BIODIVERSITAS
Volume 25, Number 1, January 2024
Pages: 249-256

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250128

Structure and distribution of palm tree species in *Altingia excelsa* planted forest in Gunung Gede Pangrango National Park, West Java, Indonesia

ASEP SADILI[1,3,♥], ANDI SALAMAH[2,♥♥], EDI MIRMANTO[3], KUSWATA KARTAWINATA[4]

[1]Graduate Program, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia. Jl. Prof. DR. Sudjono D. Pusponegoro, Kampus UI Depok, Depok 16424, West Java, Indonesia. Tel./fax.:+62-2720163, ♥email: asep016@brin.go.id
[2]Cellular and Molecular Mechanisms in Biological System Research Group, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia. Jl. Prof. DR. Sudjono D. Pusponegoro, Kampus UI Depok, Depok 16424, West Java, Indonesia. Tel./fax.: +62-2720163, ♥♥email: salamah@sci.ui.ac.id
[3]Research Center for Ecology and Ethnobiology, National Research and Innovation Agency. Jl. Raya Jakarta-Bogor Km 46, Cibinong, Bogor 16911, West Java, Indonesia
[4]Integrative Research Center, The Field Museum. 1400 S Lake Shore Drive, Chicago, IL 60605, USA

Manuscript received: 7 December 2023. Revision accepted: 24 January 2024.

Abstract. *Sadili A, Salamah A, Mirmanto E, Kartawinata K. 2024. Structure and distribution of palm tree species in* Altingia excelsa *planted forest in Gunung Gede Pangrango National Park, West Java, Indonesia. Biodiversitas 25: 249-256.* Gunung Gede Pangrango National Park (GGPNP) is a conservation area consisting of natural forest and planted forest, including *Altingia excelsa* Noronha stands which were planted in 1925. As a result of secondary succession, various plants grow under *A. excelsa* stands, including palm tree species (Arecaceae). This research was conducted to determine the structure, population, and distribution patterns of palm trees in *A. excelsa* planted forest in Bodogol Resort, GGPNP. The data were collected by establishing a one-hectare plot divided into 100 subplots of 10 m × 10 m. Palm tree species with a Diameter at Breast Height (DBH) ≥3 cm were measured, and the tree heights were estimated. Data analysis included Relative Dominance (RDo), Relative Density (RDen), Relative Frequency (RF), Importance Value Index (IVI), Shannon Wiener Diversity Index (H'), Evenness Index (E), Index of Dispersion (ID), analysis of variance values (S^2) and Chi-square analysis (Q). The study results recorded four species from three genera of Arecaceae which consisted of 171 trees with a total Basal Area (BA) of 0.63 m^2/ha. *Pinanga coronata* (Blume ex Mart.) Blume was the most dominant palm tree species with IVI of 156.89%), followed by *Pinanga* sp. (IVI=72.04%), *Caryota rumphiana* Mart. (IVI=55.77%), and *Arenga pinnata* (Wurmb) Merr. (IVI=15.38%). In term of diameter class distribution, *P. coronata* and *Pinanga* sp. were regenerating well. Spatial distribution patterns of *A. pinnata, C. rumphiana*, and *Pinanga* sp. were regular, while *P. coronata* was clustered. Periodical studies in the future to determine the mortality and natality of the palm trees are recommended to understand the dynamics of vegetation succession.

Keywords: Bodogol, diversity, palm trees, regeneration, spatial pattern

INTRODUCTION

The concept of biosphere reserve is rapidly emerging for the conservation and sustainable management of natural resources. Biosphere reserves aim to protect and support all living things in the reserve in an integrative manner by serving as the world's lungs, economic resources, flora-fauna habitat, germplasm sources, water storage, disaster control, maintenance of soil fertility, and reduction of air and water pollution (Amenu 2017). The first step to develop and manage biosphere reserve sustainably and wisely is by providing a comprehensive understanding on ecological aspect of the reserve including information on the structure, composition, and distribution patterns of plants in the reserve (Trogisch et al. 2021; Haq et al. 2023).

One of the biosphere reserves in Indonesia is Cibodas Biosphere Reserve, with the core area being the Gunung Gede Pangrango National Park (GGPNP). The forest area in GGPNP covers three districts in West Java Province, namely Bogor, Cianjur, and Sukabumi. GGPNP has been pioneering various research activities on the theme of mountain flora of Indonesia. The results of the research have been widely used to develop policies and management strategies for GGPNP and other national parks located in mountainous areas in Indonesia. Based on the Decree of the Director General of Forest Protection and Nature Conservation (PHKA) Number 39/IVKKBHL/2011 dated 22 February 2011, the area of GGPNP is 22,851.03 hectares. Then, referring to the Decree of the Minister of Forestry Number SK.3683/Menhut-VII/KUH/2014 dated 8 May 2014, the area of GGPNP is enlarged to 24,270.80 ha. Therefore, with the issuance of this decree in 2014, the TGGGP area is expanded to include the area previously managed by State Forest Company (Perhutani) in the form of planted forest stands and degraded areas in several locations (Ario et al. 2020).

Forest area management in GGPNP is divided into several resorts, one of which is Bodogol Resort. Bodogol Resort is among the few remaining lowland forests of Java, thus the existence of this resort is important in the context of biodiversity conservation. Besides that, Bodogol is also frequently used for nature conservation education for students and general public. However, biodiversity information in this resort is still limited because previous research in GGPNP was mostly conducted in the mountain forests around Cibodas to the peaks of Mount Gede and Mount Pangrango (Kartawinata and Sudarmonowati 2022). Referring to Sadili et al. (2023), there are three states of forest ecosystems in Bodogol, namely natural forests, planted forests, and restoration forests. In these three states of forests, not many studies have been carried out regarding the plants' diversity, composition, and structure. Therefore, the latest information regarding biodiversity, structure and forest composition in Bodogol is very much needed.

Four tree species are planted in Bodogol to produce wood and resin, including *Pinus merkusii* Jungh. & de Vriese, *Altingia excelsa* Noronha, *Agathis dammara* (Dum.Cours.) Poir., and *Schima walichii* (DC.) Korth.. Under the stands of the four planted trees, various species of plants resulting from secondary succession have grown. One plant group of naturally growing vegetation in Bodogol is palms (Arecaceae family) which grow along the *A. excelsa* planted stands. Palms are among the most interesting groups of higher plants, living naturally in all areas of tropical and subtropical forests, including Indonesia. Indonesia is a country with a high diversity of palm species. As many as 46 of the 215 genera in the world are found in Indonesia and grow naturally from Sumatra, Kalimantan, Sulawesi, Papua, and even on small islands (Alandana et al. 2015). Palms are mostly used as ornamental plants to meet subsistence human needs. Palms are a monocot taxon, so that quantitative research can be carried out separately from other species of dicot plants (Casapia et al. 2019).

This study aimed to assess the structure, diversity and distribution of palm tree species grow naturally in the *A. excelsa* planted forests in Bodogol Resort, GGPNP, West Java, Indonesia. This research provides a clear picture of the quantitative diversity of palm species in Bodogol Resort, GGPNP, especially under *A. excelsa* planted forests. The results of this research will enrich valuable scientific information about the structure and composition of palm species in Bodogol, so it is hoped that it can become a reference in determining a good policy strategy for forest area managers in GGPNP, especially in the Bodogol resort management area as an area used as for nature conservation education for the community.

MATERIALS AND METHODS

Study area and period

The research was conducted in Bodogol Resort, Gunung Gede Pangrango National Park (GGPNP), West Java, Indonesia which is representative of the lowland mountain tropical rainforest ecosystem on the island of Java. Bodogol is one part of the GGPNP forest area management, located at the foot of Mount Pangrango in the north-western part of GGPNP. The geographical location of the research location is at 106°51'21.92"E Longitude and 6°46'34.74"S Latitude with an elevation of ±825 m above sea level (Figure 1). Data collection was carried out in January 2023.

Procedures

Data collection was carried out by measuring the diameter of palm species in a plot area of one-hectare size (100 m x 100 m). In the one-hectare plot, subplots measuring (10 m x 10 m) were created, resulted in total of 100 subplots. Species of palms with a diameter of >3 cm were measured of its diameter at breast height (±130 cm from the ground surface). Each individual palm was measured measured its total height (topmost leaf tip). Each subplot's distance from the Y-axis (South-North) or X-axis (West-East) of each subplot was measured.

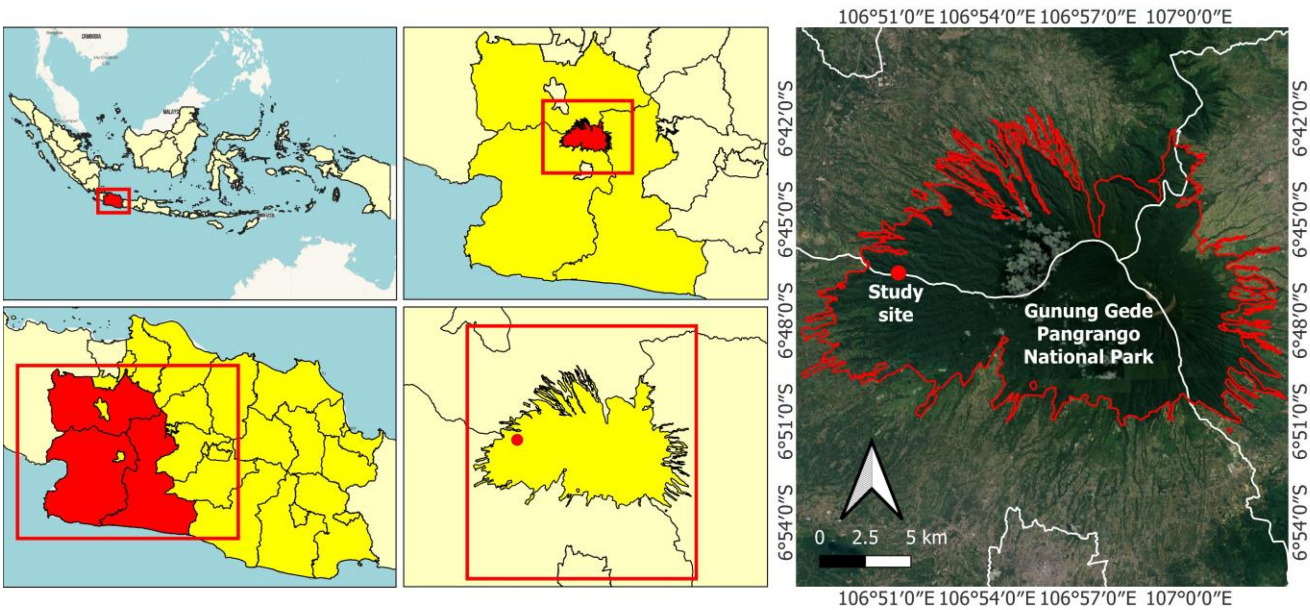

Figure 1. Map of the study site (red dot) in the *Altingia excelsa* planted forest area of Bodogol Resort, GGPNP, West Java, Indonesia

Table 1. Value of the range of distribution patterns for the Dispersion Index (DI), Clumping Index (CI), and Green Index (GI)

Indices name	Dispersion		
	Random	Reguler	Clumping
Dispersion (DI)	0	1	N
Clumping (CI)	-1	0	N-1
Green (GI)	-1(N-1)	0	1

Data analysis

Data analysis followed Mueller-Dombois and Ellenberg (2016) by calculating basal area (D), density (Dent), and Frequency (F). Then, we analyzed Relative Density (RDe), Relative Dominance (RDo), and Relative Frequency (RF). The Important Value (IV) was calculated as the sum of RDo + RDent + RF. The dominance ratio was calculated apart from IV, namely the IV value divided by three. Analysis of distribution patterns uses the statistical formula proposed by Metananda et al. (2015), which included three parameters: Random, regular, and clumping patterns (Table 1). The formulas are listed below:

$$\text{Dominance (Do)} = \frac{\text{Basal area a species}}{\text{Sample plot}}$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Dominance of a species}}{\text{Total domination of all species}} \times 100\%$$

$$\text{Density (De)} = \frac{\text{The number of individual of a species}}{\text{Sample plot}}$$

$$\text{Relative density (RDe)} = \frac{\text{Density of species}}{\text{Density of all species}} \times 100\%$$

$$\text{Frequency (F)} = \frac{\text{Number of plot found for a species}}{\text{Number of all sample plots}}$$

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

Index Value (IV) =Number result of RDo+RDe+RF

$$\text{Summed Dominace Ratio (SDR)} = \frac{\text{The number IV}}{3}$$

The Diversity Index species follows the Shannon-Wienner (H’) formula:

$$H' = -\sum\left[\left(\frac{n.i}{N}\right)\log\left(\frac{n.i}{N}\right)\right]$$

Where:
n : Number of individuals of each species
N : Number of individuals of all species

Dominance Evenness Index (E):

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

Where:
E : Dominance evenness index
H' : Shannon-Wienner (H”) diversity index
S : Number of species

The variance value (S^2) analysis with formula:

$$S^2 = \frac{\sum y^2 = \frac{(\sum y)^2}{n}}{n-1}$$

Where:
y : Number of individuals all plot inside
n : Number of plot

The Chi-square (Q) analysis with formula:

$$Q = n\sum\frac{X^2}{N-N}$$

Where:
n : Number of plot
X : Mean individual in plot
N : Total individual in plot

The Dispersion Index (DI), Clumping Index (CI), and Green Index (GI) were calculated as follow:

$$\text{Dispersion Index (DI)} = \frac{S^2}{X}$$

$$\text{Clumping Index (CI)} = \frac{S^2}{X} - 1$$

$$\text{Green index (GI)} = \frac{\frac{S^2}{X} - 1}{(n-1)}$$

Where:
X : Mean number individual per plot unit
n : Number individual in plot
N : Total number individual all plot
S^2 : Varians value of observation

RESULTS AND DISCUSSION

Composition and structure of palm trees community

Plant composition describes species that make up a vegetation community which includes the indicator of the number of species, genera, families, and individuals in a forest area (Thammanu et al. 2021). The vegetation community which grow concurrently in the *A. excelsa* planted forest in Bodogol Resort, GGPNP, West Java, Indonesia is a result of natural secondary succession including palm tree species (Arecaceae). The results of vegetation survey in the studied area showed that the diversity of palm tree species with a diameter of >3 cm is in the very low category where there were only four species from three genera of palms (Table 2). According to Omayio and Mzungu (2019) and Setyono and Himawan (2018), the criteria for the value of the species diversity index based on Shannon-Wiener (H') is said to be very low if the value of H'<1 and very high if H'>3. The low species diversity of palms in the *A. excelsa* planted forest in Bodogol are also supported by the analysis of the species diversity index, which is 0.87 (H'). In general, the more extreme the environmental conditions, such as climate, soil, or altitude, the diversity of vegetation composition will decrease (Chauvier et al. 2021), including the diversity of palm tree species in the *A. excelsa* planted forest in Bodogol Resort, GGPNP which is very low.

Communities or ecosystems with very low diversity indicate heavy ecological pressure, causing the ecosystem to become unstable. On the other hand, communities and ecosystems with very high diversity indicate better productivity so that the condition of the community and ecosystem becomes balanced and stable. According to Goswami et al. (2017), the high and low values of the diversity index can be influenced by various factors, including the number of species found, and some species are found in more significant numbers than others. Dyderski and Jagodzinski (2018) stated that extreme pressure and various disturbances result in low diversity in an ecosystem. Forests that are disturbed by both nature and humans will affect the value of their species diversity.

Population or density is the number of individuals of a species in an area (Jacquier et al. 2021). The density of each plant species in natural forest areas generally varies because they have different adaptations that depend on the physical conditions of the environment (Jamali et al. 2020; Wagner et al. 2020). Based on Table 2, the density of palm trees under the *A. excelsa* planted forest in Bodogol Resort, GGPNP was 171 trees per hectare. The highest density was *Pinanga coronata* (112 trees/ha), and the lowest was *Arenga pinnata* (2 trees/ha). Furthermore, the total basal area was 0.63 m^2/ha. The highest basal area was *P. coronata* (0.24 m^2/ha), and the lowest was *A. pinnata* (0.08 m^2/ha).

The distribution of palm species was found in 78 subplots out of 100 subplots (frequency 78%). The highest frequency was *P. coronata* (41 subplots), and the lowest was *A. pinnata* (1 subplot). Alandana et al. (2015) recorded as many as seven species of palm trees found in the Bodogol natural forest area and the Gunung Halimun Salak National Park (GHSNP) forest area. Therefore, the results of this study represent 57.14% of the species recorded in Bodogol (GGPNP) and GHSNP. The density of *P. coronata* in *A. excelsa* planted forest stands found in this study (112 trees/ha) is significantly higher than that in disturbed forest areas in GHSNP (corridor) which only 54 trees/ha as recorded by Alandana et al. (2015).

Forest vegetation is a dynamic system, sometimes continuously developing or changing according to environmental conditions (Keenan 2015; Messier et al. 2019; Wheeler et al. 2022). The presence of four species of palm trees under the *A. excelsa* planted forest in Bodogol was the result of natural succession because the area has experienced severe disturbances (Prach and Walker 2018). Therefore, the high density of *P. coronata* indicates a suitable habitat for good growth and regeneration of such palm (Ahmadipari et al. 2021; Teitelbaum et al. 2021).

The diameter of tree trunks in natural forest areas varies (Lolila et al. 2023). The lowest trunk diameter of palm species in this research was *P. coronata* (3.14 cm), with a density of 1 tree/ha. In comparison, the highest trunk diameter was *Caryota rumphiana* (31.46 cm), with a density of 1 tree/ha. The basal area of *P. coronata* and *C. rumphiana* was almost the same, but in term of density, *P. coronata* was far higher. Similarly, the basal area of *Pinanga* sp. and *A. pinnata* was almost the same, the *Pinanga* sp. had much higher density. This is because both *P. coronata* and *Pinanga* sp. have small trunk diameter, conversely *C. rumphiana* and *A. pinnata* have relatively large diameter size.

The Importance Value Index (IVI) of a species in a community is a parameter for determining the level of role of the species in its community (Lolila et al. 2023). The importance value of a species can be used as an indication that the species is considered dominant by having higher relative density, relative frequency, and relative dominance values compared to other species. The dominant species in a forest area is indicated by the results of a high importance value (Hou et al. 2023). The dominance of a species in a habitat indicates that the species can utilize most of the resources in the surrounding environment. Conversely, the species with the lowest dominance value is a species that is under pressure and unable to develop and adapt well. It can be seen that *P. coronata* dominated the palm trees community in the *A. excelsa* planted forest in Bodogol Resort, GGPNP with IVI of 156.89%, DRI of 52.89% and dominance index of 0.63 (Table 3). This result suggests that *P. coronata* has a high adaptability to environmental conditions (Schulze-Makuch et al. 2017).

Table 2. List of species, Basal Area (BA), Density (De) and Frequency (F) of palm tree species in *Altingia excelsa* planted forest area of Bodogol Resort, GGPNP, West Java, Indonesia

Species	BA (m^2/ha)	De (ha)	F (ha)
Pinanga coronata (Blume ex Mart.) Blume	0.24	112	41
Caryota rumphiana Mart.	0.22	12	11
Pinanga sp.	0.09	45	25
Arenga pinnata (Wurmb) Merr.	0.08	2	1
Total	0.63	171	78

Table 3. List of palm tree species, Relative Dominance (RDo), Relative Density (RDe), Relative Frequency (RF), Important Value Index (IVI), and Dominance Ratio Index (DRI) of palm tree species in *Altingia excelsa* planted forest area of Bodogol Resort, GGPNP, West Java, Indonesia

Species	RDo (%)	RDe (%)	RF (%)	IVI (%)	DRI(%)
Pinanga coronata	38.83	65.50	52.6	156.89	52.89
Pinanga sp.	13.67	26.32	32.1	72.04	24.01
Caryota rumphiana	34.65	7.02	14.1	55.77	18.59
Arenga pinnata	12.93	1.17	1.28	15.38	5.12
Total	100	100	100	300	100

The area of *A. excelsa* planted forest in Bodogol Resort, GGPNP has experienced disturbances and now has been undergoing succession (Thammanu et al. 2021). Therefore, *P. coronata* is a tree palm species with better regeneration abilities (Bamwesigye et al. 2020). Apart from that, the results of the high importance value also illustrate that the presence of *P. coronata* is more stable or has the opportunity to maintain its sustainability under *A. excelsa* planted forests in Bodogol Resort, GGPNP compared with *A. pinnata* (Gale et al. 2015; Mensah 2019).

The diameter classes in the studied area can be divided into four groups, namely 3.0-4.9 cm (76 trees), 5.0-9.9 cm (88 trees), 10.0-14.9 cm (2 trees), and diameter >15 cm (5 trees) (Figure 2). Therefore, based on the research results, it can be said that *P. coronata* and *Pinanga* sp. have good regeneration, but not for *A. pinnata* which only had two trees/ha. Meanwhile, in other subplots, there were only <9 trees. Furthermore, several subplots had a basal area of >0.05 $m^2/100^2$ m, namely subplot number 35/D5 (0.09 m^2), subplot 60/F10 (0.08 m^2), and subplot 24/C4 (0.06 m^2), while in the other subplots the area was only <0.05 m^2 (Figure 3).

In this study, *A. pinnata* had a very low density (2 trees/ha) but is not included in the category of rare Indonesian plants. According to De Cáceres et al. (2019), the basic assumption for analyzing stands is to estimate the condition of species both quantitatively and quantitatively because species composition in forests with very low density will experience high pressure to compete with other species or even be isolated and disappear from the ecosystem or community. This condition does not occur in the *A. pinnata* species because some animals, especially civets, might spread the seeds.

Distribution and stratification of palm trees community

Plant distribution is important in forest areas (Tadese et al. 2023). Plant distribution can generally be described in three patterns: random, regular, and clustered (Keren 2020). In general, the distribution of palm tree species in the studied area was relatively spread out, although there were several empty subplots (Figure 4). These conditions are influenced by environmental factors such as microclimate, nutrient availability, altitude, light, seed dispersal, and other disturbances that play a role in species distribution (Joswig et al. 2021; Kim et al. 2022). The distribution of palm tree species in *A. excelsa* planted forests in Bodogol Resort, GGPNP was regular and clustered. The results of the analysis of the Index of Dispersion (ID) of the spatial distribution pattern of the *P. coronata* species show that it was clustered (ID=3.8), while the distribution pattern of *A. pinnata* (ID=0.3), *C. rumphiana* (ID=0.1), and *Pinanga* sp. (ID=0.8) was regular because the ID value is <1 (Table 4).

Plants growing as a group will be able to withstand the impact of wind or inhibit water evaporation compared to solitary living, and group distribution is a typical distribution in nature for plants with high densities. Meanwhile, the regular distribution shows that the environmental conditions in the *A. excelsa* planted forest in Bodogol Resort, GGPNP was relatively similar in terms of growing space, nutrient availability, and sunlight. It can also be caused by competition between individuals or with others regarding the availability of nutrients and space. The geographical distribution of *P. coronata* and *Pinanga* sp. is also found on the Andaman Islands (Bay of Benggala-India), the Lesser Sunda Islands (Bali, Lombok, Sumbawa, Flores, Alor, to Timor), Java and Sumatra. Of these two types, they grow in groups and sometimes solitary, from coastal forests to mountain forests at an elevation of 1,900 m above sea level. However, in protected areas, *P. coronata* grows more solitary (Alandana et al. 2015).

Growth is the result of the interaction of various physiological processes that are influenced by environmental conditions (Charrier et al. 2015). Species correlation is analyzed based on IS (Index of Similarity) as a parameter that compares two or more factors. The results of the IS analysis showed that the four species of palm trees did not have a positive correlation (IS<30%), even for *A. pinnata* (IS = 0) (Figure 5). This difference is influenced by many factors (such as humidity, soil pH, altitude, temperature, nutrients, light intensity, etc.), resulting in different densities (Thammanu et al. 2021; Zhang et al. 2021). Understanding species distribution patterns is very important as basic data in forest management, namely to locate plants in the spatial dimension of species (Gu et al. 2019). Therefore, *P. coronata* and *Pinanga* sp. can reproduce perfectly because the saplings grow around the parent tree or are spread by solitary animals in several locations (Amadeu et al. 2016).

Forest canopy stratification is determined based on the height of standing trees and can be divided into five strata, namely A (height >30 m), B (height 20 m-30 m), C (height 4 m-20 m), D (shrub or tree height 1 m-4 m), and E (ground cover or height <1 m). Standing palm trees' total height (upper leaf height) varied with average 5.28 m (Figure 6). According to some literature, *Pinanga corona* and *Pinanga* sp. usually have a height of 7 m, but research results show that ten trees (15.70%) had height of >7 m high, and some were <7 m. *A. pinnata* and *C. rumphiana* species usually have a total height of around 25 m, but in this study the height was only 14 m, so they can be considered as young stands (Kupers et al. 2019; Gasperini et al. 2023).

Table 4. Distribution pattern of palm tree species on the one-hectare plot in the *Altingia excelsa* planted forest in Bodogol Resort, GGPNP, West Java, Indonesia

Species name	Index of Dispersion (ID)	Notes
Arenga pinnata	0.3	Regular
Caryota rumphiana	0.1	Regular
Pinanga sp.	0.8	Regular
Pinanga coronata	3.8	Clustered

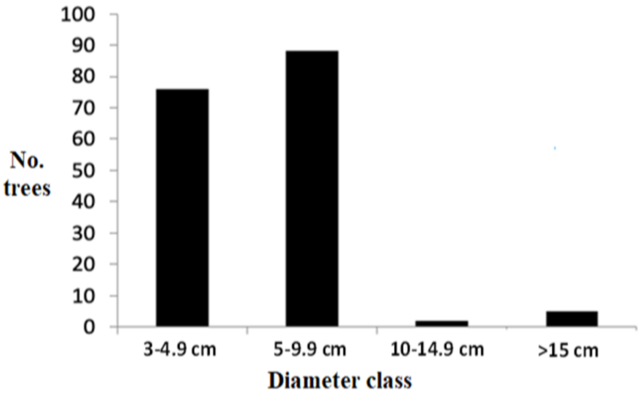

Figure 2. Diameter class distribution of palm tree species in *Altingia excelsa* planted forest in Bodogol Resort, GGPNP, West Java, Indonesia

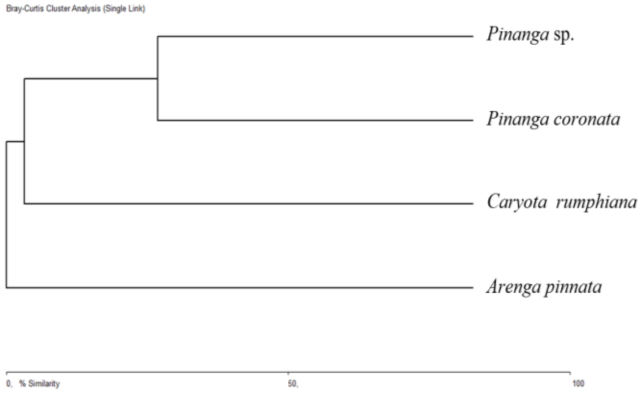

Figure 5. Similarity Index (SI) of palm tree species in *Altingia excelsa* planted forest in Bodogol Resort, GGPNP, West Java, Indonesia

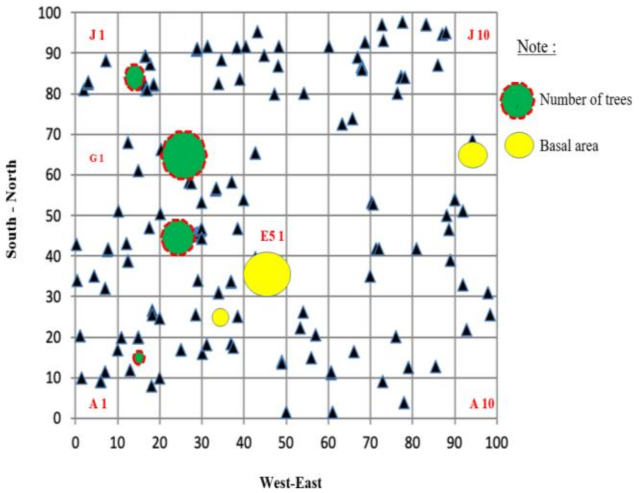

Figure 3. Spatial distribution of number of trees and basal area of palm tree species on a one-hectare plot in the *Altingia excelsa* planted forest in Bodogol Resort-GGPNP

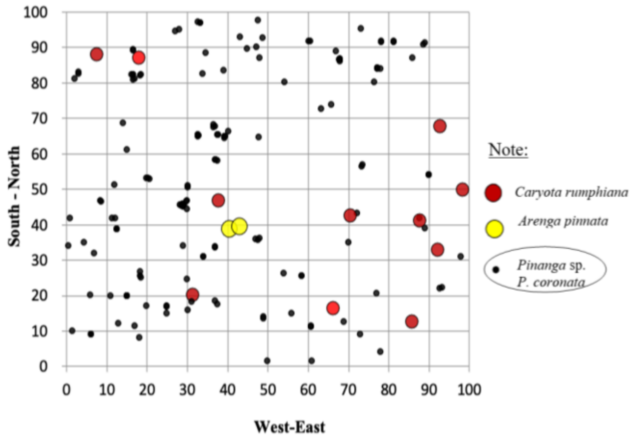

Figure 4. Palm tree species distribution on a one-hectare plot in *Altingia excelsa* planted forest area in the Bodogol Resort-GGPNP

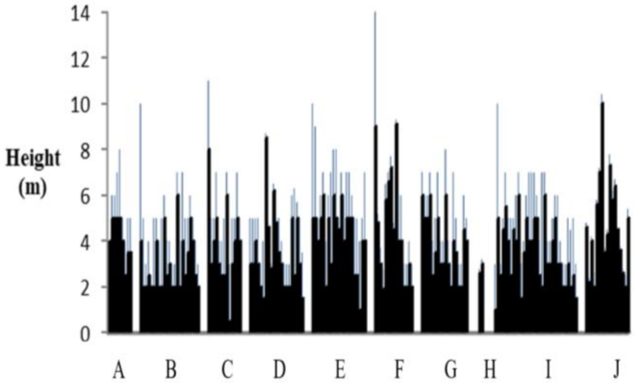

Figure 6. The total height of palm tree species stands were seen from the east side (South-North/A-J) on a one-hectare plot in the *Altingia excelsa* planted forest area in Bodogol Resort-GGPNP

In conclusion, the palm trees in the *A. excelsa* planted forest in Bodogol Resort-GGPNP are the result of secondary succession. There were four palm tree species of three genera in one-hectare plot with the dominant species was *P. coronata*, which had a clustered distribution, while the other three species were regular distributed. The highest density was *P. coronata* and *Pinanga* sp., while the density of *C. rumphiana* was medium, and *A. pinnata* was very low. We recommend this research to be continued periodically to see the dynamics that occur so that mortality and natality can be known. *Pinanga* sp. still requires further study to determine its taxonomic status.

ACKNOWLEDGEMENTS

We thank the management of Gunung Gede Pangrango National Park, West Java, Indonesia who has given permission and research facilities. We also thank Ae Setiawan and Pepen who have accompanied us during our research.

REFERENCES

Ahmadipari M, Yavari A, Ghobadi M. 2021. Ecological monitoring and assessment of habitat suitability for brown bear species in the Oshtorankooh protected area, Iran. Ecol Indic 126: 107606. DOI: 10.1016/j.ecolind.2021.107606.

Alandana IM, Rustiami H, Widodo P. 2015. Palms inventory at Bodogol Forest, Gunung Gede Pangrango National Park. Buletin Kebun Raya 18 (2): 81-98. DOI: 10.14203/bkr.v18i2.164. [Indonesian]

Amadeu LS, Sampaio MB, Dos Santos FA. 2016. Influence of light and plant size on the reproduction and growth of small palm tree species: Comparing two methods for measuring canopy openness. Am J Bot 103 (9):1678-1686. DOI: 10.3732/ajb.1600178.

Amenu BT. 2017. Review: Forest management and conservation practices in Ethiopia: Opportunities and constraints. Asian J For 1 (2): 77-82. DOI: 10.13057/asianjfor/r010204.

Ario A, Syaepulloh IL, Rahmatulloh D, Maulana I, Supian S, Junaedi D, Sonandar D, Yandar A, Sadili H, Yanuar A. 2020. A preliminary study of bird and mammal diversity within restoration areas in the Gunung Gede Pangrango National Park, West Java, Indonesia. Indones J Appl Environ Stud 1 (2): 34-42. DOI: 10.33751/injast.v1i2.2190.

Bamwesigye D, Hlavackova P, Sujova A, Fialova J, Kupec P. 2020. Willingness to pay for forest existence value and sustainability. Sustainability 12 (3): 891. DOI: 10.3390/su12030891.

Casapia XT, Falen L, Bartholomeus H, Cárdenas R, Flores G, Herold M, Coronado ENH, Baker TR. 2020. Identifying and quantifying the abundance of economically important palms in tropical moist forest using uav imagery. Remote Sens 12 (1): 9. DOI: 10.3390/rs12010009.

Charrier G, Ngao J, Saudreau M, Améglio T. 2015. Effects of environmental factors and management practices on microclimate, winter physiology, and frost resistance in trees. Front Plant Sci 6: 259. DOI: 10.3389/fpls.2015.00259.

Chauvier Y, Thuiller W, Brun P, Lavergne S, Descombes P, Karger DN, Renaud J, Zimmermann NE. 2021. Influence of climate, soil, and land cover on plant species distribution in the European Alps. Ecol Monogr 91 (2): e01433. DOI: 10.1002/ecm.1433.

De Cáceres M, Martín-Alcón S, González-Olabarria JR, Coll L. 2019. A general method for the classification of forest stands using species composition and vertical and horizontal structure. Ann For Sci 76: 40. DOI: 10.1007/s13595-019-0824-0.

Dyderski MK, Jagodzin'ski AM. 2018. Low impact of disturbance on ecological success of invasive tree and shrub species in temperate forests. Plant Ecol 219: 1369-1380. DOI:10.1007/s11258-018-0885-4.

Gale F, Davison A, Wood G, Williams S, Towle N. 2015. Four impediments to embedding education for sustainability in higher education. Aust J Environ Educ 31: 248-263. DOI: 10.1017/aee.2015.36.

Gasperini C, Carrari E, Govaert S, Meeussen C, De Pauw K, Plue J, Sanczuk P, Vanneste T, Vangansbeke P, Iacopetti G, De Frenne P, Selvi F. 2023. Trait variation in juvenile plants from the soil seed bank of temperate forests in relation to macro and microclimate. Appl Veg Sci 26 (3): e12739. DOI: 10.1111/avsc.12739.

Goswami M, Bhattacharyya P, Mukherjee I, Tribedi P. 2017. Functional diversity: An important measure of ecosystem functioning. Adv Microbiol 7 (1): 82-93. DOI: 10.4236/aim.2017.71007.

Gu L, Kevin L, O'Hara, Wei-zhong L, Zhi-wen G. 2019. Spatial patterns and interspecific associations among trees at different stand development stages in the natural secondary forests on the Loess Plateau, China. Ecology and Evolution 9 (11): 6410-6421. DOI: 10.1002/ece3.5216.

Haq SM, Khoja AA, Lone FA, Waheed M, Bussmann RW, Mahmoud EA, Elansary HO. 2023. Floristic composition, life history traits and phytogeographic distribution of forest vegetation in the Western Himalaya. Front For Glob Change 6: 1169085. DOI: 10.3389/Ffgc.2023.1169085.

Hou G, Shi P, Zhou T, Sun J, Zong N, Song M, Zhang X. 2023. Dominant species play a leading role in shaping community stability in the Northern Tibetan grasslands. J Plant Ecol 16 (3): 649-662. DOI: 10.1093/jpe/rtac110.

Jacquier M, Vandel J-M, Léger F, Duhayer J, Pardonnet S, Say L, Devillard S, Ruette S. 2021. Breaking down population density into diferent components to better understand its spatial variation. Ecol Evol 21 (1): 82. DOI: 10.1186/s12862-021-01809-6.

Jamali H, Ebrahimi A, Ardestani EG, Pordel F. 2020. Evaluation of plotless density estimators in different plant density intensities and distribution patterns. Glob Ecol Conserv 23: e01114. DOI: 10.1016/j.gecco.2020.e01114.

Joswig JS, Wirth C, Schuman MC et al. 2021. Climatic and soil factors explain the two-dimensional spectrum of global plant trait variation. Nat Ecol Evol 6 (1): 36-50. DOI: 10.1038/s41559-021-01616-8.

Kartawinata K, Sudarmonowati E. 2022. Keragaman vegetasi alami Cagar Biosfer Cibodas. Badan Riset Inovasi Nasional, Jakarta. [Indonesian]

Keenan RJ. 2015. Climate change impacts and adaptation in forest management: A review. Ann For Sci 72: 145-167. DOI: 10.1007/s13595-014-0446-5.

Keren S. 2020. Modeling tree species count data in the understory and canopy layer of two mixed old-growth forests in the dinaric region. Forests 11 (5): 531. DOI: 10.3390/f11050531.

Kim M, Lee S, Lee S, Yi K, Kim H-S, Chung S, Chung J, Kim HS, Yoon TK. 2022. Seed dispersal models for natural regeneration: A Review and prospects. Forests 13 (5): 659. DOI: 10.3390/f13050659.

Kupers SJ, Wirth C, Engelbrecht BMJ, Hernández A, Condit R, Wright SJ, Rüger N. 2019. Performance of tropical forest. seedlings under shade and drought: An interspecific trade-off in demographic responses. Sci Rep 9: 18784. DOI: 10.1038/s41598-019-55256-x.

Lolila NJ, Shirima DD, Mauya EW. 2023. Tree species composition along environmental and disturbance gradients in tropical sub-montane forests, Tanzania. PLoS One 18 (3): e0282528. DOI: 10.1371/journal.pone.0282528.

Mensah J. 2019. Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. Cogent Soc Sci 5 (1): 1653531. DOI: 10.1080/23311886.2019.1653531.

Messier C, Bauhus J, Doyon F, Maure F, Sousa-Silva R, Nolet P, Mina M, Aquilué N, Fortin M-J, Puettmann K. 2019. The functional complex network approach to foster forest resilience to global changes. For Ecosyst 6 (1): 21. DOI: 10.1186/S40663-019-0166-2.

Metananda A, Zuhud EAM, Hikmat H. 2015. Population, distribution of Kepuh (*Sterculia foetida* L.) and its associated in Sumbawa Regency, West Nusa Tenggara. Media Konservasi 20 (3): 277-287. DOI: 10.29244/medkon.20.3.%25p. [Indonesian]

Mueller-Dombois, Ellenberg H. 2016. Aims and Methods of Vegetation Ecology. John Wiley and Sons. New York. (Translation) Kartawinata K, Abdulhdi R. LIPI Press, Yayasan Pustaka Obor Indonesia, Jakarta. [Indonesian]

Omayio DO, Mzungu E. 2019. Modification of shannon-wiener diversity index towards quantitative estimation of environmental wellness and biodiversity levels under a non-comparative scenario. J Environ Earth Sci 9 (9). 46-57. DOI: 10.7176/jees/9-9-06.

Prach K, Walker LR. 2018. Differences between primary and secondary plant succession among biomes of the world. J Ecol 107 (2): 510-516. DOI: 10.1111/1365-2745.13078.

Sadili A, Salamah A, Mirmanto E, Kartawinata K. 2023. The composition and structure of natural lowland forests at Bodogol, Gunung Gede Pangrango National Park, West Java, Indonesia. Reinwardtia 22 (1): 1-25. DOI: 10.55981/reinwardtia.2023.4399.

Schulze-Makuch D, Airo A, Schirmack J. 2017. The adaptability of life on earth and the diversity of planetary habitats. Front Microbiol 8: 2011. DOI: 10.3389/fmicb.2017.02011.

Setyono P, Himawan W. 2018. Analyses of bioindicators and physicochemical parameters of water of Lake Tondano, North Sulawesi Province, Indonesia. Biodiversitas 19: 867-674. DOI: 10.13057/biodiv/d190315.

Tadese S, Soromessa T, Gebeyehu G. 2023. Effects of environmental and disturbance factors on plant community distribution in tropical moist afromontane forests, South-West Ethiopia. Intl J For Res 2023: 8521303. DOI: 10.1155/2023/8521303.

Teitelbaum CS, Sirén APK, Coffel E, Foster JR, Frair JL, Hinton JW, Horton RM, Kramer DW, Lesk C, Raymond C, Wattles DW, Zeller KA, Morelli TL. 2021. Habitat use as indicator of adaptive capacity to climate change. Divers Distrib 27: 655-667. DOI: 10.1111/ddi.13223.

Thammanu S, Marod D, Han H, Bhusal N, Asanok L, Ketdee P, Gaewsingha N, Lee S, Chung J. 2021. The infuence of environmental factors on species composition and distribution in a community forest in Northern Thailand. J For Res 32: 649-662. DOI: 10.1007/s11676-020-01239.

Trogisch S, Liu X, Rutten G et al. 2021. The significance of tree-tree interactions for forest ecosystem functioning. Basic Appl Ecol 55: 33-52. DOI: 10.1016/j.baae.2021.02.003.

Wagner FH, Dalagnol R, Casapia XT, Streher AS, Phillips OL, Gloor E, Aragão LEOC. 2020. Regional mapping and spatial distribution analysis of canopy palms in an Amazon Forest using deep learning and vhr images. Remote Sens 12 (14): 2225. DOI: 10.3390/rs12142225.

Wheeler MM, Larson KL, Cook EM, Hall SJ. 2022. Residents manage dynamic plant communities: Change over time in urban vegetation. Front Ecol Evol 10: 944803. DOI: 10.3389/fevo.2022.944803.

Zhang Q-P, Wang J, Wang Q. 2021. Effects of abiotic factors on plant diversity and species distribution of alpine meadow plants. Ecol Inform 61: 101210. DOI: 10.1016/j.ecoinf.2021.101210.