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Species diversity, richness, and conservation status of Pteridophyta in the karst ecosystem of Donorejo Forest, Kaligesing, Purworejo, Indonesia

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Abstract. *Pramudita DA, Armando MF, Rahmayani D, Afifah FN, Putri NRA, Hartanti AN, Safira RN, Mahajoeno E, Indrawan M, Nazar IA, Buot Jr IE, Setyawan AD. 2023. Species diversity, richness, and conservation status of Pteridophyta in the karst ecosystem of Donorejo Forest, Kaligesing, Purworejo, Indonesia. Intl J Trop Drylands 7: 16-25.* Pteridophyta is often used as an environmental bioindicator. It can be found anywhere because of its cosmopolite ability. Karst ecosystem is one type of Pteridophyta habitat and roles as a pioneer plant. This study aims to determine Pteridophyta's biodiversity and conservation status in Donorejo Forest, Kaligesing, Purworejo, Central Java, Indonesia. The data collection of Pteridophyta species was carried out by survey method. Furthermore, the species found were analyzed using the Shannon-Wiener species Diversity Index (H'), Margalef Species Richness Index (Dmg), and Evenness Species Index (E). The research found 1387 individuals from 14 families and 34 species. Then, from the analysis that has been carried out using the calculation of tree indices, the following results are obtained; Shanon-Wiener Index (H') = 2.53, Margalef Species Richness Index (Dmg) = 4.56, Evenness Species Index (E) = 0.72. *Selaginella plana* (Desv. ex Poir.) is the most dominant in the area. From its conservation status, there are two species in LC (Least Concern) under IUCN conservation status, namely *Pteris vittata* L. and *Sphaeropteris glauca* (Blume) R.M.Tryon., while the rest are in NE status (Not Evaluated). Moreover, the CITES found one species under Appendix II status, *S. glauca*. Those biodiversity indices showed that Donorejo Forest has a stable, productive, and complex ecosystem with moderate biodiversity, a high value for Margalef Species Richness Index (Dmg), and an Evenness Species Index (E). At the same time, it faces threats from dominant species and local community activity. This study result can be used for diversity assessment, especially karst land ecosystems, and for further research to make the appropriate conservation strategy.

Keywords: Biodiversity, conservation, Donorejo, karst, Pteridophyta

INTRODUCTION

Indonesia has a karst area of 15.4 million hectares (Setyawan et al. 2015). There are differences between karst vegetation and non-karst vegetation. The karst ecosystem has a vegetation composition different from other areas because the karst area is formed from karst and has specific hydrological characteristics, so the vegetation is unique (Suhendar et al. 2018). The vegetation in karst is highly dependent on the local environmental conditions in which it grows (Setyawan et al. 2015). Pteridophyta is one of the typical flora of the karst region (Najib 2019). The differences between Pteridophyta in karst and non-karst forests are lower diversity, unique species, and average species richness per transect (Phoutthavong et al. 2019). Pteridophyta is a flora with a high diversity and wide distribution. This Pteridophyta plant belongs to the crypto game plant, which means that this plant is vascular but does not have flowers but spores. This plant can be found in terrestrial and aquatic habitats or propagates on its host or epiphytes. The function of these spores is as a propagation tool for the Pteridophyta itself in the regeneration process (Atho et al. 2020). These spores are located in a spore box called a sporangium; a collection of these spore boxes is called a sorus. Pteridophyta, which are cosmopolitan; that is, they can grow in all areas, both in the highlands and lowlands, is one of the reasons these plants have high diversity (Salsabila et al. 2021). Based on their habitat, Pteridophyta is classified into three habitats: lithophytes, epiphytes, and terrestrial (Priambudi et al. 2022).

Pteridophyta in Indonesia is a group of plants with high diversity. Pteridophytes plants in Indonesia, according to

Murniningtyas et al. (2016), there are around 2,197 species or about 22% of Pteridophyta plants that grow in the world, and around 630 species are on the island of Java. Pteridophyta is planted in an area that can be an environmental indicator (Kurniawati et al. 2016). The diversity of Pteridophyta in an area can be an indicator of the environmental conditions of that area. The existence of Pteridophyta is an environmental component that indicates whether the environment supports the life of an organism or not because it has a reciprocal relationship and is interdependent with its environment. Habitat for Pteridophyta in Indonesia is usually in a humid place which is a habitat for terrestrial, epiphytic, and aquatic (Ramadhan and Sianturi 2022). The substrate of Pteridophyta is also one of the influential biotic factors, especially in the type of host tree epiphytic habitat, which is an important factor in the life of ferns (Majid et al. 2022). Even though they are on the same host tree, each type of epiphytic fern can have different morphological characteristics. The Polypodiaceae family has a characteristic form of leaves that are not ventilated, while the Aspleniaceae family has a characteristic feature of leaves with a stiff texture (Listiyanti et al. 2022).

Pteridophyta conservation is necessary because Pteridophyta has a role in life, providing a source of food or medicine for humans, filtering poisons such as heavy metals, and thus providing bioindicators for the health of an ecosystem. Pteridophyta is endangered due to climate change and is near extinction. Protection of Pteridophyta is not enough to restore the population, and conservation efforts are needed without any disturbance from climate change (Wang et al. 2016). The selection of Donorejo Forest as a research location was based on several reasons. First, Donorejo is a karst forest with a different vegetation composition from other forest types. The distinctions between Pteridophyta in karst and non-karst forests are lower diversity, unique species, and average species richness per transect (Phoutthavong et al. 2019). The karst ecosystem in Donorejo is still quite beautiful and well-maintained, so it is estimated that the biodiversity, especially Pteridophyta, in this area is still relatively high. In addition, there has yet to be any research on Pteridophyta's diversity, richness, and conservation status in the Donorejo Forest. The results of this study can be used as a reference for further research. Therefore, Donorejo Forest was chosen as the research location. This study aims to determine Pteridophyta's biodiversity and conservation status in the Donorejo Forest, Kaligesing, Purworejo, Central Java, Indonesia.

MATERIALS AND METHODS

Study area

Sampling in this study was conducted in November 2022 in the forest of DonorejoVillage, Kaligesing Sub-district, Purworejo District, Central Java Province, Indonesia. Donorejo Village is at coordinates S 07°45'53.07", E 110°06'15.45". Donorejo is a village in the highlands with an area of ±597.3730 ha. According to BPS (2022), Donorejo Village has an average rainfall of around 2,391 mm/year with an average daily temperature of 29°C. This village is included in the Jonggrangan karst formation of the Menoreh Mountains. The village's location, which is in the highlands with an altitude of 740 m asl., makes Donorejo Village have high species diversity (Figure 1). Donorejo Forest has heterogeneous vegetation. Located close to residential areas, at the Donorejo forest can be found many fruticultural species such as *Citrus* sp. (orange), *Cocos nucifera* L (coconut), *Artocarpus heterophyllus* Lam. (jackfruit), and *Coffea* sp. (coffee).

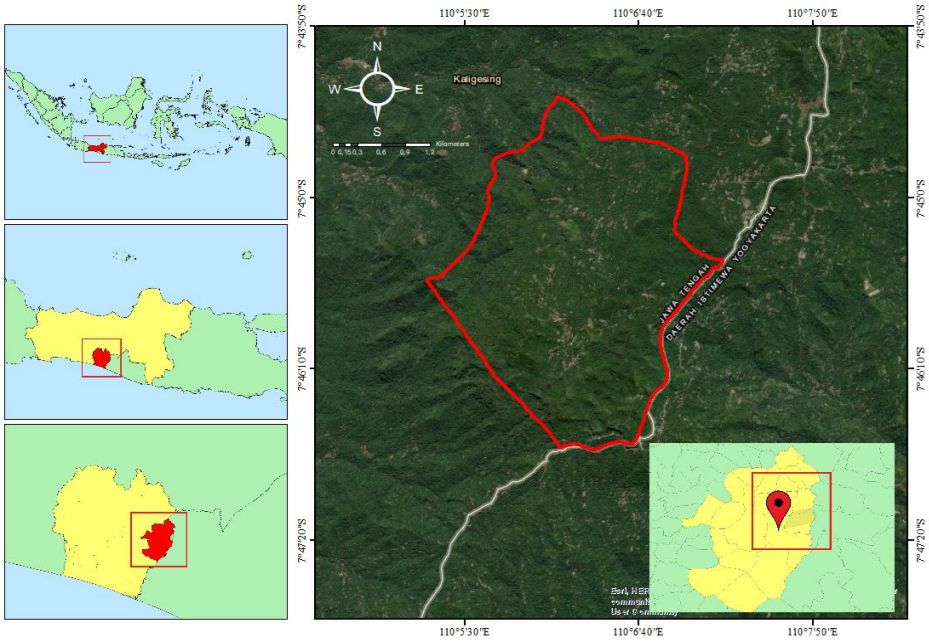

Figure 1. Pteridophyta research area in Donorejo Forest, Kaligesing, Purworejo, Central Java, Indonesia

Sampling technique

This study uses a qualitative analysis method and field observations using the survey method (Palupi et al. 2015) by purposive sampling based on the presence of Pteridophytes. The survey method by purposive sampling means that sampling was carried out by tracing the Donorejo Forest in areas that match the characteristics of the Pteridophyta habitat. Data collection was carried out by recording on a tally sheet with presumptive species names, number of individuals, morphological characters, habitat, and habitus of Pteridophytes. Sampling is also carried out by collecting Pteridophyta's generative and vegetative organs for further preservation. That preservation includes storing and drying them in newspapers and giving an identity in the form of a collection number, collector's name, and presumptive species name (Lestari and Nindira 2021).

Identification

Identification is made directly and indirectly. For unknown Pteridophyta species, the names will be identified using Hoshizaki and Moran (2001), Mehltreter et al. (2010), and Callado et al. (2016). The detailed morphological generative (spore) and vegetative (leaf, stem, rhizome, hair/scale) organs were documented for each species found (Priambudi et al. 2022). Name validation is carried out by checking the scientific name on the website of the Global Biodiversity Information Facility (GBIF) (https://www.gbif.org/).

Data processing

Then the primary data obtained will be included in the calculation of the diversity of Pteridophyta using the biodiversity indicators, namely Shannon-Wiener Index (H'), Evenness Species Index (E), and Margalef Species Richness Index (Dmg) (Priambudi et al. 2022). While secondary data were obtained from literature studies to support field findings, namely IUCN Redlist and CITES for the conservation status

Data analysis

Data analysis was performed by calculating the Shannon-Wiener Diversity Index, Margalef Species Richness Index, and Evenness Species Index, as well as identification of conservation status.

Shannon Wiener's Diversity Index

The diversity of Pteridophyta was analyzed using the Shannon-Wiener Index. A formula calculates the Shannon wiener index:

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

Where :
H' : Shannon-Wiener Diversity Index
ni : Number of individuals of the i-th species
n : Total number of individuals of all species
pi : ni/n

From the calculation results (H' value), it can be determined whether the area's species diversity level is high or low. Alwi et al. (2021) divide the level of species diversity where if:

H'<1: Low species diversity.
1≤H'≤3: Moderate species diversity
H'>3: High species diversity

Margalef Species Richness Index

Pteridophyta species richness was analyzed using the Margalef Species Richness Index. The Margalef Species Richness Index of Margalef was calculated using the formula :

$$Dmg = \frac{S-1}{lnN}$$

Where:
D : Margalef Species Richness Index
S : Number of species in the habitat
N : Total number of individuals of all species in the habitat

From the calculation results will be known the level of species richness. According to Wardhana et al. (2022), the criteria for the level of species richness are as follows:

D < 2.5: Low species richness level
2.5> D > 4: Moderate species richness level
D > 4: High species richness level

Evennes Species Index

Evenness analysis of Pteridophyta was carried out using the evenness species Evenness Index. This index is calculated to determine the distribution of the number of individuals in each species (Salami and Akinyele 2018). The formula calculates the even species Evenness Index:

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

Where:
E : Evenness Index
H' : Diversity Index
S : Number of species

The Evenness Index value of the evenness type ranges from zero to one. The lower the value, the more unequal the number of individuals in each species. Conversely, the higher the value, the number of individuals distributed among species are even. Based on Rudianto et al. (2022), the species evenness category is based on the Evenness Index value, that is:

E<0.4: Small population uniformity
0.4<E<0.6: Average population uniformity
E>0.6: High population uniformity

RESULTS AND DISCUSSION

Donorejo Forest is one of the karst areas in the Purworejo District. The ecosystem is relatively well maintained even though villages surround it. Sarwanto et al. (2017) stated that limestone mountains are landscapes

that have important values for the environment, such as water resources, biodiversity, and tourism. However, the typology of karst soil causes a lack of water in the soil and limited nutrient content (Yuslinawari et al. 2022). Pteridophytes are a group of plants commonly found on the forest floor. Plants on the forest floor live under forest stands, including shrubs, herbs, and pteridophytes (Andika et al. 2017). The presence of forest floor plants is useful as a provider of organic matter, which can increase water absorption capacity (Afriana et al. 2022). Thus, the presence of Pteridophytes can act as a provider of nutrients for surrounding plants. Pteridophyta is a group of plants that have a role as pioneers. The characteristics of Pteridophytes that make them pioneers are their adaptability and wide distribution due to their light spores being carried by the wind so that they can colonize large numbers of degraded areas (Dwisutono et al. 2019). In Donorejo Forest found 34 Pteridophytes species, as documented in Figure 2.

Discussion

Diversity

The research showed that in the Donorejo Forest, 14 families of Pteridophytes were found from 34 species and 1,397 individuals of Pteridophytes (Table 1). The Pteridophyte plant with the highest relative abundance value is *Selaginella plana* (Desv. ex Poir.) Hieron, which is 524 individuals (37.78%). According to Ismawan et al. (2015), this value is classified as high abundance. In comparison, the other 34 species belong to low abundance because they have a value of less than 15%. The six most dominant species in the Donorejo Forest area are *S. plana* with 524 individuals found; *Cyclosorus interruptus* (Willd.) H.Itô. 188 individuals (13,46%); *Adiantum capillus-veneris* L. 86 individuals (6.16%); *Amphineuron immersum* (Blume) Holttum. 50 individuals (3.58%); *Selaginella ornata* (Hook and Grev.) Spring. 50 individuals (3.58%); and *Tectaria angulata* (Willd.) Copel 40 individuals (2.86%). Two species with the lowest distribution were found: *Sphaeropteris glauca* (Blume) R.M.Tryon Copel. and *Lycopodium cernuum* L., where only two individuals were found for each species.

Table 1. Identification of Pteridophyta in this study

Family	Species	Habitats	n	Conservation status	
				IUCN	CITES
Aspleniaceae	*Asplenium nidus* L.	E	14	NE	N/A
Athyriaceae	*Deparia petersenii* (Kunze) M.Kato	T	15	NE	N/A
Blechnaceae	*Blechnum orientale* L.	T	25	NE	N/A
Cyatheaceae	*Sphaeropteris glauca* (Blume) R.M.Tryon	T	2	NE	Appendix II
Davalliaceae	*Davallia denticulata* (Burm.fil.) Mett. ex Kuhn	E	5	NE	N/A
Dryopteridaceae	*Dryopteris sparsa* (D.Don) Kuntze	T	29	NE	N/A
	Arachniodes spectabilis (Ching) Ching	T	10	NE	N/A
Gleicheniaceae	*Dicranopteris linearis* (Burm.fil.) Underw.	T	10	NE	N/A
Lycopodiaceae	*Huperzia phlegmaria* (L.) Rothm.	E	13	NE	N/A
	Lycopodium cernuum L.	T	2	NE	N/A
Nephrolepidaceae	*Nephrolepis acutifolia* (Desv.) Christ	T	8	NE	N/A
Polypodiaceae	*Drynaria quercifolia* (L.) J.Sm.	E	34	NE	N/A
	Goniophlebium percussum (Cav.) Wagner and Grether	E	26	NE	N/A
	Lepisorus mucronatus (Fée) Li Wang	E	16	NE	N/A
	Platycerium bifurcatum (Cav.) C.Chr.	E	9	NE	N/A
	Microsorum membranifolium (R.Br.) Ching	T	4	NE	N/A
	Pyrrosia nummularifolia (Sw.) Ching	E	3	NE	N/A
Pteridaceae	*Adiantum capillus*-veneris L.	T, L	86	NE	N/A
	Adiantum diaphanum Blume	T	46	NE	N/A
	Adiantum philippense L.	T	25	NE	N/A
	Pteris vittata L.	T	25	NE	N/A
	Pityrogramma calomelanos (L.) Link	T	18	NE	N/A
	Adiantum caudatum L.	T	8	NE	N/A
	Pteris ensiformis Burm.	T	5	NE	N/A
Selaginellaceae	*Selaginella plana* (Desv. ex Poir.) Hieron.	T	524	NE	N/A
	Selaginella ornata (Hook and Grev.) Spring	T	40	NE	N/A
Tectariaceae	*Tectaria angulata* (Willd.) Copel.	T	40	NE	N/A
	Tectaria dissecta (G.Forst.) Lellinger	T	15	NE	N/A
Thelypteridaceae	*Cyclosorus interruptus* (Willd.) H.Itô	T, L	188	NE	N/A
	Amphineuron immersum (Blume) Holttum	T	50	NE	N/A
	Macrothelypteris torresiana (Gaudich.) Ching	T	34	NE	N/A
	Cyclosorus sparsisorus Ching ex K.H.Shing	T	29	NE	N/A
	Christella dentata (Forssk.) Brownsey and Jermy	T	20	NE	N/A
	Christella subpubescens (Blume) Holttum	T	9	NE	N/A

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


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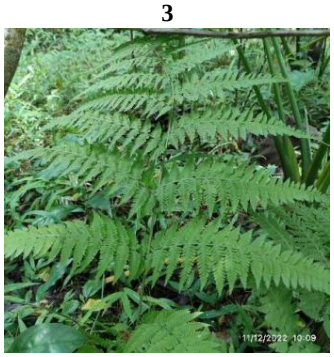
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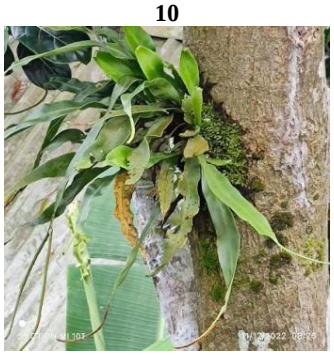
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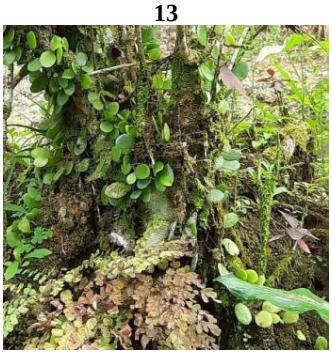
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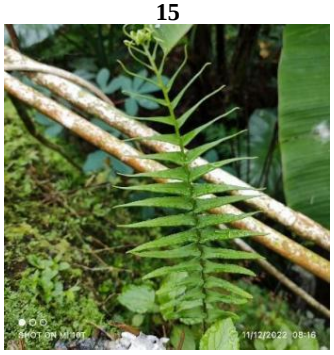
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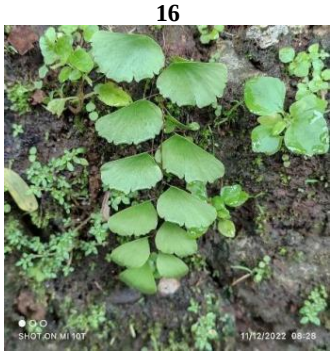
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Figure 2. Species of Pteridophyta in this study: 1. *Asplenium nidus* L., 2. *Deparia petersenii* (Kunze) M.Kato, 3. *Blechnum orientale* L., 4. *Sphaeropteris glauca* (Blume) R.M.Tryon., 5. *Davallia denticulata* (Burm.fil.) Mett. ex Kuhn, 6. *Dryopteris sparsa* (D.Don) Kuntze, 7. *Arachniodes spectabilis* (Ching) Ching., 8. *Dicranopteris linearis* (Burm.fil.) Underw., 9. *Huperzia phlegmaria* (L.) Rothm., 10. *Lycopodium cernuum* L., 11. *Nephrolepis acutifolia* (Desv.) Christ, 12. *Platycerium bifurcatum* (Cav.) C.Chr., 13. *Microsorum membranifolium* (R.Br.) Ching, 14. *Lepisorus mucronatus* (Fée) Li Wang, 15. *Drynaria quercifolia* (L.) J.Sm., 16. *Goniophlebium percussum* (Cav.) Wagner and Grether, 17. *Pyrrosia nummularifolia* (Sw.) Ching, 18. *Adiantum capillus*-veneris L., 19. *Pteris vittata* L., 20. *Adiantum philippense* L., 21. *Adiantum diaphanum* Blume, 22. *Pityrogramma calomelanos* (L.) Link, 23. *Pteris ensiformis* Burm., 24. *Adiantum caudatum* L., 25. *Selaginella plana* (Desv. ex Poir.) Hieron, 26. *Selaginella ornata* (Hook and Grev.) Spring, 27. *Tectaria angulata* (Willd.) Copel., 28. *Tectaria dissecta* (G.Forst.) Lellinger, 29. *Cyclosorus interruptus* (Willd.) H.Itô., 30. *Macrothelypteris torresiana* (Gaudich.) Ching, 31. *Amphineuron immersum* (Blume) Holttum, 32. *Christella dentata* (Forssk.) Brownsey and Jermy, 33. *Christella subpubescens* (Blume) Holttum, 34. *Cyclosorus sparsisorus* Ching ex K.H.Shing

Selaginella plana are known as the most dominant Pteridophyta in Donorejo Forest. Research by Gabi et al. (2021) shows that the species of *S. plana* also dominates the forest floor in burnt forest areas in North Sulawesi. That indicates *S. plana* have an ecological function as a pioneer plant in the succession process of an ecosystem. Since *S. plana* are cosmopolitan and can grow in various climates and soil, *S. plana* also have rhizome roots and function as a ground cover (Kurniasih 2019). Therefore, the existence of dominant species affects the stability of the ecosystem, as the dominance of certain species can decrease the value of diverse species. It could explain why the Pteridophyta species diversity values in the Donorejo Forest were at a moderate level, while the Evenness Species Index (E) and Margalef Species Richness Index (Dmg) values were at a high level.

Pteridophytes found in this study were analyzed for diversity through three indicators, namely the Shannon-Wiener Index (H'), Margalef Species Richness Index (Dmg), and Evenness Species Index (E) (Figure 3). From the analysis that has been carried out, the results show that the Shannon-Wiener Index owned by Pteridophyta in Donorejo Forest is 2.53, which means it is in moderate condition. This Shannon-Wiener Index shows the level of diversity within a community. The higher level of domination of a species in a place, the less diversity. That can make it easier to know a species' diversity in a particular community. One research related to Pteridophytes carried out in karst areas is from Press (2021). It states that the Diversity Index of Pteridophytes found is 1.37-2.36, which means they are in the moderate category. Hoshur (2022) state high values of the Shannon-Wiener Index (H') indicate a greater number of species sharing more or less equally. Therefore, the lower Diversity Index could be due to the dominance of a few species. Furthermore, most of the Pteridophytes in karst were calcium-preferring species (Ren et al. 2021), such as *Selaginella* spp., *Adiantum philippense* L, *Pteris vittata* (Kumar et al. 2016), and *A. capillus-veneris* (Hoshizaki and Moran 2001). Based on the Pteridophyte species mentioned above, it is known that this Pteridophyte calcium-preferring species was also found at the study site.

The results of the analysis of Pteridophyta in the Donorejo Forest using the Evenness Species Index obtained that E = 0.72. These results indicate that the value of E >0.6 means that the evenness distribution of individuals numbering Pteridophyta species in the Donorejo Forest is high. This condition is supported by the heterogeneous condition of the Donorejo Forest with diverse vegetation variations, which can potentially become hosts for Pteridophyta to grow. In addition, the geographical conditions of the Donorejo Forest, located in the highlands, make the soil in the Donorejo Forest relatively humid. That supports high biodiversity, including the Pteridophyta itself. Research from Press (2021) conducted in the Sangkulirang-Mangakalihat karst area, East Kutai Regency, East Kalimantan, also found that the overall Evenness Index of Pteridophyte species was at a value of >0.6, which means it was also in the high category.

The Margalef Species Richness Index determines the number of species present in a community, where the number of species will be directly proportional to the Margalef Species Richness Index. Suppose the number of species in a community is high; then the Margalef Species Richness Index value of that species is high. Vice versa, if the number of species found is low, the Margalef Species Richness Index is also low. The wealth index value owned by Pteridophyta in Donorejo Forest is 4.56. The Margalef Species Richness Index value is more than 4, meaning that Pteridophyta's species richness in the Donorejo Forest is in the high category. The high value of species richness, especially Pteridophyta, indicates that the ecosystem in the research area, namely the Donorejo Forest, is in good condition. That is why Pteridophyta has a role as environmental bioindicators. This result has a higher Margalef Species Richness Index than Priambudi et al. (2022) in Belitung Island, which showed the Margalef Species Richness Index value of Pteridophytes in the heath forest (low category 1.29) and tropical rain forest (moderate category 3.36) was below the species richness in karst ecosystems. According to (Ansari et al. 2017), several plants from different divisions of the plant kingdom, such as chlorophyta, Bryophyta, and Pteridophyta, can be used to monitor and assess water quality in freshwater or marine, lentic or lotic, wetlands and coastal aquatic ecosystems.

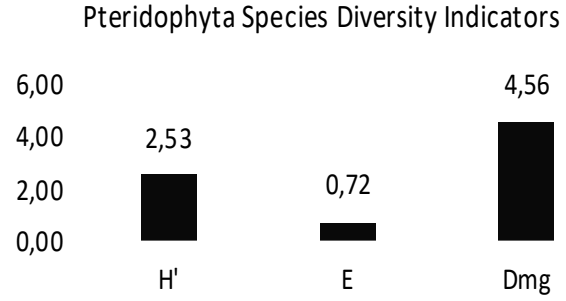

Figure 3. Biodiversity indicators of Pteridophytes species including Shannon-Wiener Diversity Index (H'), Evenness Index (E), Margalef Species Richness Index (Dmg) in this study

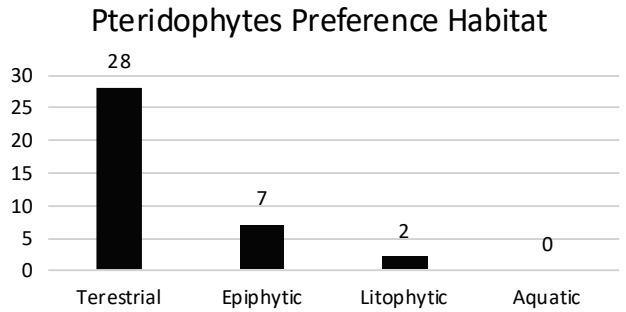

Figure 4. Pteridophytes habitat found for each species in karst ecosystem Donorejo Forest, Purworejo, Central Java, Indonesia

Pteridophyta habitat

Pteridophyta lives in terrestrial, epiphytic, lithophytic, and aquatic habitats. Pteridophyta is usually found in lowland subsoil, beaches, mountain slopes, and humid areas with an altitude of about 350 meters above sea level. On the other hand, there are Pteridophyta whose lives float in water, for example, *Azolla pinnata* R.Br. and *Marsilea crenata* C.Presl.

The observations showed that Pteridophytes were found in Donorejo Forest, namely Pteridophyta, which live in terrestrial habitats. Many Pteridophyta is found in terrestrial habitats because some Pteridophyta lives in moist and shaded soil, both in the highlands and lowlands, making terrestrial habitats suitable due to their humidity, temperature, light intensity, and rainfall (Kurniawati et al. 2016).

Observation found as many as 28 species compared to epiphytic and lithophytic habitats (Figure 4). Uniquely, the physical conditions of karst habitats result in a limited supply of moisture and restrictions to nutrient access in this ecosystem (Liu et al. 2020). Based on their habitat, Pteridophytes live as epiphytes or are attached to host trees. Pteridophytes are terrestrial living on soil substrates, and lithophytes are attached to rock substrates. This research found seven species of Pteridophyte plants that live as epiphytes, namely *Asplenium nidus* L., *Davallia denticulata* (Burm.fil.) Mett. ex Kuhn, *Huperzia phleqmaria* (L.) Rothm., *Platycerium bifurcatum* (Cav.) C. Chr., *Lepisorus mucronatus* (Fée) Li Wang, *Drynaria quercifolia* (L.) J.Sm., *Goniophlebium percussum* (Cav.) Wagner and Grether, and *Pyrrosia nummularifolia* (Sw.) Ching. The host trees of the epiphytic Pteridophytes found included *Citrus* sp. (orange), *C. nucifera* (coconut), *A. heterophyllu*s (jackfruit), and *Coffea* sp. (coffee). In comparison, the types of Pteridophyta that live in lithophytes or rock crevices are *A. capillus-veneris* and *C. interruptus*, which are also found to live terrestrially while the rest live terrestrially. Rambey et al. (2021) state that Pteridophytes with terrestrial habitats are more commonly found in karst areas than in urban areas. The existence of epiphytic Pteridophytes ecologically acts as a habitat for several types of insects. Their presence is also used as a bioindicator in a humid environment (Lestari et al. 2019). However, epiphytic Pteridophytes prefer rough stems to stick their fibrous roots easily. Moreover, conditions under the canopy also determine the growth of epiphytic Pteridophytes (Sirami 2015). In the Donorejo Forest area, a karst area, more Pteridophyte species live terrestrially than epiphytes. Many Pteridophyta is found in terrestrial habitats because some Pteridophyta lives in moist and shaded soil, both in the highlands and lowlands, making terrestrial habitats suitable for humidity, temperature, light intensity, and rainfall (Kurniawati et al. 2016).

Environmental factors

Pteridophyta in Indonesia is a group of plants with high diversity. According to Murniningtyas et al. (2016), around 2,197 species, or 22% of the Pteridophyta plants, grow worldwide, and around 630 are on Java Island. Pteridophyta is planted in an area that can be an environmental indicator (Kurniawati et al. 2016). Therefore, the diversity of Pteridophyta in an area can be an indicator of the environmental conditions of that area. The existence of Pteridophyta is an environmental component that indicates whether the environment supports the life of an organism or not because it has a reciprocal relationship and is interdependent with its environment. Habitat for Pteridophyta in Indonesia is usually in a damp place, such as near a waterfall which is a habitat both terrestrial, epiphytic, and aquatic (Ramadhan and Sianturi 2022).

Environmental factors influence the diverse types of Pteridophyta. The higher the place, the higher the humidity in the air, causing the temperature to be low and the intensity of sunlight received by the plants to be minimal, which causes the plants not to be able to live. The abiotic factor of the Pteridophyta was in a soil moisture condition of 5.25% (Table 2). That is due to the soil structure in the karst ecosystem, which is composed of limestone so that it stores relatively less water. Wahyuningsih et al. 2019 stated that the optimal soil moisture conditions for Pteridophyte growth were 8-68%, so the types of Pteridophyta found had tolerance to relatively low soil moisture. While other conditions, with air humidity at 85%, soil pH 6.75, soil temperature at 25°C, and air temperature at 27°C, are already in optimum conditions (Lubis 2009; Permana 2017). In addition, the heterogeneous and dense vegetation in the Donorejo Forest means that the intensity of sunlight needs to reach the forest floor optimally. This condition is ideal for shade-loving Pteridophytes.

Conservation status

Based on the IUCN Red List, of the 34 species of Pteridophyta found, there are two species with IUCN's most minor concern conservation status, and the rest are not evaluated. The not evaluated status means that the species has not been included in the evaluation of the IUCN Red List, which may be due to a need for more data regarding the species. That is unfortunate because initial data is needed for conservation efforts, especially for Pteridophyta. Meanwhile, the species included in the most minor concern category are *P. vittata* and *S. glauca*. The minor concern category means that the species has a low risk. According to Saputro and Utami (2020), a minor concern category is a category in which the species has a limited distribution but has been evaluated and is not included in the upper category. Then, based on CITES, of the 34 species found, 1 type of Pteridophyta is included in the Appendix II category, while the others are included in the not protected category (Table 1)

Table 2. Abiotic factor in this study

Abiotic factor	Average score
Soil moisture (%)	5.25
Air humidity (%)	85
Soil pH	6.75
Soil temperature (°C)	25
Height (masl)	735
Air temperature (°C)	27
Light intensity (lux)	8100

The not protected category means that the species is not a protected species. The type of Pteridophyta found in the Appendix II category is *S. glauca*. Appendix II category means that the species is not endangered, but while it is traded continuously without binding regulations or limits, it can result in the extinction of the species. Thus, species included in the Appendix II category may only be traded in particular situations, specifically for the use of non-detriment findings, and have been included in the determination of harvesting allowances. The data above shows that data collection related to Pteridophyta species, especially those found in research locations, still needs to be examined to determine their conservation status. In addition, some species need further attention, such as *P. vittata* and *S. glauca*. Although these two species are included in the low-risk category according to the IUCN Red List, even *S. glauca* are included in the Appendix II category according to CITES. Therefore, those two species still need to be given more attention to prevent these species' extinction.

Other species that have not been evaluated or are still not protected must also be maintained so that the diversity and richness of Pteridophyta in the Donorejo Forest remain good. According to Phoutthavong et al. (2019), the diversity of Pteridophyta in karst areas cannot be protected simply by preserving several habitat patches. Because each patch plays a very important role in the diversity of Pteridophyta, therefore, just the loss of one habitat patch can cause the extinction of local or endemic species. In addition, humans can use Pteridophyta as a source of food and medicine, materials for handicrafts, ornamental plants, and growing media in plant cultivation (Syukur 2019). For example, *P. vittata* is helpful as an ornamental plant for the heavy metal mercury hyperaccumulator and a source of antioxidants (Nurcahyani 2021). Then, *Dryopteris sparsa* (D.Don) Kuntze can be used as a medicine for worms (Nikmatullah et al. 2020). The *S. glauca* are also widely used as a planting moderate (Suryana et al. 2018). Even though the extensive use of Pteridophyta can threaten their sustainability, excessive utilization without regard to the environment can lead to their extinction. In addition, land conversion or pollution as a result of human activities can also damage the Pteridophyta habitat.

In conclusion based on the research, it can be concluded that the diversity of Pteridophyta species in the Donorejo forest consists of 34 species and 14 families. The Shannon-Wiener Species Diversity Index (H') is in the moderate category, while the Evenness Species Index (E) and Margalef Species Richness Index (Dmg) are in the high category. That means the current condition of the Donorejo Forest is in stable condition, but the existence of the dominant species (*S. plana*) could be threatening the biodiversity of Pteridophyta. Moreover, from their conservation status, out of 34 species, there are two species in LC (Least Concern) under IUCN conservation status, namely *P. vittata* and *S. glauca*, while the rest are in NE status (Not Evaluated). In addition, of the 2 LC species, one is included in Appendix II, *S. glauca*, which means that special attention is needed to conserve this species so that its existence is maintained. Further research is needed regarding the ethnobotanical of Pteridophyta by the community to develop appropriate conservation strategies, especially in the karst ecosystem, both in nature and in vitro.

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