals/ha, Cisarua with 53.1 individuals/ha, and Selabintana with five individuals/ha.

The slope percentage, revealed that *C. tungurrut* species tends to be more abundant in areas with steep to extremely steep slopes, ranging from 25% to greater than 45% (Table 5). The slope category refers to the Ministerial Decree Agriculture of the Republic of Indonesia No. 837/Kpts/um/11/1980 about Criteria and procedures for designating protected forests.

In addition, the distribution pattern of *C. tungurrut* across all 4 locations exhibited a clumped distribution with a non-uniform distribution (Table 6).

Based on the standardized Morisita index, *C. tungurrut* exhibited a clumped distribution pattern, similar to that of *Castanopsis argentea* observed in Gede Pangrango National Park (Hilwan & Irfani 2018). This clumping pattern is commonly observed in natural habitats and serves as an adaptation to the availability of nutrients and seed dispersal. Furthermore, plant clumping can impact plant competitiveness. Eccles *et al.* (2001) found that clumped plants tend to outperform isolated plants, while Béland & Baldocchi (2020) discovered that clumping factor values are higher in wet areas compared to dry ones.

However, Callaway (1997) found that both competition and facilitation play significant roles in plant communities. These findings suggest that while clumping is one factor that may influence plant competitiveness, it is just one of several variables to consider when assessing plant competitiveness. The influence of plant clumping on plant competitiveness is complex and context-dependent.

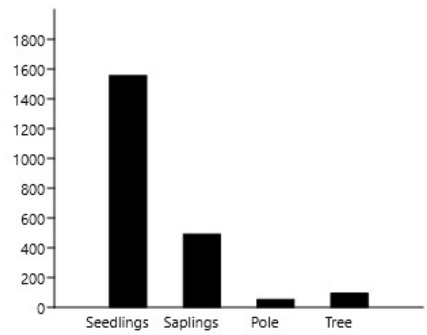

Figure 4 The population structure of *C. tungurrut* of all locations

Table 5 Distribution of *C. tungurrut* tree on slope category

Slope (%)	Number of trees	Category
0 - < 8	1	Flat
8- < 15	5	Sloping
15 - < 25	7	Rather steep
25 - < 45	12	Steep
> 45	13	Extremely steep

Table 6 Morisita Index and distribution pattern of *C. tungurrut* of all locations

Index Dispersion Morisita (Id)	Uniform index (Mu)	Clumped index (Mc)	Standardized Morisita index (Ip)	Distribution pattern
1.1	2.63	1.68	0.07	Clumped

CONCLUSION

The assessment conducted at four locations within Cibodas Biosphere Reserve revealed variations in the number of species and the presence of *C. tungurrut*. These variations were observed in relation to altitude and the presence of invasive alien species. The ideal habitat for *C. tungurrut* was found to be within the altitude range of 750 to 1,500 m asl or in zones I and II, particularly in areas with sloping terrain and abundant vegetation. As the altitude range deviated from this ideal, either lower or higher, the species was either absent or decreased in abundance.

C. tungurrut, a unique species, showed a distinct preference for growing on steep to extremely steep slopes, as opposed to flat areas. This unique characteristic of the species is intriguing and warrants further investigation. It is likely that the species is more inclined to inhabit locations with steeper terrain. The species exhibited a clumped distribution pattern with an interrupted inverted "J" curve, indicating that the regeneration of the species is hindered, potentially due to natural disasters or human activities.

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