

Fern diversity and conservation status in the South Gombang karst forest, Kebumen District, Indonesia

Keanekaragaman tumbuhan paku dan status konservasi di hutan karst Gombang Selatan, Kabupaten Kebumen, Indonesia

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Abstrak. Afifah FN, Putri NRA, Hartanti AN, Pramudita DA, Armando MF, Rahmayani D, Indrawan M, Safira RN, Buot Jr IE, Setyawan AD. 2023. Keanekaragaman tumbuhan paku dan status konservasi di hutan karst Gombang Selatan, Kabupaten Kebumen, Indonesia. *Pros Sem Nas Masy Biodiv Indon 9: 186-195*. Pteridophytes adalah organisme kosmopolitan yang dapat hidup di berbagai habitat dan memiliki persebaran yang luas, seperti ekosistem karst. Namun, masih ada beberapa spesies yang perlu diinventarisasi. Salah satu ekosistem karst di Kabupaten Kebumen ada di Desa Ayah. Penelitian ini bertujuan untuk mengkaji keanekaragaman dan status konservasi Pteridophyta di ekosistem hutan karst di Desa Ayah, Kebumen, Jawa Tengah, Indonesia. Data primer penelitian ini diperoleh dari pengamatan lapangan yang dilakukan dengan metode survei, serta pengukuran berbagai faktor abiotik. Data dikumpulkan dengan metode survei dan dianalisis dengan indeks keanekaragaman spesies Shannon-Wiener (H'), indeks kekayaan spesies Margalef (D_{mg}), dan indeks keseragaman spesies (E), sedangkan status konservasi Pteridophyta diperoleh dari IUCN Red List dan CITES. Dari hasil penelitian ditemukan Pteridophytes terdiri dari 736 individu yang digolongkan dalam 22 spesies dan 8 famili. Hasil analisis menunjukkan indeks keanekaragaman spesies (H') pada kategori sedang (2,57), indeks kekayaan spesies Margalef (D_{mg}) pada kategori sedang (3,33), dan indeks keseragaman spesies (E) pada keseragaman populasi tinggi (0,83). Dari penilaian status konservasi IUCN Red List, tiga spesies termasuk dalam kategori Least Concern (LC): *Cyclosorus interruptus* (Willd.), *Adiantum capillus-veneris* L., dan *Pteris vittata* L. Tidak ada satu pun spesies pteridophyta yang ditemukan berstatus konservasi dari CITES. Oleh karena itu, penelitian ini dapat digunakan sebagai evaluasi untuk melestarikan spesies Pteridophyta yang berstatus memprihatinkan agar keberadaannya dapat dipertahankan.

Kata kunci: Hutan Desa Ayah, keanekaragaman jenis, metode survei, Pteridophyta, status konservasi

Abstract. Afifah FN, Putri NRA, Hartanti AN, Pramudita DA, Armando MF, Rahmayani D, Indrawan M, Safira RN, Buot Jr IE, Setyawan AD. 2023. *Fern diversity and conservation status in the South Gombang karst forest, Kebumen District, Indonesia. Pros Sem Nas Masy Biodiv Indon 9: 186-195*. Pteridophytes are cosmopolitan organisms that can live in various habitats and have a wide distribution, such as karst ecosystems. However, there are still some species that need to be inventoried. One of the karst ecosystems in the Kebumen district is located in Ayah Village. This study aimed to examine the diversity and conservation status of Pteridophytes in the karst ecosystem of the Ayah Forest, Kebumen, Central Java, Indonesia. The primary data of this study were obtained from field observations carried out using the survey method, as well as measurements of abiotic factors. The data were collected by survey method and analyzed with the Shannon-Wiener species diversity index (H'), Margalef species richness index (D_{mg}), and the Evenness species index (E). Conservation status of Pteridophyta obtained from IUCN Red List and CITES. From the research results, the Pteridophytes found consisted of 736 individuals belonging to 22 species and 8 families. The results of the analysis showed to species diversity index (H') in the moderate category (2.57), Margalef species richness index (D_{mg}) in the moderate category (3.33), and evenness species index (E) in the high population uniformity (0.83). From the IUCN Red List conservation status assessment, three species are included in the Least Concern (LC) category: *Cyclosorus interruptus* (Willd.), *Adiantum capillus-veneris* L., and *Pteris vittata* L. None of the pteridophyta species found has conservation status from CITES. Therefore, this research can be used as an evaluation to conserve Pteridophytes species that have worrying status so that their existence can be maintained.

Keywords: Ayah forest, conservation status, Pteridophytes, species diversity, survey method

INTRODUCTION

Pteridophytes are categorized into cosmopolitan plant species that live in various habitats, such as aquatic, terrestrial, and epiphytic (PPG I 2016). The sensitive nature of Pteridophytes to humidity and air temperature makes them can be used for being indicators of climate change (Pouteau et al. 2016). However, the diversity and distribution of species in different altitude zones vary based on their resistance to the conditions and ecological aspects in the area (Patil et al. 2016). Abiotic factors for the life expectancy of Pteridophytes include high humidity, soil acidity, large water flow, high rainfall, and light intensity. In contrast, biotic factors are shade or canopy of other plants (Sianturi et al. 2021). In Indonesian forests, the families Polypodiaceae and Selaginellaceae are the most commonly encountered groups. This group likes shade with less light intensity and high humidity, so it is suitable for Indonesian forest conditions (Maupaung 2019).

The karst ecosystem consists of unique parts and is sensitive to environmental damage. One effort to protect it is to maintain the level of biodiversity above and below the surface of the karst habitat. Concerning the life of flora, karst ecosystems also have an important role in helping the growth of trees and plants around them. This function makes the karst ecosystem a tool for preventing climate change (Widyaningsih 2017). The presence of Pteridophytes (Pteridophyta) in this area is important, considering its role as a supporting component that helps maintain ecosystem stability (Masykur et al. 2019). Temperature rise is a common indicator of climate change. The species on earth have undergone many changes due to climate change gradually and over a long period, one of which is the Pteridophyta population (Sharpe 2019). Pteridophyta has a role as a bio-indicator, one of which is related to climate change and can be used to evaluate the effectiveness of protected areas based on diversity. Some Pteridophyta, including *Asplenium* spp., *Blechnum* spp., *Adiantum* spp., *Polypodium* spp., *Pteris* spp., *Equisetum* spp., and *Thelypteris* spp. has been reported as an indicator of soil and habitat features (Mehrabian et al. 2020). Climate change is a challenge in facing high extinction risks, especially for species with limited geographic distribution (Loiseau et al. 2020).

Therefore, conservation status is needed in nature conservation measures pursued by communities worldwide. One of them uses the IUCN Red List status as a category that classifies species of endangered living things. In addition, to protect living beings from international trading that is not following the provisions and threatens their sustainability may refer to the CITES guidelines (Aisyah and Fahraby 2021). The threat to Pteridophytes in nature is utilization that needs to be followed by cultivation. Pteridophytes also have a reasonably high economy, especially in beauty as ornamental plants (Karim et al. 2022). The lack of soil, humus/topsoil, has created a flora

with a high level of adaptation. This adaptation is in the form of being able to survive in dry conditions, poor in nutrients, and limited water. As pioneer organisms, Pteridophytes have an important role in karst vegetation. As early organisms, Pteridophytes are an indicator of the habitat that can be used as a habitat indicator for terrestrial organisms (Notosoedarmo and Fauzi 2020). The ecological function of Pteridophytes can play a role in maintaining the balance of the ecosystem, namely erosion prevention, water regulation, soil formation processes, and assisting the weathering process (Andries et al. 2022)

In the karst ecosystem area of the Ayah Kebumen Forest, no research has been conducted related to the diversity and conservation status of Pteridophytes. However, the presence of Pteridophytes in Ayah forest ecosystems is important to study because, at this time, the loss of some pteridophyte plants in that location was caused by habitat loss. So this study aims to provide a database to analyze the diversity and conservation status of Pteridophytes in the karst ecosystem of the Ayah Forest, Kebumen. The presence of research on the topic makes the research a new source of information and a basis for further research.

MATERIALS AND METHODS

Study area

This research was conducted in November 2022 in the Ayah Forest, Ayah Village, Ayah District, Kebumen District, Central Java, Indonesia. *Tectona grandis* L.f and *Acacia mangium* Willd dominate vegetation conditions in the Ayah Forest. Ayah Forest, located in the Kebumen district, is one of the karst forest areas in Indonesia. It has a location that is quite far from residential areas, located in a state-owned teak forest area with contours of coral hills, and below it is Logending beach (Syraifudin et al. 2021). Furthermore, it is in the lowland zone at an altitude of 101 masl with an average temperature of 29.4°C, and its humidity scale is 85.55%. The light intensity in Ayah's forest was 6640 lux, with a soil temperature of 35.6°C, soil moisture of 5.66%, and a neutral soil pH of 7. The coordinates for the research location are S 07°43'36.09" E 109°23:58.98" (Figure 1).

Procedures

Sampling technique

Primary data were obtained from field observations through the survey method (Marpaung 2019) with purposive sampling site selection based on the presence of Pteridophyta. In addition, data collection was carried out by recording habitat, habitus, morphological features, and the number of individuals so that a presumption of species names was found.

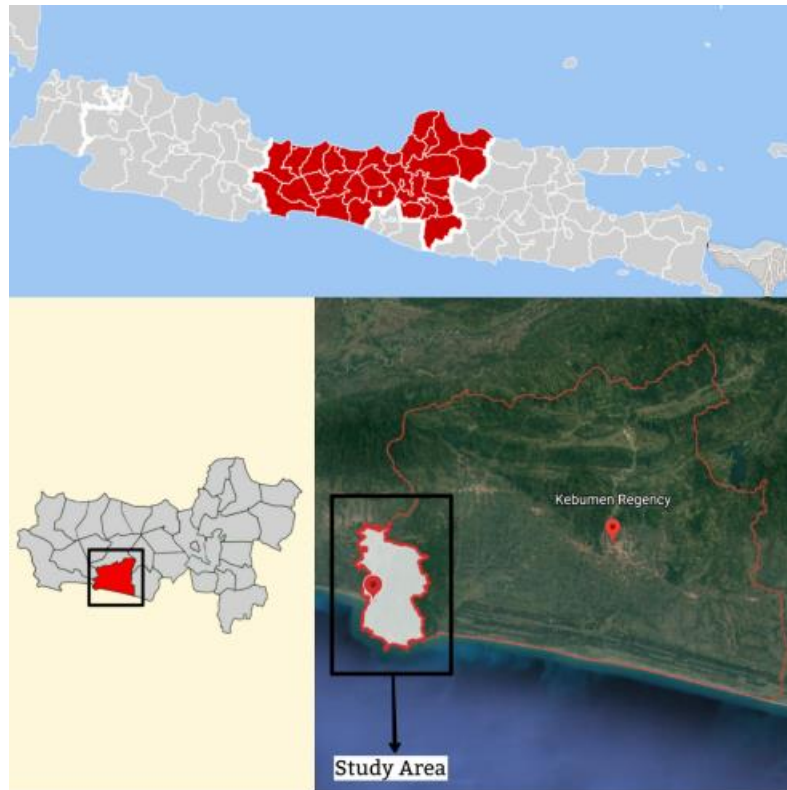


Figure 1. Research location in Ayah Forest, Kebumen district, Central Java, Indonesia

Identification

The identification process is carried out in two ways, namely, directly and indirectly. First, temporary preservation will be photographed and carried out in species that are unknown. Identification was carried out with the help of literature in the form of books from Hoshizaki (2010), Callado et al. (2016), Mehlterter (2010), and GBIF.

Data processing

In the study, primary and secondary data processing will be carried out. The results of the primary data will be included in the calculation of the diversity of the Pteridophyta using the Shannon-Wiener index (H') (i), evenness index (E) (ii), and Margalef species richness index (D_{mg}) (iii). At the same time, secondary data are obtained from literature studies to support field findings, namely IUCN Redlist and CITES.

Data analysis

As mentioned before, data analysis was performed by calculating the Shannon-Wiener diversity index (H'), the Margalef species richness index (D_{mg}), and the Evenness species index (E), and the Secondary data was analyzed on a literature basis, as follows:

The Shannon wiener index is an index used to calculate species diversity

$$H' = - \sum p_i \ln p_i$$

$$P_i = \frac{\text{species } to - i}{\sum \text{total species}}$$

Where:

H' = Shannon Wiener diversity index

P_i = Abundance index

According to Magurran (1988) in Pertiwi (2020), the determination of the H' criterion category is as follows

$H' < 1$ = Low diversity

$1 < H' < 3$ = Moderate diversity

$H' > 3$ = High diversity

The Evenness index of evenness species determines the Evenness of individual species in a community

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

Where:

E = Evenness index

H' = Diversity index

S = number of types

According to Magurran (1988) in Kanedi (2021), the determination of the E range category is as follows:

$E < 0,4$ = Uniformity of small populations

$0,4 < E < 0,6$ = Moderate population uniformity

$E > 0,6$ = high population uniformity

If the value is 0, it means that the level of Evenness of plant species in the community is very uneven. Meanwhile, if the value is close to 1, almost all existing species have the same Abundance.

Margalef species richness index is used to analyze differences in species richness

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

Where:

D = Margalef type Wealth Index

S = number of species in habitat

N = Total number of individuals of all types in habitat

According to Wahyuningsih (2019), the classification of category D criteria is as follows

$D < 2,5$ = low type wealth level

$2,5 > D > 4$ = moderate level of richness

$D > 4$ = high level of breed richness

RESULTS AND DISCUSSION

Ayah Village Forest, located in the Kebumen district, is one of the karst forest areas in Indonesia. It has a location that is quite far from residential areas, located in a state-owned teak forest area with contours of coral hills, and below it is Logending beach (Syraifudin et al. 2021). The 22 species and eight families found (Table 1) came from epiphytes, lithophytes, and terrestrial habitats. Meanwhile, aquatic habitats were not found at the study site because the study area is a terrestrial karst area. Compared with non-karst forests, the pteridophyte diversity is lower in karst forests, where the porous substrate and thin soil layers cannot hold moisture. Furthermore, higher pH and lower soil nutrient concentration in limestone habitats may reduce

the diversity of pteridophyte species (Phoutthavong et al. 2019). The Pteridophytes identification found in Ayah Forest can be seen in Figure 2.

Diversity

Based on research results in the Ayah Forest, Ayah sub-district, the Kebumen District, nine families of Pteridophytes were found, including the family Polypodiaceae, Thelypteridaceae, Pteridaceae, Tectariaceae, Lygodiaceae, Selaginellaceae, Nephrolepidaceae, and Davalliaceae. Of the eight families found, there were 732 total individuals from 22 species of Pteridophyta, as shown in Figure 3. The family with the most species is the Pteridaceae (8 individuals), with eight species. Pteridaceae is the family with the most common species found in Ayah Forest. It is because the types of Pteridophytes from the Pteridaceae family are Pteridophytes that can grow in open and dry areas to moist and shaded areas at certain altitudes (Muswita 2013). Pteridaceae found in this research are *Adiantum capillus-veneris* L., *Adiantum philippense* L., *Pteris multifida* Poir, and *Pteris ensiformis* Burm., *Pteris vittata* L., *Pteris biaurita* L., *Pityrogramma calomelanos* (L.) Link, and *Cheilanthes farinosa* (Forssk.) Kaulf. Pteridaceae species play an important role ecologically because they are pioneer plants. In addition, the large number of species from this family also makes the species have an important role in human life because they are used both as ornamental plants, such as *Pteris biaurita*, and as medicinal plants, such as *Pityrogramma calomelanos* (Yusna and Sofiyanti 2016).

Table 1. Pteridophyta species and conservation status

Family	Species	n	Habitat	Conservation status	
				IUCN	CITES
Davalliaceae	<i>Davallia denticulata</i> (Burm.fil.) Mett. ex Kuhn	10	E,T	NE	N/A
Lygodiaceae	<i>Lygodium circinatum</i> (Burm.fil.) Sw.	42	L,T	NE	N/A
	<i>Lygodium japonicum</i> (Thunb.) Sw.	5	E, T	NE	N/A
Nephrolepidaceae	<i>Nephrolepis brownii</i> (Desv.) Hovenkamp and Miyam.	182	L	NE	N/A
Polypodiaceae	<i>Drynaria quercifolia</i> Linnaeus	46	E, L, T	NE	N/A
	<i>Drynaria sparsisora</i> (Desv.) Moore	26	E, L, T	NE	N/A
	<i>Microsorium scolopendria</i> (Burm.fil.) Copel.	4	E	NE	N/A
	<i>Pyrrosia nummularifolia</i> (Sw.) Ching	8	E	NE	N/A
	<i>Adiantum capillus-veneris</i> L.	111	T	LC	N/A
Pteridaceae	<i>Pteris multifida</i> Poir	18	T	NE	N/A
	<i>Pteris ensiformis</i> Burm.	35	T	NE	N/A
	<i>Pteris vittata</i> L.	23	T	LC	N/A
	<i>Pteris biaurita</i> L.	12	T	NE	N/A
	<i>Pityrogramma calomelanos</i> (L.) Link	24	T	NE	N/A
	<i>Adiantum philippense</i> L.	24	L, T	NE	N/A
	<i>Cheilanthes farinosa</i> (Forssk.) Kaulf.	2	T	NE	N/A
	<i>Selaginella plana</i> (Desv. ex Poir.) Hieron.	63	T	NE	N/A
Sellaginellaceae	<i>Selaginella ornata</i> (Hook and Grev.) Spring	7	T	NE	N/A
Tectariaceae	<i>Tectaria angulata</i> (Willd.) Copel.	6	T	NE	N/A
Thelypteridaceae	<i>Cyclosorus interruptus</i> (Willd.)	36	T	NE	N/A
	<i>Amblovenatum terminans</i> (Wall. ex Hook.) J.P.Roux	9	T	NE	N/A
	<i>Christella subpubescens</i> (Blume) Holttum	43	T	NE	N/A

Note: E: epifit, NE: not evaluated, n: number of individu, L: litofit, LC: least concern, T: terrestrial, N/A: not available



Figure 2. A. *Davallia denticulata* (Burm.fil.) Mett. ex Kuhn, B. *Lygodium circinatum* (Burm.fil.) Sw., C. *Lygodium japonicum* (Thunb.) Sw., D. *Nephrolepis brownii* (Desv.) Hovenkamp and Miyam., E. *Drynaria quercifolia* Linnaeus, F. *Drynaria sparsisora* (Desv.) Moore, G. *Microsorium scolopendria* (Burm.fil.) Copel., H. *Pyrrosia nummularifolia* (Sw.) Ching, I. *Adiantum capillus-veneris* L., J. *Adiantum philippense* L., K. *Pteris multifida* Poir, L. *Pteris ensiformis* Burm., M. *Pteris vittata* L., N. *Pteris biauarta* L., O. *Pityrogramma calomelanos* (L.) Link, P. *Cheilanthes farinosa* (Forssk.) Kaulf., Q. *Selaginella plana* (Desv. ex Poir.) Hieron., R. *Selaginella ornata* (Hook and Grev.) Spring, S. *Tectaria angulata* (Willd.) Copel., T. *Cyclosorus interruptus* (Willd.), U. *Amblovenatum terminans* (Wall. ex Hook.) J.P.Roux, V. *Christella subpubescens* (Blume) Holttum.

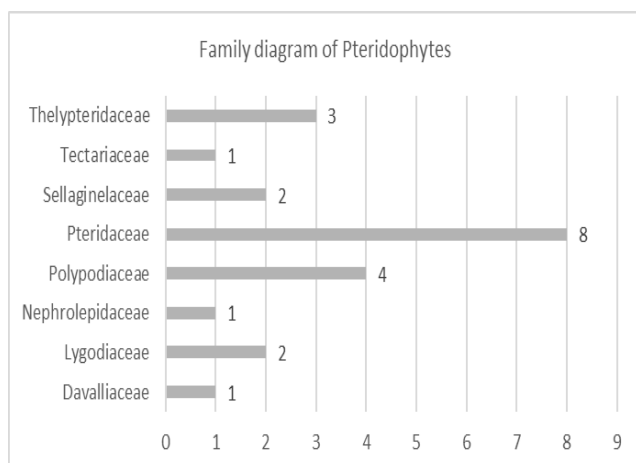


Figure 3. Family diagram of Pteridophytes found in Ayah Forest

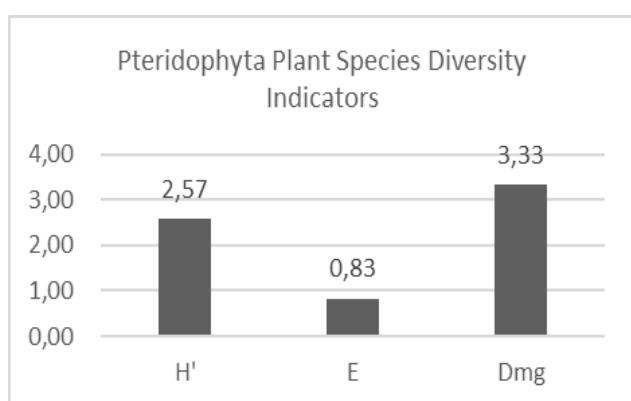


Figure 4. Biodiversity Indicator of Pteridophytes Species in the karst ecosystem of Ayah Forest, Kebumen, Central Java, Indonesia. Shannon-Wiener diversity index (H'), Evenness index (E), Margalef species richness index (Dmg)

On the other hand, Families such as Tectariaceae, Nephrolepidaceae, and Davalliaceae have only one species variation. However, the highest number of individuals, with a total of 182, was obtained from *Nephrolepis brownii* (Desv.) Hovenkamp and Miyam which is a family of Nephrolepidaceae. The second highest number of individuals is *Adiantum capillus-veneris* L which belongs to the family Pteridaceae, with a total of 111 individuals found. Finally, the lowest number of individuals were found from the same family, with a total of only two individuals, namely from the species *Cheilanthes farinosa* (Forssk.) Kaulf.

The existence of *Nephrolepis brownii* quite dominates the Ayah Forest area. Lacouture (2021) states that *Nephrolepis brownii* has an invasive character if not handled properly. That means that *Nephrolepis brownii* has high adaptability and a short reproductive period. Nugroho and Zaman (2019) also stated that the presence of *Nephrolepis brownii* is known as a disturbing weed because it can reach > 45 cm in height. However, the *Nephrolepis* genus group has economic potential because it

is used as an ornamental plant (Renjana et al. 2021). Whereas *Cheilanthes farinosa* (Forssk.) Kaulf is a rock-dwelling Pteridophytes with a global tropical to subtropical distribution in warm and dry areas, also often growing in small crevices on cliffs (Srivastava and Uniyal 2014). In this case, the research location has high enough humidity, so the growth of the species *Cheilanthes farinosa* (Forssk.) Kaulf is not optimal. Whereas the genus *Pteris* is the most frequently found in the study, out of 22 species found, four are from the genus *Pteris* (Table 1). Astuti et al. (2019) state *Pteris* are cosmopolitan Pteridophytes that can inhabit various habitat types. The species from this genus can grow in damp places with low to high elevations (0–3,500 masl), both in open and shaded places.

Ecological index

From several Pteridophytes species obtained, a species diversity analysis was carried out using the indicator of diversity, such as the species diversity index (H'), the evenness index (E), and the species richness index (Dmg). The results showed that the Shannon Wiener diversity index of Pteridophytes species in the Ayah Forest was 2.57. From these criteria, Pteridophyta in the Ayah Forest is categorized as having a moderate diversity index (Figure 4). Khamalia et al. (2018) stated that the high number of species found is proportional to the high value of diversity. However, if the value of diversity is small, then the location is dominated by one or several species only. The level of the species diversity index can be influenced by the species' ability to compete and survive in different growing conditions (Laely et al. 2020). In this case, differences in nutrient utilization designations from existing carrying capacity lead to varying species diversity values at each site. Abiotic and biotic factors of habitat play a role in determining species diversity. Variables such as water and energy are the main factors that influence the distribution of species on the biogeographic scale, while biotic factors influence the niches realized on the habitat scale (Abotsi et al. 2020). In addition, each species' distribution of Pteridophytes also correlates with their diversity. If species diversity is low, it can be interpreted that the vegetation is spread unevenly. In this study, calculations were carried out to determine the level of Evenness of Pteridophytes species using the Evenness species index.

Ayah Forest has an evenness value (E) of 0.83 which means it is in the category of high Evenness (Figure 4). It indicates that the distribution of Pteridophytes species in this location is evenly distributed, so no dominant species are found. The value of Evenness is used in measuring the degree of Evenness of the Abundance of individual species in one community. Correspondingly, the evenness index can indicate dominance in each species in one community. Nahlunnisa (2016) states that species evenness occurs when the existence of a community with another community is balanced. The species with the most individuals found is derived from *Nephrolepis brownii* (Desv.) Hovenkamp and Miyam. Although it has the largest number of individuals, its existence does not interfere with the balance of the ecosystem. Therefore, it can be interpreted that the growth of *Nephrolepis brownii*

(Desv.) Hovenkamp and Miyam. In the karst ecosystem of the Ayah forest, Kebumen is still controlled and not invasive. With an evenness index value of 0.83, apart from indicating a good level of Evenness, this also indicates a high level of ecosystem stability. Harahap et al. (2020) stated that there are three criteria for environmental communities based on the value of Evenness, i.e., if $E' < 0.50$, then the community is in a condition stressed. If $0.50 < E' < 0.75$, the community is in an unstable condition, while the community is in a stable condition of $0.75 < E' \leq 1.00$. In tropical ecosystems with characteristic biotic and abiotic factors and high initial biodiversity, the chances of a successful invasion of undisturbed communities are very small (Abywijaya et al. 2014). This statement is in line with the condition of the environmental factors in the Ayah forest because the location still has an ecosystem that is classified as natural, with biotic and abiotic factors that influence each other in a balanced way.

The species richness index (Dmg) is a measure of the diversity of each species in a community (Figure 4). Pteridophytes in the Ayah Forest get a Margalef Index (Dmg) value of 3,33, so they are categorized as medium species-richness. The species richness index obtained is directly proportional to the number of species found. The greater the number of species found, the higher the Dmg value (Wahyuningsih et al. 2019). Therefore, this species richness index is related to the species diversity index (H'), which in this study, the two indices are in the same category, a moderate. Environmental factors such as latitude and elevation patterns combined with biotic factors influence Pteridophytes species richness. According to Hernandez et al. (2020), a climatically stable environment with suitable habitat humidity will provide an advantage for the growth of Pteridophytes. Therefore, if the index of species diversity and species richness in this location is in the moderate category, then the environmental conditions in that area are suitable for the growth of Pteridophytes.

However, compared to the diversity of Pteridophytes species on peatlands, karst areas have lower H' and higher E' index values. For example, East Kalimantan has an H' value of 0.43 (low category) and an E' value of 0.94 (high evenness category). As for the Margalef species richness index (Dmg), the Dmg index in the Ayah Forest karst region has the same category (medium category) compared to tropical rain forests in Gurok Beraye, Belitung Priambudi et al. (2022).

Pteridophytes habitat

This study shows that from 22 Pteridophytes, six species lived as epiphytes (Figure 5), namely *Davallia denticulata* (Burm.fil.) Mett. ex Kuhn, *Lygodium japonicum* (Thunb.) Sw., *Drynaria quercifolia* Linnaeus, *Drynaria sparsisora* (Desv.) Moore, *Microsorium scolopendria* (Burm.fil.) Copel., and *Pyrrosia nummularifolia* (Sw.) Ching. The Host trees as a place for epiphytic Pteridophytes to live are *Acacia mangium*, *Tectona grandis*, and *Ficus septica*. The host plant has a large stem diameter with known characteristics of thick, crusted skin, rough textured, cracked stem surface, and many grooves and holes. That will allow the formation of

heaps of litter and humus, which will be the source of nutrients and water availability for the growth of epiphytic Pteridophytes (Listiyanti et al. 2022). While 3 species of Pteridophytes live in lithophytes or live in rock crevices, namely *Drynaria quercifolia* Linnaeus, *Drynaria sparsisora* (Desv.) Moore, and *Lygodium circinatum* (Burm.fil.) Sw. In general, Pteridophytes are found living terrestrially. The dominance of terrestrial Pteridophytes' habitat is influenced by the environmental conditions where it grows (Rizy et al. 2018). Ayah forest has soil conditions of good humidity and temperature, which are optimal media for Pteridophytes growing.

Environmental factors

Abiotic factors affect these Pteridophytes' diversity, including altitude, soil temperature, air temperature, light intensity, soil moisture, humidity, and pH (Table 2). Based on the measuring results, the height of the research site in Ayah Forest is 101.3 meters above sea level. Such heights belong to the lowlands. Ayah Village is one of the villages with the lowest elevation in the Ayah District (BPS 2020). Pteridophytes can be found in diverse habitats, from terrestrial, epiphytic, and aquatic habitats in many ecosystems, from mountain forests to coastal ecosystems (Mildawati et al. 2020). Also, high environmental adaptability allows pteridophytes to grow in various habitats. Therefore, pteridophytes can grow in various habitats, either lowlands or highlands.

Table 2. Results of measurement of abiotic factors

Abiotic factor	Value
Height (masl)	101.3
Temperatures (°C)	29.4
Air humidity (%)	85.5
Light intensity (lux)	6640
Soil temperature (°C)	35.6
Soil moisture (%)	5.66
Soil pH	7

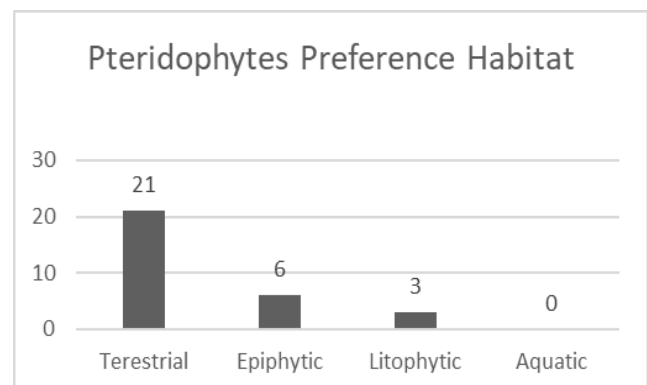


Figure 5. Pteridophytes habitat found for each species in karst ecosystem Ayah Forest, Kebumen, Central Java, Indonesia

The average temperature in lowland areas ranges from 23°C-28°C, and the result of the air temperature measurement obtained in The Ayah Forest is 29.4°C. Such temperatures are suitable for supporting the life of Pteridophytes. Moreover, the optimal air temperature for Pteridophytes in tropical areas is 20-35 °C (Listiyanti et al. 2022). Increasing air temperature will have an impact on increasing transpiration and evaporation so that air humidity also increases. The air humidity obtained in the Ayah Forest is 85.5%. Air humidity is categorized as less good because, according to Majid et al. (2022), the optimum air humidity for Pteridophytes is 50-80%.

Light intensity plays an important role in helping plant photosynthesis. The level of sunlight intensity is affected by canopy cover and clouds (Rizky et al. 2018). Pteridophytes usually like habitats that are shady or protected from the hot sun (Andiana and Renjana 2021). The result of measuring the light intensity in the Ayah Forest is 6640 Lux. Pteridophyta can grow optimally in shaded conditions and not be exposed to excessive sunlight, namely at the light intensity range of 2200-7700 lux (Ngadiani and Restia 2020). Furthermore, the soil temperature measurement result in Ayah's Forest is 35.6°C, and soil moisture is 56%. The optimum soil moisture for Pteridophytes is 50%-80% (Salsabila et al. 2021). It means that soil moisture in the Ayah Forest is good for the Pteridophytes living there. Furthermore, the result of measuring soil pH in Ayah's Forest is 7, which means that the soil is in a neutral condition. Neutral pH conditions are one of the characteristics of fertile soil. In rocky areas, Pteridophytes require a more alkaline pH of 7-8 (Pramudita et al. 2021).

Conservation status

Conservation status is one of the conservation efforts that aim to protect and preserve the ecological integrity of forests and is an assessment tool for achieving conservation goals (Castello et al. 2017). So the conservation status is used to categorize the extinction level of a species of living things. However, plant species generally find it more difficult to detect their conservation status. It can be due to the need for more information and difficulty identifying the whole species. In identifying living things, e.g., Pteridophytes, one can refer to the IUCN Red List of Threatened Species and CITES Appendices. Both are global conservation status reference agencies. As a result, the IUCN became the most authoritative and objective system in categorizing the risk of extinction of living things (Young et al. 2014). The assessment is carried out on the quantitative basis of geographical range thresholds and population size, structure, and trends for inclusion in the category of extinction risk. There are also five criteria in judging extinction risk, namely criterion A (decreased distribution of ecosystems within a certain period), criterion B (limited geographical distribution), criterion C (degradation of environmental components within a certain period), criterion D (the most influential interaction on the ecosystem in a certain period), and criterion E (estimated potential for ecosystem extinction based on quantitative analysis) (Noh et al. 2020). In addition, generation length

and expected changes in conservation status become determining factors when predicting extinction with IUCN status (Andermann et al. 2021).

Based on Table 1, the 20 dominant Pteridophytes species were categorized as Not Evaluated (NE) according to the IUCN Red List. The species belong to Polypodiaceae, Thelypteridaceae, Lygodiaceae, Tectariaceae, Selaginellaceae, Nephrolepidaceae, Pteridaceae, and Davalliaceae. However, the Not Evaluated (NE) category is not evaluated based on IUCN requirements. That can be due to the need for more sufficient data to produce the conservation status of these species, even though initial data collection or database preparation is an important step in conservation strategy. For example, *Drynaria quercifolia* Linnaeus is an ornamental plant and traditional medicine for stomach ulcers, headaches, swelling medicine, and fever (Hartini 2006). In addition, there are many species of the Selaginellaceae family, one of which is *Selaginella plana*, which has existed since hundreds of years ago and is observed to have decreased population from the impact of climate change (Setyawan et al. 2018). The two species are among the predominantly Pteridophytes species found at the study site but are evaluated based on their distribution.

Furthermore, three species belonging to the family Pteridaceae, categorized as Least Concern (LC), are defined as a low-risk group. This group is a species that does not fall into any category despite being evaluated. *Pteris vittata* L. is widely used in Chinese medicine, such as rheumatism, wounds, influenza, and scabies, and can potentially become phytoremediation (Lin et al. 2016). High utilization potential will reduce the number of distributions and even extinction. The threat of extinction gives rise to an alternative solution, namely the reintroduction of species to restore ecology (Evans et al. 2022). Furthermore, CITES was born as a follow-up step for the IUCN, an international agreement regulating the international trade in endangered plants and animals to control the trade between countries. Based on Table 1, all Pteridophyta species found are in the Not Protected category.

Based on research conducted on the Ayah's Forest ecosystem, Kebumen found an abundance of pteridophytes, as many as 732 individuals from 22 species belonging to the families Polypodiaceae, Thelypteridaceae, Lygodiaceae, Tectariaceae, Selaginellaceae, Nephrolepidaceae, Pteridaceae, and Davalliaceae. In the Shannon Wiener index, there was a moderate species diversity of 2.60, high Evenness Evenness index of 0.83 and a moderate Margalef species richness index of 3.33. That is supported by various abiotic factors such as altitude, air temperature, soil temperature, light intensity, and pH. However, this diversity has not been supported by conservation efforts as a conservation procedure. There are two assessments of conservation status, namely, based on IUCN assessments in terms of distribution. There was found that the Pteridophyta groups in the Ayah's Forest ecosystem, Kebumen, have not been evaluated as a whole or Not Evaluated except for the species *Cyclosorus interruptus* (Willd.), *Adiantum capillus-veneris* L. and *Pteris vittata* L. Those species are

categorized as Least Concern (LC), while based on CITES assessments in terms of trade, almost all Pteridophyta species found are categorized as Not Protected. That is an evaluation that needs to be done strategy to conserve plants, especially Pteridophytes in the Ayah Forest, Kebumen, Central Java, so their sustainability will be maintained.

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