



Diversity of Fern Types (Pteridophyta) in the Grojogan Sewu, Parang Ijo, and Jumog Waterfall Tourist Areas of Karanganyar Regency

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Abstract

Background: The condition of the area in the three waterfall areas in Karanganyar Regency is very suitable for the growth of various organisms, both flora and fauna, especially ferns. These three areas have different environmental factors and regional topography, which allow various types of Pteridophyta to occur. This study aims to determine differences in fern diversity across three waterfall locations in Karanganyar Regency: Grojogan Sewu, Jumog, and Parang Ijo. **Method:** This research uses a purposive sampling method with plot and roaming techniques. **Results:** The research identified 35 terrestrial and epiphytic Pteridophyta, comprising 15 families and 6 orders: Polypodiales, Cyatheales, Gleicheniales, Lindseales, Salviniiales, and Marattiales. The highest diversity index (H') and evenness (E) of ferns are found in the Parang Ijo Waterfall area, which are 2.14 and 0.71. The Parang Ijo Waterfall area has various environmental and topographic factors that support fern adaptation. The highest dominance index (C) is 0.51 in the Grojogan Sewu Waterfall area. **Conclusion:** The Grojogan Sewu Waterfall area has a more homogeneous and extensive habitat, thus supporting the dominant types of ferns to grow in large numbers.

Keywords: Diversity; Epiphytic; Pteridophyta; Terrestrial; Waterfall

Introduction

Biodiversity requires special attention to address the fundamental problem of biodiversity decline. Ferns remain relatively unknown, particularly in various waterfall areas of Karanganyar Regency, Central Java Province, Indonesia. An inventory was conducted to identify the types of ferns in the area. Ferns (Pteridophyta) are members of the Cryptogamae plant division, each species clearly possessing a cormus, possessing true roots, stems, and leaves, as well as vascular bundles of xylem and phloem. These plants live in humid habitats (hygrophytes), in various aquatic environments (hydrophytes), and on rock, soil, and tree surfaces (epiphytes). They prefer areas with high humidity (Ratu Pradipta et al., 2023).

The Grojogan Sewu Waterfall area is located on the slopes of Mount Lawu, approximately 27 km east of Karanganyar City, Central Java. Grojogan Sewu has a plateau topography at an altitude of \pm 1,100m above sea level, with an average air temperature of \pm 22°C to 32°C. The height of Grojogan Sewu Waterfall is approximately 81 m (Falah, 2019). The Parang Ijo Waterfall area is located in Munggur Hamlet, Girimulyo Village, Ngargoyoso District, Karanganyar Regency, Central Java. The natural tourism area is located at an elevation of approximately 1,000 meters above sea level, with a waterfall height of approximately 60 m (Pradipta & Satiti, 2022). The Jumog Waterfall area is located on the slopes of Mount Lawu, approximately 500m west of Suku Karanganyar Temple, located in Berjo Village, Ngargoyoso District, Karanganyar Regency, Central Java. The area is approximately 1,000 meters above sea level, with a waterfall height of around



Article history

Received: 23 Feb 2025

Accepted: 24 Jan 2026

Published: 31 Dec 2025

Publisher's Note:

BIOEDUSCIENCE stays neutral about jurisdictional claims in published maps and institutional affiliations.

Citation: Sholikhah, S.A. & Muzzazinah. (2025). Diversity of Fern Types (Pteridophyta) in the Grojogan Sewu, Parang Ijo, and Jumog Waterfall Tourist Areas of Karanganyar Regency. *Jurnal BIOEDUSCIENCE*, 9(3), 395-406, doi: [10.22236/jbes/18421](https://doi.org/10.22236/jbes/18421)



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30 m (Roziaty et al., 2016).

The conditions of the waterfall tourist area make the environment very suitable for the growth of various organisms, both flora and fauna, especially ferns. Ferns (Pteridophyta) prefer shaded areas with low temperatures and high humidity. Waterfalls are one type of fern habitat. In general, waterfalls are green open spaces with favorable bioecology that support various fern species (Khairunisa & Wisanti, 2023). Pteridophyta require water for fertilization, so the splash of water from the waterfall onto the walls and rocks in the waterfall area ensures the ferns receive sufficient water for growth and reproduction and helps accelerate spore dispersal (Fauziah et al., 2022).

Developing a tourist area around a waterfall can certainly attract visitors, but it can also affect pteridophyte diversity. This is supported by IUCN data indicating that Indonesia faces significant environmental threats, particularly habitat destruction, which is driving biodiversity decline. One problem with declining biodiversity is the disappearance of many Pteridophyte species before their existence and potential are discovered, which are crucial for ecosystems and human life (Leksono, 2011). Therefore, research on the diversity and abundance of Pteridophyte species in waterfall tourist areas is crucial.

Research on pteridophyte diversity has been conducted in the Jumog Waterfall area, but only on epiphytic pteridophytes. Eleven species of epiphyte pteridophytes from seven families were identified (Roziaty et al., 2016). The fern diversity of the Grojogan Sewu and Parang Ijo Waterfalls remains unexplored, so researchers are interested in assessing pteridophyte diversity in these three areas. This study aims to determine the diversity and abundance of Pteridophyte species in the Grojogan Sewu, Parang Ijo, and Jumog waterfalls in Karanganyar Regency. This research is also expected to examine the diversity of ferns found in tourist areas and to serve as a reference for the development and preservation of plants, especially in the lower plant division.

Method

The research was conducted in July-August 2024 at the Grojogan Sewu, Parang Ijo, and Jumog waterfalls in Karanganyar Regency, Central Java. Grojogan Sewu Waterfall is precisely located at coordinates 7°39'37.71"S, 111°7'49.96"E with an altitude of 1,030 meters above sea level. Parang Ijo Waterfall is located at coordinates 7°37'14.54"S, 111° 7'57.48" E with an altitude of 1,175 meters above sea level. Jumog Waterfall is located at coordinates 7°37'48.95"S, 111° 7'10.90" E with an altitude of 1,057 meters above sea level. Data were collected using plot-based determination techniques for terrestrial ferns and exploration methods for epiphytic ferns. Plot determination in this study was conducted using purposive sampling, with observation plots measuring 10 m x 10 m: 16 plots for the Grojogan Sewu and Jumog waterfall areas and 12 for the Parang Ijo waterfall area. The number of plots was calculated using a representative area, defined as 10% of each area's total area (Sutherland, 2006). The exploration method involved direct observation and exploration along paths that could represent the types of ecosystems and vegetation in the study area (Lestari et al., 2020).

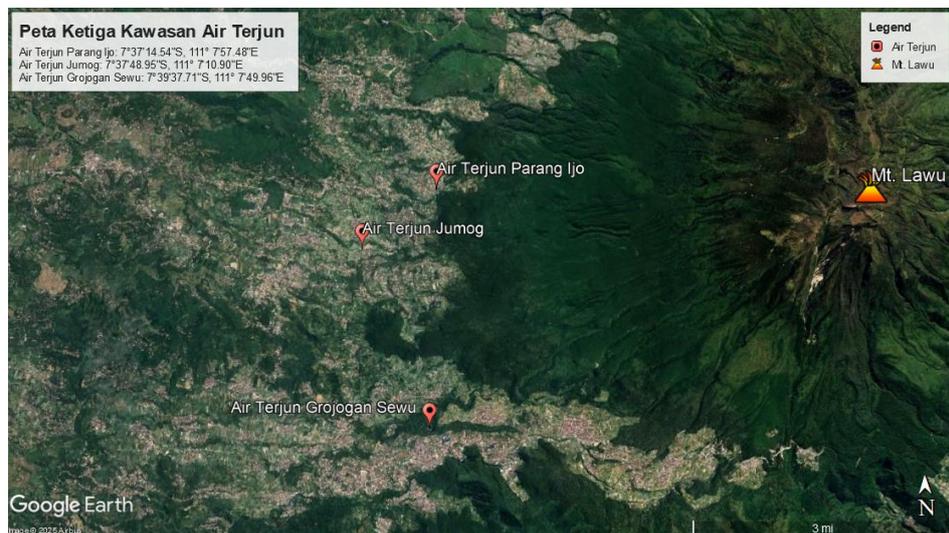


Figure 1. Map of the Grojogan Sewu, Parang Ijo, and Jumog waterfall areas

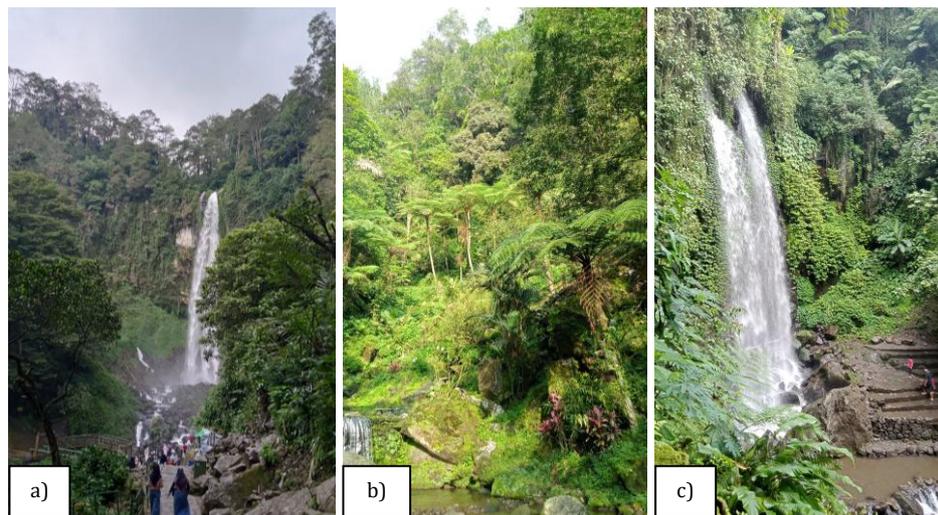


Figure 2. Documentation of the three waterfall areas: a) Grojogan Sewu, b) Parang Ijo, and c) Jumog.

Data Collection

The data collected included: 1) Data on terrestrial and epiphytic pteridophytes, including Order, Family, Genus, and Species. 2) Data on time and location, including the date, time, and location of sampling. 3) Data on abiotic factors, including altitude, air temperature, air humidity, soil temperature, and light intensity. Data analysis included: 1) Identification of epiphytic and terrestrial pteridophytes, 2) Calculation of diversity, 3) Calculation of dominance, and 4) Calculation of evenness.

Procedure

At the research site, abiotic factors were measured, including altitude with an altimeter; humidity, soil pH, and light intensity with a soil tester; and temperature with a thermometer. Measurements were conducted three times in each observation plot, and the average value was taken at the same time of observation (Nursanti et al., 2022). Abiotic factors were measured three times in each plot: at 8:00 AM, 12:00 PM, and 4:00 PM. The measurements were averaged, and the range between the first and last plots was calculated. All fern species within the plots, each with distinct morphological characteristics, were documented and sampled. The samples were labeled, and field data were recorded, including sample code, species name, number of individuals, plot number, characteristics of each fern species, habitat, and morphology, on a tally sheet. Further sample identification was conducted in the

Ecophysiology Laboratory of the Department of Biology Education, Faculty of Teacher Training and Education, Sebelas Maret University.

Data Analysis

Pteridophyte morphological descriptions were conducted through direct observation of their morphological characteristics, including stems, leaf structure, roots, sorus shape, and spores. The observations were then compiled into a data table, along with descriptions of the species found and their classification. Identification was conducted using the identification books Field Guide to the Pteridophytes of Chiang Mai, Thailand (Callado et al., 2016), Cryptogams: Ferns and Fern Allies (Winter & Amoroso, 2003), Flora Malesiana Series II – Pteridophyta, Plant Taxonomy: Schizophyta, Thallophyta, Bryophyta, and Pteridophyta, Revised Edition (Tjitrosoepomo, 2023), and related journals. The diversity index was analyzed quantitatively using the Shannon-Wiener formula, the dominance index using the Simpson dominance index, and the evenness index using the Evenness formula. The formula for the diversity index is as follows:

$$H' = -\sum (P_i \ln P_i), P = (n_i/N)$$

Note:

H' = Shannon-Wiener diversity index

n_i = Number of individuals of species i

N = Number of individuals of all species

The criteria for the diversity index (H') are as follows:

$H' < 1$ = low diversity

$1 < H' \leq 3$ = moderate diversity

$H' > 3$ = high diversity

The following is the formula for Simpson's dominance index (D):

$$D = \sum (n_i/N)^2$$

Information:

D = Simpson's Dominance Index

N_i = Number of Individuals of each species

N = Number of Individuals of all species.

The dominance index ranges from 0 to 1, with lower values indicating no species dominates, and higher values indicating the presence of a particular species (Rahman, 2021).

The formula for Evenness' evenness index (E') is as follows:

$$E' = H' / 1n S$$

Information:

E = Evenness index

H' = Species diversity index

S = Number of species.

The species evenness index ranges from 0 to 1. If the value is close to 0, it means that a species is dominant in the community, whereas if the value is close to 1, it means that all species have almost the same level of species evenness (Wibisono & Azham, 2017).

Result

The results of the Pteridophyta research in the three waterfall tourist areas are presented in characterization tables (Tables 1 and 2). All species were then identified by their species codes, resulting in 34 species of both epiphytic and terrestrial ferns. The number of

individuals for each terrestrial Pteridophyta species in the three waterfall areas is presented in Table 3, and the number of individuals for each epiphytic Pteridophyta species is presented in Table 4. In the Grojogan Sewu Waterfall area, 22 species from 9 families were identified, in the Parang Ijo Waterfall area, 26 species from 15 families were identified. In the Jumog Waterfall area, 22 species from 12 families were identified.

Table 1. Morphological Characterization of Pteridophyta from Codes 1-18

Pteridophyta Characters		Species Code																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Habitats	Terrestrial	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Epiphytes					√		√				√				√			
Habits	Tree										√		√		√				
	Shrub	√			√					√								√	√
	Herb			√		√	√	√	√	√	√			√		√	√		√
Rhizome	Long-upright	√		√	√	√	√	√	√			√	√		√	√	√	√	√
	Short-upright		√											√		√			
Rhizome Edge	Serrated	√								√	√					√			
	Scale		√				√	√		√	√	√	√	√	√		√		
	Fibrous				√									√		√			
Stipe Color	Brown	√			√		√	√					√		√		√		
	Dark Brown			√		√			√										
	Purple Red		√									√							
	Green																√		√
Stipe Edge	Serrated	√		√									√	√	√				
	Scale		√				√	√	√	√	√							√	√
	Smooth				√	√					√	√						√	
Frond	Bipinnate	√		√		√	√	√				√		√	√	√	√	√	√
	Tripinnate				√				√				√						
Lamina Type	Monomrphic	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dimorphic										√								
Lamina Shape	Pinnate		√		√	√							√	√	√		√	√	√
	Oval						√			√									
	Fragile										√								
	Parallel									√	√	√				√			
Lamina Texture	Hard							√											
	Lateral	√																	
	Linear		√					√											
Pinna Tip	Pointed	√	√	√		√	√	√		√	√			√	√		√	√	√
	Rounded				√					√		√	√	√	√				
	Serrated															√			
Pinna Base	Rounded	√			√	√	√										√	√	√
	Tapered			√											√				
	Fused									√	√			√					
Rachis	Dichotomous									√		√	√			√			
Sori shape	Rounded			√		√		√	√	√							√		
	Oval				√		√	√				√	√	√	√	√		√	√
Sori location	Near Costule	√		√						√		√	√		√				
	Along Costa		√																
	Near Lobe Apex						√							√					
	Edge Along Pinnule				√			√									√	√	√
	Lamina Tip										√								
Sori Location on Pinnae	Following Veins															√			
	Irregular					√													
	Upper		√																
	Lower	√	√	√	√	√	√	√	√	√							√	√	√
	Both Sides												√	√	√	√			

Table 2. Morphological Characterization of Pteridophyta from Code 19-34

Pteridophyta Characters		Species Code																	
		19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
Habitats	Terrestrial	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Epiphytes			√		√							√					√	√
Habits	Tree																		
	Shrub			√	√	√	√				√	√			√	√			√
	Herb	√							√	√			√			√	√		√
Rhizome	Long-upright	√	√	√	√	√				√	√	√		√	√	√	√	√	√
	Short-upright								√	√		√	√	√					√
Rhizome Edge	Serrated														√				
	Scale		√	√	√	√				√	√	√	√						√
	Fibrous						√	√								√	√	√	√
Stipe Color	Brown	√				√	√		√	√	√		√						√

Table 4. Number of Individuals of Each Species of Epiphytic Pteridophyta in Three Waterfall Areas

No	Species Code	Species Name	Family	Waterfall Tourism Area		
				Grojogan Sewu	Parang Ijo	Jumog
1	21	<i>Davallia denticulata</i>	Davalliaceae	-	9	-
2	1	<i>Diplazium polypodioides</i>	Dryopteridaceae	-	-	7
3	25	<i>Dryopteris intermedia</i>	Dryopteridaceae	-	-	73
4	22	<i>Nephrolepis biserrata</i>	Nephrolepidaceae	-	2	-
5	10	<i>Drynaria rigidula</i>	Polypodiaceae	12	4	7
6	11	<i>Phymatosorus scolopendria</i>	Polypodiaceae	25	8	2
7	9	<i>Platyterium bifurcatum</i>	Polypodiaceae	19	2	18
8	33	<i>Psilotum nudum</i>	Psilotaceae	-	-	16
9	19	<i>Adiantum tenerum</i>	Pteridaceae	-	-	7
10	34	<i>Haplopteris elongata</i>	Pteridaceae	4	-	-
11	20	<i>Haplopteris ensiformis</i>	Pteridaceae	4	29	-
12	35	<i>Polytaenium cajenense</i>	Pteridaceae	-	11	5
13	15	<i>Selaginella eurynota</i>	Selaginellaceae	-	-	5
14	5	<i>Tectaria heracleifolia</i>	Tectariaceae	-	14	-
15	2	<i>Thelypteris palustris</i>	Thelypteridaceae	-	16	4

Based on Tables 3 and 4, the Pteridophyta species found in the three waterfall areas are mostly terrestrial Pteridophyta (living on land). The epiphytic Pteridophyta found are few in number due to the lack of trees that can be used as host trees for ferns to attach to. In the three waterfall areas, most of the trees are dry-textured. The study also found various pteridophyte species across the three waterfall areas. The family with the highest species diversity is Pteridaceae with eight species, while the genus with the highest diversity is Pteris with four species. The highest diversity of pteridophyte species is in the Jumog Waterfall Tourism Area, with 29 species, while the lowest is in the Grojogan Sewu Waterfall Tourism Area, with 23 species.

Discussion

Each waterfall area shows distinct characteristics of species and families. Grojogan Sewu Waterfall has three different species compared to the other two waterfall areas, namely *Drynaria rigidula*, *Pteris biaurita*, and *Pteris ensiformis*. Parang Ijo Waterfall has six species and six families, compared with the other two areas: terrestrial Pteridophyta from the Blechnaceae, Gleicheniaceae, and Marattiaceae, and epiphytic Pteridophyta from the Davalliaceae, Nephrolepidaceae, and Tectariaceae. Jumog Waterfall has five species from three families, compared with the other two areas, which have terrestrial Pteridophyta, including Psilotaceae, Pteridaceae, and Selaginellaceae.

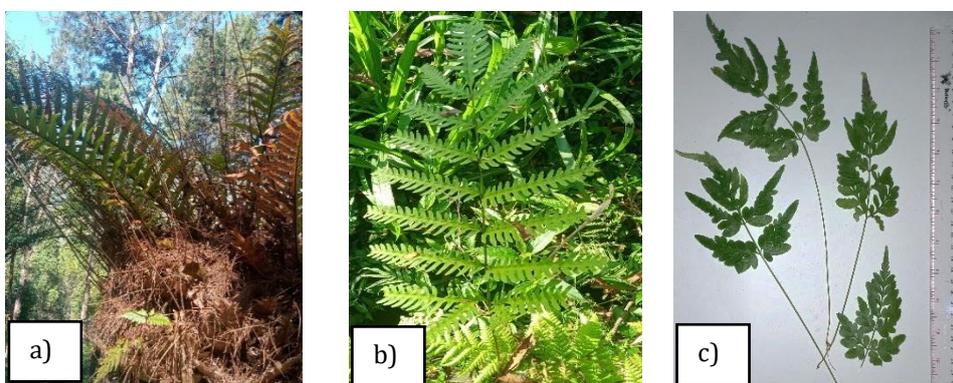


Figure 3. Characteristics of species at Grojogan Sewu Waterfall, a) *D. rigidula*, b) *P. biaurita*, c) *P. ensiformis*

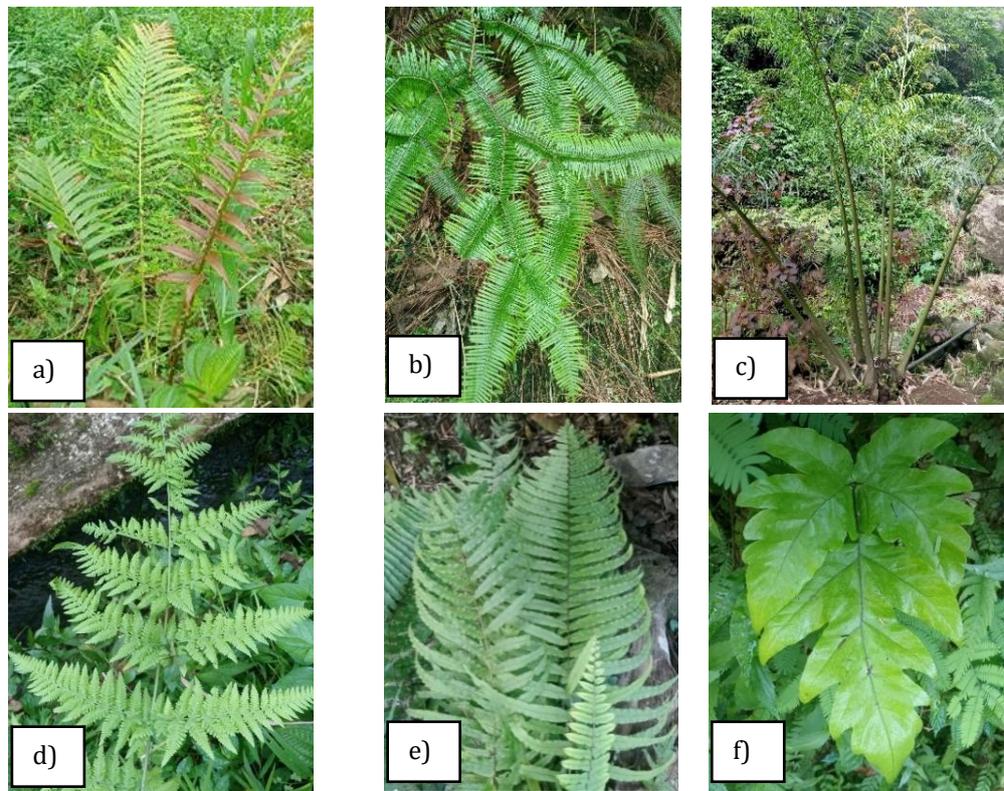


Figure 4. Pteridophyta species that can only be found at Parang Ijo Waterfall, a) *B. occidentale*, b) *D. linearis*, c) *A. evecta*, d) *D. denticulata*, e) *N. biserrata*, f) *T. heracleifolia*

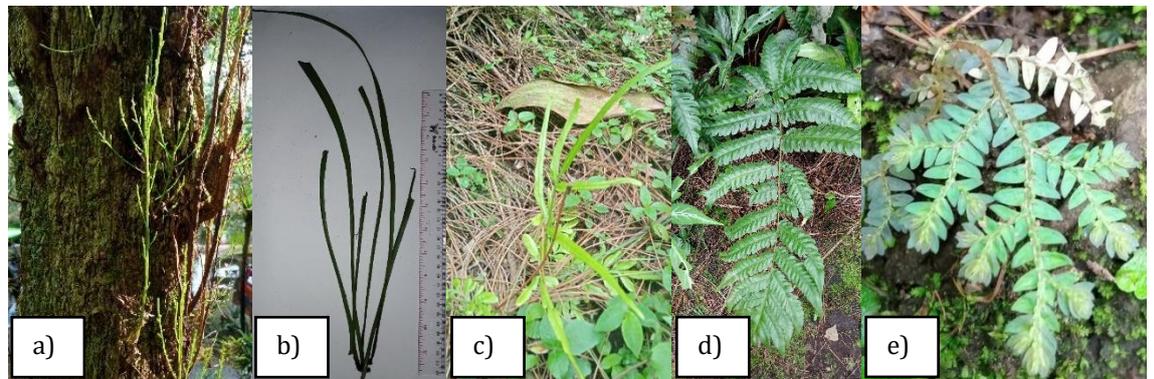


Figure 5. Characteristics of species at Jumog Waterfall, a) *P. nudum*, b) *H. elongata*, c) *P. multifida*, d) *P. fauriei*, e) *S. eurynota*

Figure 2. Pteridophyta species found only at Grojogan Sewu Waterfall belong to the Polypodiaceae family, namely *Drynaria rigidula*, and the Pteridaceae family, namely *Pteris biaurita* and *Pteris ensiformis*. *Drynaria rigidula* is an epiphytic fern, having two types of leaves: sterile leaves that are shaped like a nest and fertile leaves with linear leaflets that grow on stalks that reach 40 cm in length. *Pteris biaurita* is a terrestrial fern that has a short, upright or creeping rhizome that is slightly hairy; the lower leaflets look larger and have a gapped edge. Sorus appears as a line along the lower leaf edge (Winter & Amoroso, 2003). *Pteris ensiformis* is a terrestrial fern that has a short, upright or creeping rhizome with brown scales, opposite leaves with serrated leaf edges, and is accompanied by small white hairs. These two species thrive in calm, humid, and sheltered areas, making them ideally suited to the Grojogan Sewu Waterfall area, which offers more shade than the other two waterfalls.

Figure 3. Characteristics of the Parang Ijo Waterfall species include *Blechnum occidentale*, which has reddish-green leaves when young and dark green when mature, with thin, linear sori (Sofiyanti et al., 2018). *Dicranopteris linearis* has a long rhizome with 4-5

veins and rounded sori located on the underside of the leaflets. *Angiopteris evecta* is large with a long pinnate lamina and sori located on the underside of the leaves (Nugroho et al., 2018). *Davallia denticulata* has fringed, triangular fronds with serrated edges. *Nephrolepis biserrata* has linear leaves with pointed tips, short, pinnate stems, and finely serrated edges (Maulidia et al., 2019). *Tectaria heracleifolia* has finger-like, coral-like leaves with a smooth, glossy surface and scattered sori underneath. *Nephrolepis biserrata* and *Blechnum occidentale* from the *Gleichenia* family are examples of light-loving ferns (Febriyani et al., 2022), so these two species can be found in the Parang Ijo Waterfall area, which receives less shade than Grojogan Sewu Waterfall.

Figure 4. Characteristics of species at Jumog Waterfall include *Psilotum nudum*, which is characterized by spores located in spore sacs in the form of round, bright yellow bumps, and a round stipe (Hanas & Bria, 2019). Several species from the Pteridaceae family, not found in the other two areas, are also found in this area. *Haplopteris elongata* is an epiphytic fern characterized by rope-like, hanging leaves and a short rhizome. Another species, *Pteris multifida*, is characterized by slender stems and elongated, oval leaves measuring 10-60 cm. The final species in the Pteridophyta family, *Pteris fauriei*, is characterized by lanceolate leaves, serrated edges, and tapered tips with a smooth or shiny surface (Leki et al., 2022). The sori are located on the underside of the leaves along the veins. *Selaginella eurynota* has oppositely arranged leaves that are green with yellowish tips (Tjitrosoepomo, 2023).

The results of the species diversity calculations using existing provisions, namely the Shannon-Wiener diversity index (H'), indicate that the three waterfall areas have a moderate diversity index. A high species diversity index indicates that a region or ecosystem has many different species with a relatively even number of individuals (uneven numbers) among these species. Parang Ijo Waterfall has a higher diversity index because the area still contains several pristine plots that tourists rarely visit. Calculations using the Evenness dominance index (E) indicate that Parang Ijo and Jumog waterfalls have stable dominance, while Grojogan Sewu waterfall is classified as unstable. Grojogan Sewu waterfall is dominated by terrestrial pteridophytes, namely *Diplazium polypodioides*. Calculations using the Simpson evenness index (D) indicate that Grojogan Sewu and Jumog waterfalls have moderate evenness, while Parang Ijo waterfall has high evenness. The analysis results are shown in Table 5.

Table 5. Analysis Results of Various Indices for Each Waterfall Area

Waterfalls	Diversity index	Dominance index	Evenness index
Grojogan sewu	1,18 (Moderate)	0,51 (Unstable)	0,40 (Moderate)
Parang Ijo	2,14 (Moderate)	0,19 (Unstable)	0,71 (Stable)
Jumog	1,14 (Moderate)	0,42 (Unstable)	0,47 (High)

The higher the diversity index value, the lower the species dominance in the ecosystem. The species diversity index (H') for pteridophytes at all locations indicates a moderate diversity category, ranging from $1 \leq H' \leq 3$. The diversity index can be influenced by each fern species' ability to survive or compete under different growth conditions. Nutrient availability and nutrient utilization vary significantly (Laely et al., 2020). Parang Ijo Waterfall has several plots that humans rarely visit, as visitors often head directly to the main waterfall, thereby maintaining fern diversity.

The highest dominance index was recorded at Grojogan Sewu Waterfall (0.51), indicating dominance by a single species. This species is *Diplazium polypodioides*, with a relative dominance value of 69%. The other two waterfalls, Parang Ijo and Jumog, are also dominated by the same species. Parang Ijo Waterfall has a dominance value of 0.19 and a relative dominance of 38% for *Diplazium polypodioides*. Jumog Waterfall has a dominance value of 0.42 and a relative dominance of 63% for *Diplazium polypodioides*. Plant species with higher dominance values are dominant and contribute to their sustainability. If a plant species grows in a suitable location, it can become a dominant species (Kuswantoro et al., 2018).

The highest evenness index is at Parang Ijo Waterfall, with a value of 0.71. This indicates that the location has a relatively equal number of species across individuals. Jumog Waterfall comes in second with 0.47, and Grojogan Sewu Waterfall has the lowest evenness index at 0.40. The low index value is due to the presence of species with high numbers of individuals or dominant species, as well as uneven numbers of individuals within each species. Differences in this index across several waterfall locations indicate that each location has a different composition of individual numbers. Evenness is a measure of the relative abundance of species within a community.

Table 6. Results of Environmental Factor Analysis for Each Waterfall Area

Waterfalls	Environmental Factors				
	Altitude (masl)	Air Temperature (°C)	Air humidity (%)	Soil temperature (°C)	Light intensity (lux)
Grojogan Sewu	1.004 - 1.030	21 - 26	74 - 80	20 - 25	35 - 325
Parang Ijo	1.008 - 1.175	21 - 24	72 - 89	22 - 23	230 - 502
Jumog	1.006 - 1.057	19 - 24	75 - 90	19 - 22	22 - 554

Based on Table 6, the diversity of fern species can be influenced by various environmental factors, such as altitude, air temperature, humidity, soil temperature, and light intensity. A suitable altitude for ferns is 1,100-1,300 meters above sea level. The higher the altitude, the greater the species diversity. For example, at Parang Ijo Waterfall, the higher species diversity value is due to the presence of unique species found only at this location, namely *Dicranopteris linearis*, *Blechnum occidentale*, and *Blechnum officinale*. *Dicranopteris linearis* is characterized by growing at higher elevations than other pteridophyte species (Sofiyanti et al., 2021). In this study, *Dicranopteris linearis* was found in the last, highest plot, characterized by lower upper-vegetation cover. The ideal temperature for the growth of Pteridophyta in tropical areas is typically 21–27°C (Imaniar et al., 2017). At relatively low temperatures, not many species can thrive. At Jumog Waterfall, in its humid, cool conditions, one species, *Selaginella eurynota*, thrives. This plant is found on damp tree trunks and in areas with little or no sunlight. Suin (2002) stated that favorable temperature and humidity can encourage the growth and reproduction of particular plant species. The lowest humidity level tolerated by ferns is 30%. Meanwhile, the ideal humidity range for ferns is 50–80% (Situmorang & Hasibuan, 2021).

pH also influences fern growth. The ideal pH range for ferns growing in shaded environments is typically 5.5–6.5. Furthermore, optimal light intensity for growth ranges from 117–1603 lux (Yolla et al., 2022). The Parang Ijo Waterfall area has a more varied environmental profile, with high humidity around the waterfall and drier conditions in the rocky areas. These factors support the diversity of fern species. The Grojogan Sewu Waterfall area has a very humid, shady microclimate, making it suitable only for ferns that require high humidity and limiting the presence of fern species tolerant of dry conditions or brighter light. The diversity of species at Parang Ijo Waterfall is also due to the more heterogeneous habitat, as the waterfall has various substrates, including rocks, moist soil, and dry rocky areas. Research by Moulatlet (2019) shows that areas with high sand and clay content have fern species that can specifically adapt to these conditions. These different substrate types will create more ecological niches for fern species, even though only a few individuals occupy each niche. The high and low numbers of individuals of each species are due to soil conditions that are suitable for the life and growth of Pteridophyta species (Hutasuhut & Febriani, 2019).

Conclusions

The number of Pteridophyta species, both epiphytic and terrestrial, found in the three waterfall areas is 35, belonging to 15 families. In the Grojogan Sewu Waterfall Tourism Area, 22 species from 9 families were identified, in the Parang Ijo Waterfall Tourism Area, 26 species from 15 families were identified. In the Jumog Waterfall Tourism Area, 22 species from 12 families were identified. The diversity and evenness of Pteridophyta species are

highest in the Parang Ijo Waterfall area because this area has a variety of environmental factors and topography that support the adaptation of each fern species. In the Grojogan Sewu Waterfall area, there is high species dominance because a more homogeneous, extensive habitat supports the growth of dominant species in large numbers.

Acknowledgments

Thank you to the research supervisor for providing suggestions and input throughout this research. Thank you also to the Manager of the Grojogan Sewu, Jumog, and Parang Ijo Waterfall Areas, Karanganyar Regency, for granting permission and providing information for this research, and to all parties who assisted with it.

Declaration statement

The authors report no potential conflict of interest.

References

- Callado, J. R. C., Adjie, B., Suksathan, P., Lestari, W. S., & Darnaedi, D. (2016). *Field Guide to the Pteridophytes of Chiang Mai, Thailand* (E. . Fernando, H. Miwa, & F. A. Pollisco (eds.); 2nd ed.). ASEAN Centre for Biodiversity.
- Falah, D. (2019). Analisis pemanfaatan Dan pengembangan Hutan Wisata Tawangmangu. *Jurnal Wana Tropika*, 9(2), 89–103.
- Fauziah, A., Hasanuddin, H., & Andayani. (2022). Jenis Pteridophyta yang terdapat di Kawasan Wisata Brayeun Kecamatan Leupang Kabupaten Aceh Besar. *Jurnal Jeumpa*, 9(1), 705–711.
- Febriyani, H., Hutasuhut, E., & Handayani, N. (2022). Keanekaragaman Tumbuhan Paku Di Taman Nasional Batang Gadis Resort 7 Sopotinjak Sumatera Utara. *SITek : Jurnal Sains, Informatika, Dan Teknologi*, 1(1), 7–12.
- Hanas, D. F., & Bria, E. J. (2019). International Standard of Serial Number 2622-1020. *Jurnal Saintek Lahan Kering*, 2(2), 30–32. <https://doi.org/10.32938/silk.v2i2.789>
- Hutasuhut, M. A., & Febriani, H. (2019). Keanekaragaman Paku-Pakuan Terrestrial Di Kawasan Taman Wisata Alam Sicike-Cike. *Jurnal Biolokus*, 2(1), 146. <https://doi.org/10.30821/biolokus.v2i1.441>
- Imaniar, R., Pujiastuti, & Mardiyah, S. (2017). Identifikasi Keanekaragaman Tumbuhan Paku di Kawasan Air Terjun Kapas Biru Kecamatan Pronojiwo, Kabupaten Lumajang serta Pemanfaatannya sebagai Booklet. *Jurnal Pendidikan Biologi*, 6(3), 337–345.
- Karim, W. A., Nurlia, Ndolan, Y., & Samaduri, A. (2022). Inventarisasi Tumbuhan Paku (Pterydophyta) di hutan Batu Tikar Kecamatan Luwuk Kabupaten Banggai. *JBB: Jurnal Biologi Babasal*, 1(1), 28–33.
- Khairunisa, K., & Wisanti, W. (2023). Keanekaragaman Spesies Pteridophyta di Kawasan Wisata Air Terjun Supit Urang Pujon Kabupaten Malang. *LenteraBio: Berkala Ilmiah Biologi*, 12(3), 343–353. <https://doi.org/10.26740/lenterabio.v12n3.p343-353>
- Kuswanto, F., Lugrayasa, I. N., & Sujarwo, W. (2018). Studi Ekologi Kuantitatif Hutan Pilon Sebagai Dasar Pengembangan Kebun Raya Gianyar. *Jurnal Ilmu Kehutanan*, 12(2), 184. <https://doi.org/10.22146/jik.40147>
- Laely, S. N., Widyastuti, A., & Widodo, P. (2020). Keanekaragaman Tumbuhan Paku Terrestrial di Cagar Alam Pemalang Jawa Tengah. *BioEksakta: Jurnal Ilmiah Biologi Unsoed*, 2(1), 116–122. <https://doi.org/10.20884/1.bioe.2020.2.1.1966>
- Leki, P. T., Makaborang, Y., & Ndjoeroemana, Y. (2022). Keanekaragaman Tumbuhan Paku (Pteridophyta) di daerah Aliran Sungai Pepuwatu Desa Prai Paha Kabupaten Sumba Timur sebagai Sumber Belajar Biologi. *BIOEDUKASI: Jurnal Pendidikan Biologi*, 13(1), 42–58.
- Leksono, A. S. (2011). *Keanekaragaman Hayati*. Universitas Brawijaya Press.
- Lestari, I., Murningsih, & Utami, S. (2020). The Diversity of Fern in Petungkriyono Mixed Forest Pekalongan, Central Java. *Journal of Physics: Conference Series*, 1524(1), 1–4. <https://doi.org/10.1088/1742-6596/1524/1/012141>
- Maulidia, A., Sedayu, A., Panca Sakti, D., Dwi Puspita, E., Kusumaningtiyas, F., Hendi Ristanto, R., & Rahmah, S. (2019). Keanekaragaman Tanaman Paku (Pteridophyta) di Jalur Ciwalen Taman Nasional Gunung Gede Pangrango, Jawa Barat. 4(1)
- Moulatlet, G. M., Zuquim, G., & Tuomisto, H. (2019). The Role Of Soils For Pteridophyte Distribution In Tropical American Forests. *Fern Gaz*, 21(1), 1–20.
- Nugroho, C., Larasati, D., Yuliawati, P.S., E., Ramadhan, N., Savira, S., S., T. I., S., A., & Ristanto, R. H. (2018). Karakteristik Tumbuhan Paku (Pterydophyta) di Jalur Ciwalen, Taman Nasional Gunung Gede Pangrango, Cisarua, Jawa Barat. . *Biodidaktika: Jurnal Biologi Dan Pembelajarannya* , 13(1), 14–19.
- Nursanti, N., Adriadi, A. A., & Sai'in, S. (2022). Komponen Faktor Abiotik Lingkungan Tempat Tumbuh Puspa (*Schima Wallichii* Dc. Korth) di Kawasan Hutan Adat Bulian Kabupaten Musirawas. *Jurnal Silva Tropika*, 5(2), 438–445.

<https://doi.org/10.22437/jsilvtrop.v5i2.14566>

- Pradipta, M. P. Y., & Emmelia Nadira Satiti. (2022). Potensi Pengembangan Obyek Wisata Air Terjun Parang Ijo Kabupaten Karanganyar Jawa Tengah. *Jurnal Ekonomi, Manajemen Pariwisata dan Perhotelan*, 1(2), 210–215. <https://doi.org/10.55606/jempper.v1i2.401>
- Rahman, D. A. (2021). *Dasar-Dasar Ekologi Kuantitatif: Teori dan Aplikasi*. PT Penerbit IPB Press.
- Pradipta, A.R., Hariani, S.A., & Novenda, I.L. (2023). Identifikasi Tumbuhan Paku Berdasarkan Letak dan Posisi Sorus dengan Ketinggian Berbeda di Kabupaten Bondowoso. *Biologi Edukasi: Jurnal Ilmiah Pendidikan Biologi*. <https://doi.org/10.24815/jbe.v15i1.30490>
- Roziaty, E., Agustina, P., & Nurfitrianti, R. (2016). Pteridophyta Epifit Kawasan Wisata Air Terjun Jumog Ngargoyoso Karanganyar Jawa Tengah. *Bioedukasi*, 9(2), 76–78. <https://doi.org/10.20961/bioedukasi-uns.v9i2.8586>
- Situmorang, J. T., & Hasibuan, R. (2021). An Inventory of Ferns (Pteridophyta) in Plantation PTPN Nusantara 3 Rantau Prapat District Labuhanbatu. *Budapest International Research and Critics Institute (BIRCI- Journal): Humanities and Social Sciences*, 4(2), 3122–3126. <https://doi.org/10.33258/birci.v4i2.2030>
- Sofiyanti, N., Iriani, D., Fitmawati, F., & Atika Marpaung, A. (2018). Morphology, palynology, and stipe anatomy of four common ferns from Pekanbaru, Riau Province, Indonesia. *Biodiversitas Journal of Biological Diversity*, 20(1), 327–336. <https://doi.org/10.13057/biodiv/d200138>
- Sofiyanti, N., Iriani, D., Taufiq, I., Sari, M., Irawan, A., & M. Syauqi, F. (2021). Diversity, structure and composition of pteridophyte in varying habitats in Karimun Besar Island, Riau Islands Province, Indonesia. *Biodiversitas Journal of Biological Diversity*, 22(11), 4847–4856. <https://doi.org/10.13057/biodiv/d221117>
- Suin, M. (2002). *Metode Ekologi*. Padang: Universitas Andalas.
- Sutherland, W. J. (2006). *Ecological Census Techniques*. Cambridge University Press.
- Tjitrosoepomo, G. (2023). *Taksonomi Tumbuhan: Schizophyta Thallophyta Bryophyta Pteridophyta EDISI REVISI* (12th ed.). Gadjah Mada University Press.
- Winter, W. P. de, & Amoroso, V. B. (2003). *Plant resources of South-East Asia. No. 15(2), Cryptogams. Ferns and fern allies*. Backhuys.
- Yolla, A. S., Damayanti, F., & Gresinta, E. (2022). Keanekaragaman Tumbuhan Paku Terrestrial di Kawasan Hutan Pinus Gunung Pancar, Bogor. *EduBiologia: Biological Science and Education Journal*, 2(1), 63. <https://doi.org/10.30998/edubiologia.v2i1.11844>