

Research Article

Vegetation Analysis and Species Diversity in the Protection Block and Natural Forest of KGPAA Mangkunagoro I Grand Forest Park, Central Java, Indonesia

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ABSTRACT

Grand Forest Park (GFP) is a conservation area designated for biodiversity preservation and native and non-native fauna collections. Comprehensive data on vegetation diversity is crucial for scientific knowledge and effective conservation management. This study analysed tree species diversity and community structure in two locations: the GFP Mangkunagoro I Conservation Block and the BKPH Lawu Utara Natural Forest in Karanganyar, Central Java. Vegetation analysis was performed across four growth stages: seedlings, saplings, poles, and trees. The results revealed that the GFP Conservation Block hosts 42 tree species from 34 families. In this area, *Helicia robusta* (locally known as Cebongan) dominated the seedling (IVI 174.60) and sapling (IVI 73.79) stages, while *Quercus* sp. (Pasang) dominated the pole stage (IVI 36.23), and *Oenanthe javanica* was most prominent in the tree stage (IVI 60.29). Conversely, the BKPH Lawu Utara Natural Forest recorded 24 tree species from 23 families. Dominance in this area was characterised by *Helicia robusta* in the seedling stage (IVI 41.26), but transitioned to *Quercus* sp., which dominated the sapling (IVI 52.93), pole (IVI 42.91), and tree stages (IVI 115.80). These findings illustrated distinct patterns of species dominance and composition between the conservation block and natural forest, providing essential baseline data for forest management in the Lawu region.

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INTRODUCTION

The Grand Forest Park (GFP) is a specialised conservation area designated for biodiversity preservation, research, and education, housing both native and non-native species (Republic of Indonesia 1990). Beyond its recreational appeal, similar to the Batur Geopark in Bali (Mihardja et al. 2023), the primary value of a GFP lies in its vegetation diversity, which serves as the foundation for biological resource development and floristic conservation (Malik et al. 2021; García-Navas et al. 2022). These forests act as critical wildlife habitats and provide essential ecosystem services, including watershed protection, soil fertility maintenance, and microclimate regulation (Fikadu & Argaw 2021; Basuki et al. 2022; Wardah et al. 2022; Gelelcha et al. 2023).

GFP KGPAA Mangkunagoro I, located in Karanganyar, Central Java, possesses significant biophysical potential and diverse germplasm (Cahyono et al. 2021). However, this area faces mounting anthropogenic pressure due to the high dependence of surrounding communities on forest resources (Rahman et al. 2021; He et al. 2022). Despite its importance, the comprehensive identification of its vegetation diversity remains incomplete. Furthermore, the ecological stability of this region is not only determined by the GFP itself but also by the adjacent natural forests, such as the BKPH Lawu Utara managed by Perum Perhutani. Both areas represent different management regimes that collectively sustain the Lawu mountain ecosystem.

Understanding the diversity, structure, and composition of tree species in both the GFP Mangkunagoro I and the BKPH Lawu Utara natural forest is vital for local managers. Previous studies have often focused solely on protected blocks, overlooking the comparative state of adjacent managed natural forests. Therefore, this study aims to provide a detailed analysis of vegetation status in the GFP Conservation Block and the BKPH Lawu Utara Natural Forest. These findings are expected to serve as a scientific baseline for forest managers to maintain species composition and to guide reforestation efforts with ecologically appropriate species in both conservation and production forest zones.

MATERIALS AND METHODS

Study area

The research was conducted in the Grand Forest Park (GFP) Mangkunagoro I, Karanganyar, Central Java. Data collection and vegetation analysis were carried out in two distinct management regimes: the GFP Conservation Block and the adjacent Natural Forest of BKPH Lawu Utara (managed by Perum Perhutani) (Figure 1).

Data Collection

The study utilised primary vegetation data collected through field surveys. A systematic sampling with a nested plot design was employed across both locations. We recorded tree diameter at breast height (DBH), total height, and the number of individuals for each species. The growth stages and their respective plot sizes were classified as follows:

- a. Seedlings: Individuals from sprouts to tillers with a height of <1.5 m, measured in 2×2 m subplots.
- b. Saplings: Individuals with a height of ≥ 1.5 m and a DBH of <10 cm, measured in 5×5 m subplots.
- c. Poles: Individuals with a DBH of 10 to <20 cm, measured in 10×10 m subplots.
- d. Trees: Mature individuals with a DBH of ≥ 20 cm, measured in 20×20 m plots.

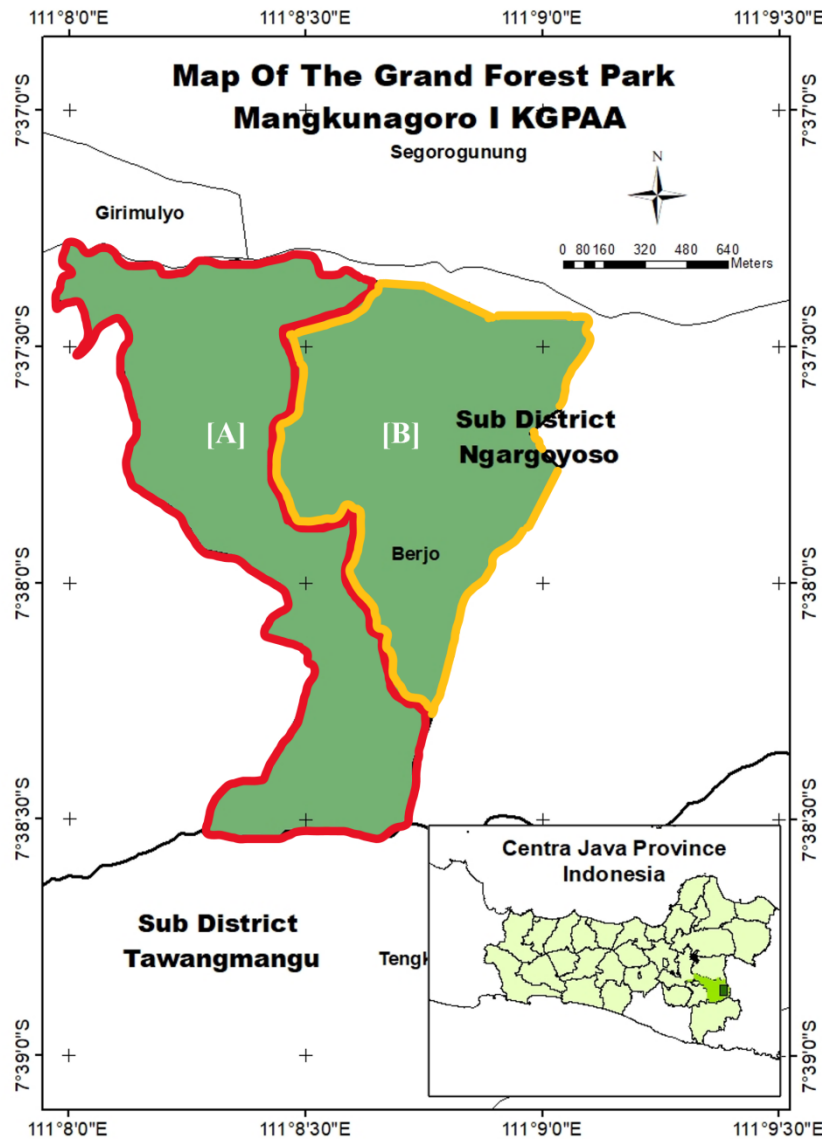


Figure 1. The study area is located in the GFP Conservation Block [B] and the BKP Lawu Utara Natural Forest of Perum Perhutani [A], Karanganyar, Central Java.

Data Analysis

The data obtained from the field survey were analysed to determine the vegetation structure and diversity in both study locations. The analysis included the following indices:

1. Species Richness Species richness was calculated using the Margalef's Richness Index (R_1) (Margalef 1958) to determine the variety of species in each location:

$$R_1 = \frac{S - 1}{\ln N}$$

Where S is the total number of species and N is the total number of individuals.

2. Species Diversity and Evenness To assess the stability of the ecosystem, the Shannon-Wiener Diversity Index (H') was applied (Shannon & Weaver 1949; Magurran 2004):

$$H' = - \sum_{i=1}^S (P_i \ln P_i)$$

Where P_i is the proportion of the i th species calculated as n_i/N , with n_i repre-

senting the number of individuals of a species and N being the total number of individuals in the community. Furthermore, the Evenness Index (E) was used to measure the distribution of individuals among species (Pielou 1966):

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

The value of E ranges from 0 to 1, where a value closer to 1 indicates a more uniform distribution of species.

3. Importance Value Index (IVI) The ecological role and dominance of species in the community were determined using the Importance Value Index (IVI) (Curtis & McIntosh 1950). For the tree stage, IVI is the sum of Relative Density (RD), Relative Frequency (RF), and Relative Dominance (RDo). For seedlings, saplings, and poles, IVI is the sum of RD and RF (Soerianegara & Indrawan 1998):

$$IVI = RD + RF + RDo$$

Where:

Relative Density (RD) = (Number of individuals of a species) \times 100 %

Relative Frequency (RF) = (Frequency of a species) \times 100 %

Relative Dominance (RDo) = (Basal area of a species) \times 100 %

4. Community Similarity To compare the species composition between the GFP Conservation Block and the BKPH Lawu Utara Natural Forest, the Sorensen's Similarity Index (IS) was used (Sorensen 1948; Magurran 2004):

$$IS = \left(\frac{2w}{a + b} \right) \times 100\%$$

Where w is the number of species common to both locations, a is the number of species in area A, and b is the number of species in area B.

RESULTS AND DISCUSSION

Vegetation Composition and Diversity Indices

The vegetation inventory across two management blocks revealed a significant difference in taxonomic richness. In the GFP Conservation Block, we identified 42 tree species belonging to 34 families (Table 1). Meanwhile, the BKPH Lawu Utara Natural Forest showed a lower richness with 24 tree species from 23 families (Table 2).

Community Structure and Species Dominance

The importance of each species within the community was assessed using the Importance Value Index (IVI). In the GFP Conservation Block (Table 3), the community structure is heavily dominated by *Helicia robusta* (Cebongan) in the early regeneration stages, reaching an IVI of 174.60 in the seedling stage. This dominance gradually decreases as the trees mature, with *Oenanthe javanica* (Pampung) becoming more prominent in the tree stage with an IVI of 60.29.

In contrast, the BKPH Lawu Utara Natural Forest (Table 4) exhibited more stable dominance pattern by the Fagaceae family. *Helicia robusta* (Cebongan) remained present in the seedling stage (IVI 41.26), but the subsequent growth stages (sapling, pole, and tree) are dominated by *Quercus* sp. (locally known as Pasang). The IVI of *Quercus* sp. increased significantly at the tree stage, reaching 115.80, indicating its role as the primary canopy-forming species in this natural forest block.

Table 1. Tree species and their families and tree significance index based on growth rate in the GFP Protection Block (Raw data source: GFP KGPAA Mangkunagoro 1).

Local Name	Scientific name	Family	IVI Block GFP Protection (%) Phase			
			Seedlings	Saplings	Poles	Trees
Akasia	<i>Acacia decurrens</i> (J.C.Wendl.) Willd.	Fabaceae			1.55	2.07
Bagan	<i>unidentified</i>	<i>unidentified</i>		15.49	7.75	4.18
Bertupuk	<i>unidentified</i>	<i>unidentified</i>		5.16	4.65	4.53
Bintami	<i>Cupressus</i> sp.	Cupressaceae				15.04
Cale	<i>Ficus fistulosa</i> Reinw. ex Blume	Moraceae		56.08	35.62	24.69
Cebongan	<i>Helicia robusta</i> (Roxb.) R.Br. ex Blume	Proteaceae	174.60	73.79	13.72	3.64
Cuwut	<i>unidentified</i>	<i>unidentified</i>			5.31	8.39
Dempul	<i>Glochidion rubrum</i> Blume	Apocynaceae			9.30	23.72
Ganitri	<i>Elaeocarpus angustifolius</i> Roxb. ex- G. Don	Elaeocarpaceae				1.60
Gulma	<i>unidentified</i>	<i>unidentified</i>				7.18
Jebukan	<i>Galearia filiformis</i> (Blume) Boerl.	Pandanaceae			13.06	16.65
Kebak	<i>Ficus alba</i> Reinw. ex Blume	Moraceae			1.55	2.01
Kendit	<i>unidentified</i>	<i>unidentified</i>				1.05
Kengkeng	<i>Polinia ciliata</i> trin.	Poaceae				3.43
Kesambi	<i>Schleichera oleosa</i> (Lour.) Oken	Sapindaceae				1.03
Kina	<i>Cinchona pubescens</i> Vahl	Rubiaceae			19.22	4.26
Lotrok	<i>Wenlandia dasythyrsa</i> Miq.	Rubiaceae				2.09
Ndokndokan	<i>Xanthophyllum vitellinum</i> (Blume) D.Dietr.	Polygalaceae				6.84
Nogosaren	<i>Mesua ferrea</i> L.	Calophyllaceae				2.89
Nyampuh	<i>Actinodaphne procera</i> Ness	Lauraceae				4.77
Pampung	<i>Oenanthe javanica</i> (Blum) DC.	Apiaceae			1.55	60.29
Pacalkidang	<i>Aglaia heptandra</i> Coord. & Valetton	Meliaceae				1.16
Pasang	<i>Quercus</i> sp.	Fagaceae			36.23	40.49
Pinus	<i>Pinus merkusii</i> Jungh. & de Vriese	Pinaceae			2.87	10.02
Puspa	<i>Schima wallichii</i> (DC.) Korth.	Theaceae			1.55	7.69
Renik	<i>Eurya acuminata</i> DC.	Pentaphylacaceae			14.61	6.54
Sarangan	<i>Castanea argentea</i> (Bl.) Bl.	Fagaceae			4.65	23.85
Sembung	<i>Blumea balsamifera</i> (L.) DC.	Asteraceae				1.08
Tanen	<i>Celtis</i> sp.	Cannabaceae			1.55	3.20
Walikputih	<i>Acer laurinum</i> Hassk.	Sapindaceae			1.55	3.43
Wangwung	<i>unidentified</i>	<i>unidentified</i>				1.69
Wilodo/Cale	<i>Ficus fistulosa</i> Reinw. ex Blume	Moraceae			3.10	1.00
Apit	<i>unidentified</i>	<i>unidentified</i>	12.70	42.09	1.55	
Cemara	<i>Casuarina junghuhniana</i> Miq.	Casuarinaceae		7.39	5.97	
Ampel	<i>Bambusa</i> sp.	Poaceae	12.70			
Ekaliptus	<i>Eucalyptus</i> sp.	Myrtaceae			1.55	
Imer	<i>Flueggea virosa</i> (Roxb. ex Willd.) Royle	Phyllanthaceae			1.55	

Table 1. Contd.

Local Name	Scientific name	Family	IVI Block GFP Protection (%) Phase			
			Seedlings	Saplings	Poles	Trees
Jowor	<i>Actinorhysis calapparia</i> (Blume) H. Wendl. & Drude ex Scheff.	Arecaceae			1.55	
Kayu manis	<i>Glycyrrhiza glabra</i> L.	Fabaceae			2.22	
Rasamala	<i>Altingia excelsa</i> Noronha	Altingiaceae			1.55	
Suren	<i>Toona sinensis</i> (A. Juss.) M. Roem.	Meliaceae			1.55	
Talok	<i>Mallotus moritzianus</i> Müll. Arg.	Euphorbiaceae			3.10	

Table 2. Tree species and their families and tree importance value index based on growth rate and measuring plots in the North Lawu BKPH Natural Forest Block (Raw data source: GFP KGPAA Mangkunagoro 1).

No.	Local name	Scientific name	Family	BKPH North Lawu Natural Forest Block, IVI (%) Phase			
				Seedlings	Saplings	Poles	Trees
1	Anggrung	<i>Trema orientale</i> (L.) Blume	Cannabaceae				3.24
2	Pasang	<i>Quercus</i> sp.	Fagaceae	22.16	52.93	42.91	115.80
3	Cebongan	<i>Helicia robusta</i> (Roxb.) R.Br. ex Blume	Proteaceae	41.26	10.80	5.30	
4	Preh	<i>Ficus retusa</i> L.	Moraceae	12.32	3.95		
5	Dempul	<i>Glochidion rubrum</i> Blume	Apocynaceae				6.31
6	Ganitri	<i>Elaeocarpus ganitrus</i> Roxb. ex- G. Don	Elaeocarpaceae		3.95		2.79
7	Puspa	<i>Schima wallichii</i> (DC.) Korth.	Theaceae	24.19	16.59	23.31	25.33
8	Jebugan	<i>Galearia filiformis</i> (Blume) Boerl.	Pandanaceae		7.9		13.07
9	Kengkeng	<i>Polinia ciliata</i> trin.	Poaceae		3.95	27.01	20.96
10	Pampung	<i>Oenanthe javanica</i> (Blume) DC.	Apiaceae			7.15	14.10
11	Putek	<i>unidentified</i>	<i>unidentified</i>		3.95		4.82
12	Jenggutri	<i>Eurya acuminata</i> DC.	Pentaphylacaceae	5.54	12.25	5.30	8.18
13	Walikputih	<i>Acer laurinum</i> Hassk.	Sapindaceae				8.38
14	Cuwut	<i>unidentified</i>	<i>unidentified</i>	5.54		10.60	
15	Puspa	<i>Schima wallichii</i> (DC.) Korth.	Theaceae	24.19	16.59	23.31	25.33
16	Piji	<i>Areca pumila</i> Blume	Arecaceae		7.90		
17	Renik	<i>unidentified</i>	<i>unidentified</i>	5.54	12.25		
18	Nagasari	<i>Mesua ferrea</i> L.	Calophyllaceae	10.63	11.20	10.86	3.92
19	Pinus	<i>Pinus merkusii</i> Jungh. & de Vriese	Pinaceae		3.95		40.94
20	Kidangan	<i>Phyllanthus indicus</i> (Dalzell) Müll. Arg.	Phyllanthaceae				
21	Klembir	<i>unidentified</i>	<i>unidentified</i>		11.85	5.30	6.63
22	Nyampuh	<i>Actinodaphne procera</i> Nees	Lauraceae	11.08	3.95		
23	Lotrok	<i>Wenlandia dasythyrsa</i> Miq.	Rubiaceae		7.50	17.75	
24	Tlutup	<i>unidentified</i>	<i>unidentified</i>	5.54			2.27

Regeneration and Successional Patterns

A high IVI in a community indicated species' superior ability to utilise environmental resources compared to its associates (Wrońska-Pilarek et al. 2023). Based on the data in Table 3 and Table 4, both locations showed healthy regeneration status, characterised by the presence of dominant species across various growth stages.

The extreme dominance of *Quercus* sp. in BKPH Lawu Utara suggests a climax community where this species has successfully adapted to the extreme monsoon conditions and environmental stressors (Yin et al. 2023). For the GFP, the shift from *Helicia robusta* to other species in the tree stage suggested more dynamic successional process. These findings provide critical baseline data for forest managers; ensuring the protection of *Quercus* mother trees in BKPH and maintaining the enrichment planting in GFP which is essential for the long-term sustainability of the Karanganyar forest ecosystem.

CONCLUSION

This study demonstrated significant differences in vegetation composition and community structure between the GFP Mangkunagoro I Conservation

Table 3. Species diversity index and species uniformity index as well as richness index from Marglef, based on the growth rate of protected forest blocks and BKPH North Lawu forest blocks.

Size	GFP Protection Block				
Plot (m ²)	S	N	R1	H'	E
2x2	2	17	0.35	0.224	0.323
5x5	6	45	1.31	1.468	0.819
10x10	28	152	5.37	2.260	0.678
20x20	32	289	5.47	2.762	0.797
Size	North Lawu BKPH Natural Forest Block				
2x2	7	34	1.70	1.501	0.771
5x5	19	108	3.84	2.221	0.754
10x10	22	137	4.27	2.314	0.749
20x20	18	244	3.09	1.994	0.690

Note: S (Sorensen's Similarity Index), N (Importance Value Index), R1 (Margalef's Richness Index), H' (Species diversity), E (Evenness Index).

Table 4. Tree species similarity index in the GFP protected area and the North Lawu BKPH natural forest block based on growth rate.

Size	Amount Species	Quantity	IS
20x20	In Protection block (A)	32	0.22
	In the North Lawu BKPH Natural Forest block (B)	18	
	In both blocks (C)	13	
	In Protection block (A)	28	
10x10	In the North Lawu BKPH Natural Forest block (B)	22	0.16
	In both blocks (C)	9	
5x5	In Protection block (A)	6	0.36
	In the North Lawu BKPH Natural Forest block (B)	19	
	In both blocks (C)	2	
2x2	In Protection block (A)	2	0.52
	In the North Lawu BKPH Natural Forest block (B)	7	
	In both blocks (C)	1	

Block and the BKPH Lawu Utara Natural Forest. The GFP area exhibited higher species richness (42 species) compared to the natural forest of BKPH Lawu Utara (24 species), reflecting its role as a biodiversity conservation and collection zone. In terms of dominance, *Helicia robusta* characterised the early successional stages in both locations, while the climax stage in the natural forest was heavily dominated by *Quercus* sp. (IVI 115.80). These findings suggested that while both areas showed healthy natural regeneration, different management strategies are required. Conservation efforts should prioritise the protection of climax species like *Quercus* sp. in natural forests, while GFP management should focus on maintaining high taxonomic diversity through enrichment plantation and habitat preservation.

AUTHORS CONTRIBUTION

H.D.R. Conceptualisation, Methodology, Writing – original draft. B.H. Supervision, Validation. P. Project administration, Resources. C.Y.L. Data curation, Investigation. A.W. Formal analysis. S.A.C. Software, Visualisation. N.P.N. Methodology, Validation. A.W.N. Investigation. A.I. Supervision. I.A. Writing & review. F.M.H.N. Data curation. D.P. Investigation. M.N. Formal analysis. M.S. Investigation, Methodology, Writing – review & editing. W. Resources, Data curation. I.L.P.P. Review

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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