Journal of Tropical Biodiversity and Biotechnology
Volume 09, Issue 03 (2024): jtbb87781
DOI: 10.22146/jtbb.87781

Research Article

Fern Species-Area Relationship in Urban Anthropogenic Islands in Slawi, Tegal, Central Java

Agung Sedayu[1]*, Novita Putri[1], Aminudin[2], Muchtar Mawardi[2], M. Isnin Noer[1], Lana Maulana[3]
1)Biology Study Program, Faculty of Mathematics & Natural Sciences, Universitas Negeri Jakarta, Gd. Hasjim Asjarie lt.9. Jl. Rawamangun Muka, Jakarta 13220, Indonesia
2)Environment Agency (DLH) Kabupaten Tegal, Jl. Professor Muhammad Yamin, Kudaile, Kec. Slawi, Kabupaten Tegal, Central Java 52413, Indonesia
3)Herbarium Biologi (JUNJ), Faculty of Mathematics & Natural Sciences, Universitas Negeri Jakarta, Gd. Ex BAAK lt 1. Jl. Rawamangun Muka, Jakarta 13220, Indonesia
* Corresponding author, email: asedayu@unj.ac.id

Keywords:
Green spaces
Island biogeography
Pteridophytes
Spontaneous ferns
Urban biodiversity
Submitted:
08 August 2023
Accepted:
25 April 2024
Published:
26 August 2024
Editor:
Furzani Binti Pa'ee

ABSTRACT
In anthropogenic islands as urban parks, the fern species richness and composition may be determined ecologically by the quality of habitat, including area greenness, or biogeographically by area size. As the development of the theory of island biogeography also includes man-made parks, it is feasible to test whether area-species relationship applies in these urban parks, and is more pronouncedly evident compared to another ecological factor, such as NDVI. Total species number and composition of 8 urban parks in a *kecamatan* (subdistrict) in Tegal Regency were collected and arranged in clustering methods to understand the similarity between parks. The similarity analysis result is important for the management of the parks in Slawi. The species richness data is subsequently tested using Pearson correlation and regression against NDVI and area sizes. The relation between NDVI and species richness is non-significant ($p=0.058$), while area size and species richness is significant ($p=0.003$). This signifies that the urban fern species richness is determined by area as biogeographical factor, compared to NDVI as ecological factor. This result is important for the purpose of designing and managing urban parks as evidently size is important in the effort of attracting native biodiversity into urban parks and in turn enhancing the well-being of urban population.

INTRODUCTION
The theory of island biogeography (MacArthur & Wilson 1963; MacArthur & Wilson 1967) was originally developed to understand the effect of island environment, including isolation, to species richness and species speciation. It was developed to understand the biodiversity occurring in newly formed oceanic islands in relation to distance to larger land masses, especially continents. The key factors involved in the original and recently developed theory (Whittaker & Fernández-Palacios 2007) are the size of island, the relative distance to neighboring island and mainland, the time of isolation, climate, and past relation with land masses. Along its development, this theory is not applied only in real island environment, but into several island-like environments, including human-derived environments (Gleditsch et al. 2023). This theory is also applied in differ-

ent sense rather than only real island, such as succulent vegetation in arid environment in Africa (Desmet & Cowling 2004) and completely submerge marine habitat (Neigel 2003). Human activities alter natural vegetation into anthropogenic habitats according to specific human needs, creating islands surrounded by human habitats. Human managers call these islands urban green spaces, which in- turn may take several forms including urban parks.

In these anthropogenic islands, wild species thrive from several sources, mostly from deliberate human introduction, followed by natural vegetation remnants, and natural vegetation new immigrants (Savard et al. 2000). While deliberate human introduction is sometimes thought of as unnatural, and vegetation remnants are mostly unlikely in small urban parks, entirely altered during construction, new immigrants are thought as natural and reflecting the vegetation capability in dispersal from nearby sources including nearby parks or nearby natural habitats. This component of urban park biodiversity is an interesting object of biodiversity study. In parks, this natural vegetation component interacts with human vegetation introductions, sharing a certain park area size. It is interesting to understand the species' richness and composition in these island urban habitats, as they vary in size and management.

Fern is a suitable plant group to test the interchange ability among populations, as they are mostly airborne, capable of long-distance dispersal, with the exception of several aquatic fern, Marsileales and Salviniales (Dassler & Farrar 2001; De Groot et al. 2012). A wild fern individual in an urban park is almost certainly a newly established individual, or can be called as a spontaneous fern, growing from airborne spores into minute gametophytes and subsequently into adult sporophytes (Sato 1982; Taylor et al. 2005); a process that makes them feasible subject of biogeography study. As ferns are mostly airborne, angiosperms are dispersed in various manners, from ballistic-anemochory to intricate zoochory. Variable dispersal methods in the angiosperms compared to the ferns makes the latter is ideal and rather homogenous group to study, in terms of dispersal and spontaneous colonization of an area.

Urban parks vary not only in size, but also in management. Several parks with variability in trees and shrubs; many with mostly grass; others with extensive tiling or concretes. The greener a park, the more likely to attract biodiversity, flora, fauna, and microorganisms, compared to those less green. A popular measure in quantifying the greenness, thus healthiness of a park, is NDVI (Normalized Difference Vegetation Index), a remote sensing tool. In a place with high NDVI, it is expected to encounter higher biodiversity, both in flora (Pau et al. 2012), and fauna (Seto et al. 2004). In small parks where source of biodiversity, as nearby forest or nearby mountain is neglectable, it is interesting to consider whether island biogeography most pronounced factor, the island size, or the greenness of an area, determined the species richness in an area.

MATERIAL AND METHODS

This research was conducted for 6 months from July to December 2022. The location of this research is in the 8 city parks in *Kecamatan* (Subdistrict) Slawi, Tegal Regency (Figure 1, Table 2). Eight parks are appointed based on the advice of the Tegal Regency Environmental Service (Dinas Lingkungan Hidup Kabupaten Tegal), as these parks are the most managed amongst 18 *kecamatan* (subdistrict) in Tegal Regency and have the feature of most urbanized surroundings. In appointing parks only in a single *kecamatan* (subdistrict), we deliberately reduce the effect of isolation from species immigration sources (like Mt. Slamet, 50 km south), meaning all parks have relatively similar isolation to Mt. Slamet. Therefore, the biogeographic driver in determining species number of a park is solely park area size.

Fern censuses were done in the manner of exhaustive census, i.e., all fern individual possible for identification, within the perimeter of a park were included in the data collection. According to sizes, each park takes about 3—7 days observation to conclude all identifiable fern individuals in the data collection. As some ornamental ferns are commonly found as garden adornments, we limit our censuses to include only spontaneous ferns/vegetations (Robinson & Lundholm 2012). Consequently, individuals obviously planted in pots (as maidenhairs, *Adiantum*) or tied on tree trunks (as staghorns, *Platycerium*) were excluded. However, careful considerations were taken when dealing with adults, juveniles and (especially) sporelings of the escaping naturalized ornamental. These individuals, when clearly free living, even though from ornamental/planted parents, are included in the data collection. All individuals living within the park perimeter, including high up on the roof of tree branches or down below sewer system walls were recorded their species names and their habitats, as terrestrial (on ground), epiphytes (on trees), lithophytes (on rocks, concretes, walls, rooftiles or other stone-like materials), or combinations; and photographed. The photos were crosschecked with the description in *Flora of Malaya vol II. Ferns of Malaya* (Holttum 1966) and *Panduan lapangan paku-pakuan (Pteridophyta) di Taman Margasatwa Ragunan* (Agatha et al. 2019). Nomenclature follows POWO (2023). When it is thought to be difficult to identify through photos, herbarium specimens were taken to be identified in the lab. Herbarium sheets were deposited at the *Herbarium Biologi Universitas Negeri Jakarta* (JUNJ).

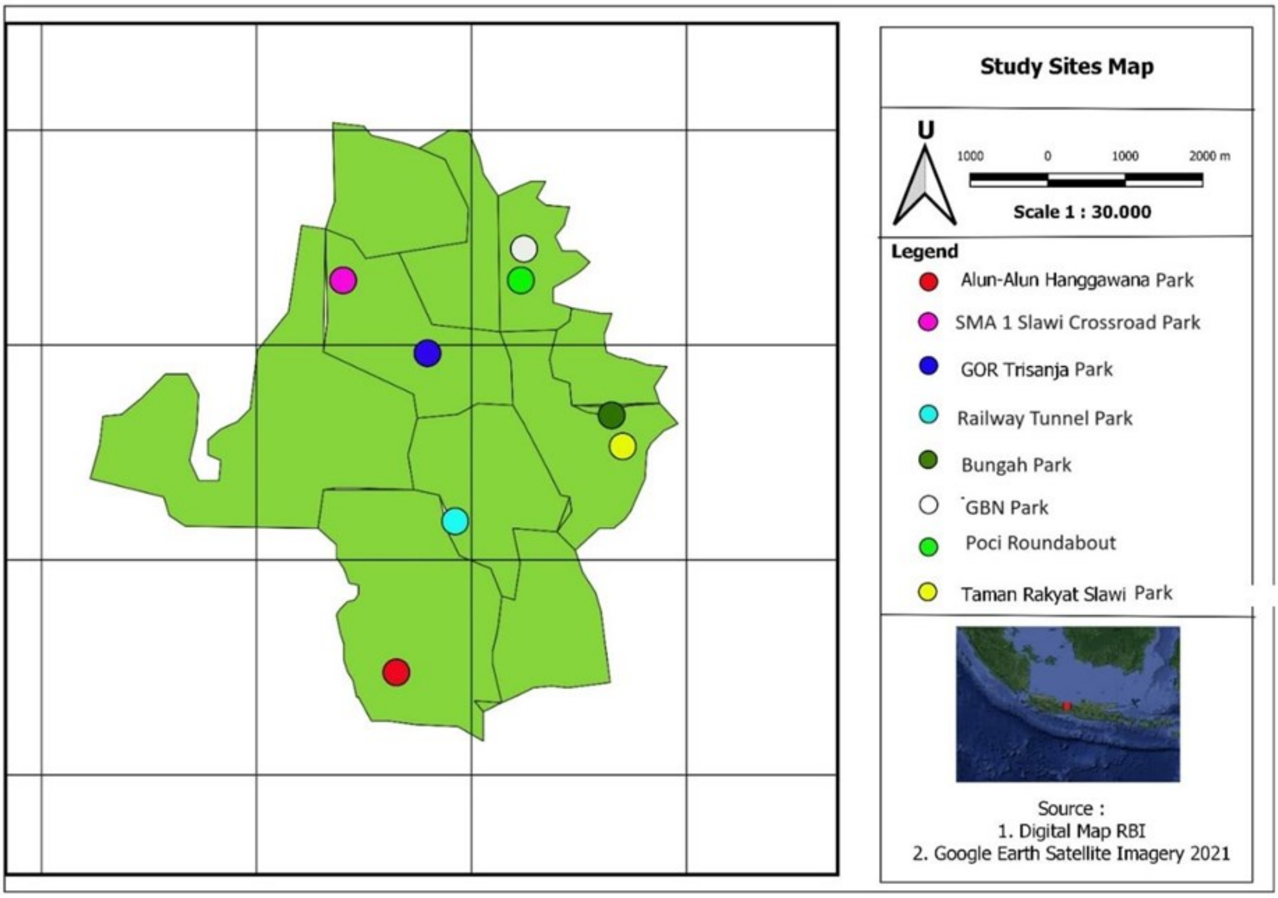

Figure 1. The study locations are at 8 urban parks in *Kecamatan* (Subdistrict) Slawi, *Kabupaten* (Regency) Tegal, Central Jawa.

Species encountered were arranged into a present-absent matrix against park names (Table 1). The matrix was then processed using clustering method in R 4.3.1 (R Core Team 2023). We used *Euclidean* for distance calculation, and *hclust* command in R for UPGMA dendrogram construction.

We obtained the exact area sizes of the parks from the official records deposited in the Tegal Regency Environmental Service. The Normalized Difference Vegetation Index (NDVI; Gessesse & Melesse 2019; Johansen & Tømmervik 2014) values for each park were calculated using QGIS 3.10 (QGIS.org 2023). Images of each park acquired from Landsat 8 of the year 2022 (USGS 2022) were made into raster layers. Data entried into QGIS was NIR (Near Infrared Reflectance) band spectral 5 and RED (visible red reflectance) band spectral 4. NDVI was obtained by calculating both bands in raster calculator using formula:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

To verify the NDVI result, we did an actual angiosperm census, covering the ornamental plants planted by park managements. All ornamental angiosperms living in each park were recorded carefully not to pass a single species. Large canopy arboreal species in the park such as *Magnolia champaca*, *Ficus benjamina* or *Dialium indum* or shrubby *Annona muricata* and *Wrightia religiosa* planted within a park (Appendix 1) may be important in determining park microhabitat for spontaneous fern species. However, this census did not cover the smaller spontaneous weedy angiosperms.

The NDVI values used in this study are the mean NDVIs, which were tested, along with ornamental angiosperm species number and park area sizes on Pearson's correlation and simple regression test against fern species numbers. Statistics tests were done in R 4.3.1.

RESULT AND DISCUSSION

Species number and habitat of urban Slawi ferns

Eight parks in Slawi, Tegal, Central Java, harbor 24 species belonging to 7 families of Leptosporangiate ferns (Table 1). No Lycophytes and Eusporangiate ferns were encountered. The 7 families in all parks are typical of urban environment, as no forest families such as Hymenophyllaceae (Proctor 2012) and Cyatheaceae (Lehnert et al. 2013) were found. All species and families encountered in Slawi is of the same species and families with other urban habitat in Java, as in Jakarta (Andayaningsih et al. 2013; Agatha et al. 2019). This indicates that urban Slawi park fern communities are unable to maintain continuity with its adjacent forest communities, as in neighboring Mount Slamet, about 50 km to the south, where fern species composition is much diverse (Budiana & Sukarsa 2012; Sungkono et al. 2012; Praptosuwiryo 2013; Sedayu et al. 2022). Ferns in urban Slawi perhaps stand as a distinct type of urban fern community different from forest community. In biogeography point of view, this means that urban Slawi, environment is highly managed according to anthropogenic needs that no forest species can immigrate and establish in eight parks, despite the ability of most ferns to disperse long distance using their airborne spores. In this sense, eight parks in Slawi, Tegal are justified to be defined as anthropogenic islands, with hypothetically, forests in the neighboring Mt. Slamet as the "mainland", where the genetic variability, i.e. spore rain of various fern species may be sourced.

Only 2 species found in all parks are terrestrial. As in parks, terrestrial habitat is reserved for managed ornamentals, trees, shrubs, and ground covers, it is logical that intensively managed parks harbor lowest

Table 1. Species, habitat, nativity and present-absent matrix of all fern species in 8 urban parks in Tegal.

NO	FAMILY	SPECIES	HABITAT	NATIVITY	GOR Tri-sanja Park	Poci Round-about Park	Slawi GBN Park	Alun-Alun Hang-gawana Park	Railway tunnel Park	Bungah Park	SMA 1 Slawi Crossroad Park	Taman Rakyat Slawi Park
1	Dennstaedtiaceae	*Microlepia speluncae (L.) T.Moore*	C	Native	1	0	0	0	0	0	0	0
2	Lygodiaceae	*Lygodium flexuosum (L.) Sw.*	A	Native	1	0	0	0	0	0	0	0
3	Nephrolepidaceae	*Nephrolepis biserrata (Sw.) Schott*	C	Native	1	0	0	0	0	0	0	0
4	Polypodiaceae	*Davallia solida (G.Forst.) Sw.*	B	Native	0	0	0	0	0	1	0	0
5	Polypodiaceae	*Drynaria quercifolia (L.) J.Sm.*	E	Native	1	1	1	1	1	1	1	1
6	Polypodiaceae	*Phymatosorus scolopendria (Burm.f.) Pic.Serm.*	D	Native	0	1	0	0	0	1	0	0
7	Polypodiaceae	*Pyrrosia longifolia (Burm.f.) C.V.Morton*	B	Native	1	0	0	1	0	0	0	1
8	Polypodiaceae	*Pyrrosia piloselloides (L.) M.G.Price*	B	Native	1	0	1	0	0	0	1	1
9	Polypodiaceae	*Pyrrosia stigmosa (Sw.) Ching*	B	Native	0	0	0	1	0	0	0	0
10	Pteridaceae	*Adiantum capillus-veneris L.*	C	Native	1	0	0	1	1	1	0	0
11	Pteridaceae	*Adiantum philippense L.*	C	Native	1	0	1	0	1	1	1	0
12	Pteridaceae	*Adiantum tenerum Sw.*	C	Alien (South America)	0	1	0	0	0	0	0	0
13	Pteridaceae	*Hemionitis tenuifolia (Burm.f.) Christenh.*	C	Native	1	1	0	0	1	1	0	0
14	Pteridaceae	*Pityrogramma calomelanos (L.) Link*	D	Alien (Central America)	0	0	1	1	1	0	0	1
15	Pteridaceae	*Pteris biaurita L.*	C	Alien (Central America)	1	0	1	0	0	0	0	1
16	Pteridaceae	*Pteris ensiformis Burm.f.*	D	Native	1	0	0	0	1	1	0	1
17	Pteridaceae	*Pteris tripartita Sw.*	C	Native	1	0	0	1	0	0	0	0
18	Pteridaceae	*Pteris vittata L.*	D	Native	1	1	1	1	1	1	1	1
19	Tectariaceae	*Tectaria angulata (Willd.) Copel.*	C	Native	1	0	0	0	0	0	0	0
20	Tectariaceae	*Tectaria siifolia (Willd.) Copel.*	C	Native	1	0	0	0	0	0	0	0
21	Thelypteridaceae	*Thelypteris dentata (Forssk.) E.P.St.John*	D	Native	0	0	1	1	0	0	0	0
22	Thelypteridaceae	*Thelypteris parasitica (L.) Tar-dieu*	C	Native	0	0	0	0	1	0	0	0
23	Thelypteridaceae	*Thelypteris subpubescens (Blume) K.Iwats.*	D	Native	1	0	0	1	1	1	0	1
24	Thelypteridaceae	*Thelypteris opulenta (Kaulf.) Fosberg*	A	Alien (Thailand)	1	0	0	0	0	0	0	0
Total	**7**	**24**			**17**	**5**	**7**	**9**	**9**	**9**	**4**	**8**

0= absent; 1: present; Habitat: A: Terrestrial; B: Epiphyte; C: Lithophyte; D: Terrestrial-Lithophyte; E: Epiphyte-Lithophyte species of spontaneous vegetation, especially ferns. Furthermore, in competition with other spontaneous spermatophyte vegetation, ferns lower, because ferns intrinsically with inferior ecophysiological features, i.e., inefficiency in the two-stage life cycle (Watkins et al. 2007) and inferior vascular system (Watkins et al. 2010), compared to spermatophytic spontaneous vegetation. It is why, when spontaneous vegetation establishes in a suitable terrestrial habitat, ferns are less competitive compared to spermatophytes, hence lower species number in terrestrial habitat of a highly managed park.

Living on trees, the epiphytic lifestyle has provided less competition compared to terrestrial lifestyle. It is why more epiphytic species found in 8 parks (4 species). In Indonesia, fern species is second behind orchids as the most diverse vascular epiphytes (Böhnert et al. 2016), and sometimes number one exceeding orchids in succession environment as in Krakatau (Partomihardjo et al. 2004). Living on trees exposed epiphytes to low light and water scarcity. That is why only specialized species like orchids and ferns can live as epiphytes. And as lower competition occurs on trees, the diversity of epiphytic ferns is logically higher compared to the terrestrials.

Amongst all habitats, the lithophyte habitat has the highest fern diversity (11 species). As ferns are known as successive species, with the ability to thrive in difficult situations, it is not surprising that they are found in a higher number of species. This lifestyle also posed ferns on less competition with spermatophytes, as less spermatophytes are specialized in lithophyte lifestyle. Furthermore, we observe many ferns are found not only as (horizontal) lithophyte, but also as wall (vertical) lithophyte, meaning they anchored on a vertical stony substrate as sewer wall. This is double hindrance for the spermatophyte, as wall is not only stony -like substrate, but also permanent shade for the lithophytes. It is why many of our park ferns are found on rather dark and super humid sewer walls where no spermatophytes thrive. This phenomenon of ferns occupying man made solid substrate is not only in Indonesia, but also in India (Morajkar et al. 2015), and probably in other part of the world. Two other habitats are combination of terrestrial-lithophyte (6 sp.) and epiphyte-lithophyte (1 sp.). This confirms the importance of lithophytic lifestyle for ferns in competition with other spermatophyte spontaneous vegetation in urban setting, that the combination habitats always include lithophyte, and no combination as terrestrial-epiphyte encountered. Our finding may be similar to what was found in India where lithophytic ferns composed the most important life-forms, compared to other life forms, such as terrestrial, epiphyte and aquatic (Anjum et al. 2014).

We found 4 alien ferns (16.6%; Table 1) on our list of spontaneous ferns in eight parks in Slawi. Some introduced species as *Adiantum latifolium* (Muhaimin 2017), might easily established in urban green spaces including parks, however in low species number, as revealed by our observation. The reproduction pattern and ecophysiology of fern might be important in explaining why unlike in spermatophyte, where alien species is major contributor in urban species number (Gleditsch et al. 2023), alien ferns are not highly represented in this study.

Similarity between urban parks

The composition of fern species in each park is depicted in Figure 2., as a visualization of the data in Table 1. GOR Trisanja Park, the park with the most (17) species is placed on the basal most branch of the dendrogram. The second basal is Alun-Alun Hangawana Park, which harbors a similar number of species to Railway Tunnel Park and Bungah Park.

However, Alun-Alun Hangawana Park is placed second most basal in the dendrogram. This is due to the uniqueness of the park in harboring the only individual of *Pyrrosia longifolia* and *P. stigmosa*, which are absent in other parks. Both *P. longifolia* and *P. stigmosa* are epiphytic Polypods uncommon to urban habitats and encountered more in rural or forested area (Jannah et al. 2015; Salamah et al. 2020). This uniqueness is the reason why Alun-Alun Hanggawana Park is different from other parks, aside from GOR Trisanja park which species numbers exceed other parks. *Drynaria quercifolia*, a quite handsome epiphyte, is the most common species found in all parks and serves as the unifying species for all clusters.

Two major park clusters in Figure 2 are the cluster of [Taman Rakyat Slawi Park [Slawi GBN Park, SMA1 Slawi Crossroad Park]] and the cluster of [Poci Roundabout Park [Railway Tunnel Park, Bungah Park]]. Again, in these major clustering, species number is not the unifying factor, as the parks with lowest fern species (SMA 1 Slawi Crossroad Park and Poci Roundabout Park) are placed on a different cluster. Species composition is important in defining similarities between parks. This similarity analysis is important in terms of urban biodiversity management. Some wild species of ferns are quite handsome with ornamental potential and might be left alone in managed areas as additional ornamental plants. Similarity between parks might be a tool in defining which park is more impoverished or, alternatively, with unique species compared to others. This, along with species richness will serve an important recommendation to park managements on how to attract native vegetation to urban environment. In general, the occurrence of native plant species in an urban habitat will attract other native animal species; and native species in an urban habitat will suppress introduced alien species (Ossola & Niemelä 2017).

Relationship between NDVI, ornamental angiosperm species, area and fern species number

NDVI is a standardized measure in quantifying vegetation healthiness and has been used widely in conjunction with classical vegetation surveys. Several surveys have exhibited the correlation of NDVI with species richness, as in butterflies and birds (Seto et al. 2004) and in plants (Pau et al. 2012) including forest ferns (Oldekop et al. 2012). This can be interpreted as the higher the NDVI, which means the healthier the vegetation, the more species of plant live in the area, including ferns. This is not the case in ferns in Slawi's parks, as we found that there is no significant correlation between NDVI and fern species number (Table 2; Pearson r=0.691, p=0.058). This means that urban fern species number in Slawi parks is not determined by NDVI. Pau et al. (2012) reveals that while their research showed NDVI has positive correlation with the species number in Hawaiian dry forest species, they believe that the actual driver in determining species number are other abiotic factors as precipitation. This may also be the reason behind the non-significant relationship between NDVI and fern species number. However, this research does not propose any factor (as precipitation) possible as alternative factors.

The NDVI analysis is further confirmed by the i nsignificant Pearson's correlation (p=0.7) between the species number of angiosperms (Table 2, Appendix 1) planted in each park and the species number of ferns. It turns out that planted angiosperm species as the major associated species of fern community does not rule the species richness of the ferns in a park. NDVI is an indirect measurement of an area "greenness"; and when measured directly as the total richness of planted ornamental angiosperms (Table 2), both measures are not significant correlates to the fern species richness. Indeed, our angiosperm survey did not cover total angiosperm species richness, as smaller spontaneous angiosperms, generally weedy species, were not covered. However weedy angiosperms are usually much smaller in posture compared to tree and shrubby angiosperm ornamentals which posture may determine the park microhabitat crucial, undoubtedly important for spontaneous fern community.

In our case, apparently the fern species number in Slawi parks is related to area, a major factor in island biogeography in determining species number. The Pearson correlation test for area versus species number is significant (Table 2; Pearson r=0.891, p=0.003), with simple regression values: R^2 =0.806, F(1)=24.907, p=0.002. This means that the area of a park is a determining 80.6% variance in a park species number, as plotted on Figure 3.

In island biogeography, isolation and area size are considered the most important drivers of the species number (MacArthur & Wilson 1967; Whittaker & Fernández-Palacios 2007). As we deliberately appoint our study areas in only a single *kecamatan* (subdistrict) (Figure 1), reducing the effect of isolation, we believe that our study is ideal in demonstrating the effect of urban anthropogenic island size to the diversity of spontaneous fern species, in urban environment. Anthropogenic islands are essentially biodiversity islands resulting from fragmentation of surrounding area into urban structure and infrastructure. Some urban specialists and rural or forest immigrants, including ferns, can utilize these islands and subsequently integrated into the park biodiversity. It is a general rule that the more species living in an urban habitat, the healthier the urban habitat is. In turn, healthier urban habitat will affect better

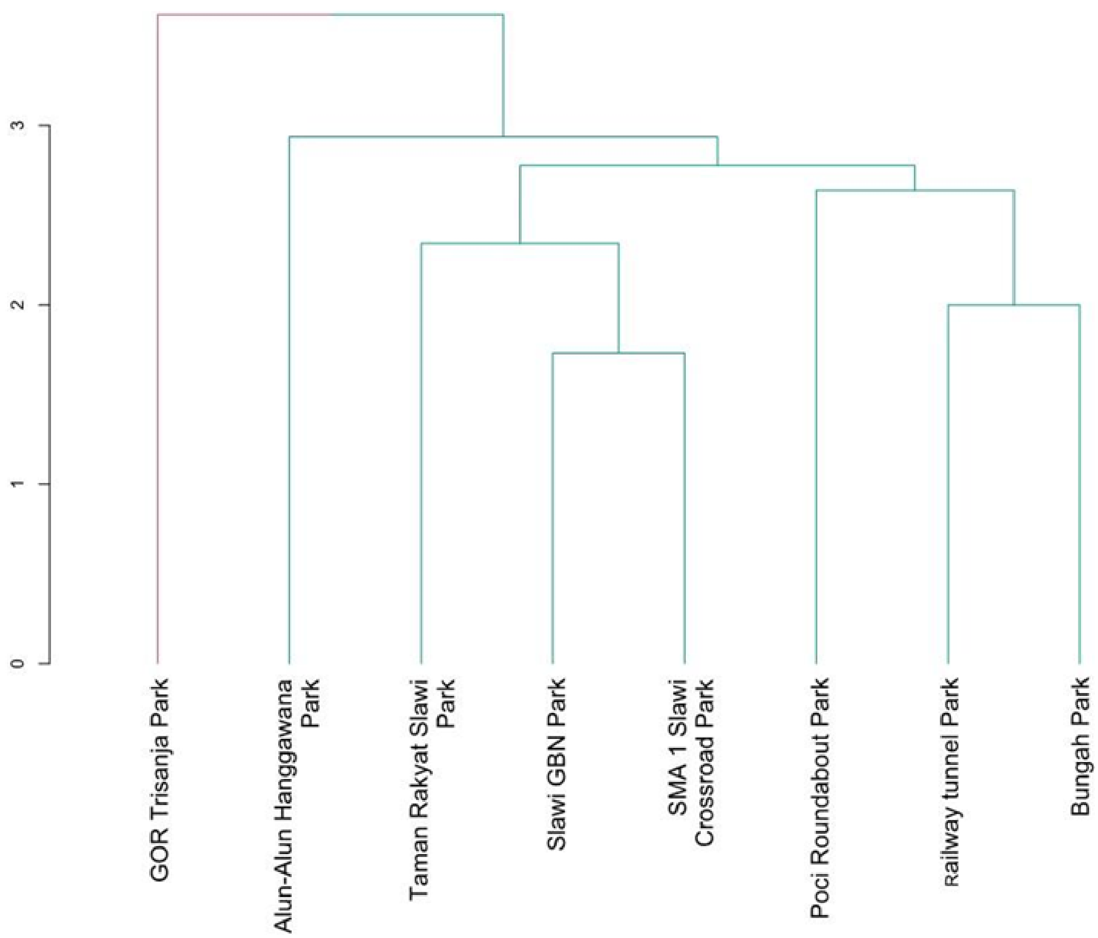

Figure 2. Park clustering based on fern species presence-absence.

human health and well-being (Brown & Grant 2005).

The relationship between area size and species number (Figure 3) explicitly illustrates the importance of park size in harboring biodiversity. We can see that on the left side where park sizes are smaller, the smaller number of ferns are observed. Conversely, at the furthest right point, GOR Trisanja Park which area is largest, harbors largest number of fern species.

It is interesting why NDVI, and further, the species number of ornamental angiosperms are not correlated to fern species richness as the area size. NDVI and ornamental angiosperm species are definitely measures of associated species cohabitate the spontaneous ferns in a park. Ferns in general need humid environment provided by other large trees, that a park with more plant species logically provides more niche for ferns. This may not be the case in urban parks, as there are areas managed and less managed (Sedayu et al. 2022). In the ornamental trees, bushes and shrubs are routinely managed. Pruning and cleaning may clear epiphytic gametophytes and young sporophytes from tree surfaces. It is why our census revealed more terrestrial and lithophytic ferns, independent of host tree habitat, compared to epiphytes. However, these terrestrial and lithophytic ferns may thrive in parks in areas less managed with suitable condition, especially humidity, such as man-made park's sewer wall or roofing. Indeed, study in forest environment revealed that tree species richness is not correlated to fern species richness, however tree species richness is correlated to epiphytic species richness (Williams-Linera et al. 2005).

Since our finding illustrates the importance of area size (compared to NDVI, the vegetation greenness), it is reasonable to propose that in managing urban green spaces, the size of a park or other green spaces be

Table 2. NDVI, park area (m2) and fern species number in 8 observed parks in Slawi.

NO	PARK NAMES	NDVI	Area (m^2)	ANGIOSPERM SP. NOs	FERN SP. NOs
1	GOR Trisanja Park	0.331	74,174.81	6	17
2	Poci Roundabout Park	0.2139	4,400.00	12	5
3	GBN Park	0.2139	4,093.06	18	7
4	Alun-Alun Hanggawana Park	0.1687	15,426.18	18	9
5	Railway tunnel Park	0.2679	800	5	9
6	Bungah Park	0.3098	4,550.00	19	9
7	SMA 1 Slawi Crossroad Park	0.1337	228.02	6	4
8	Taman Rakyat Slawi Park	0.1309	4,000.00	7	8

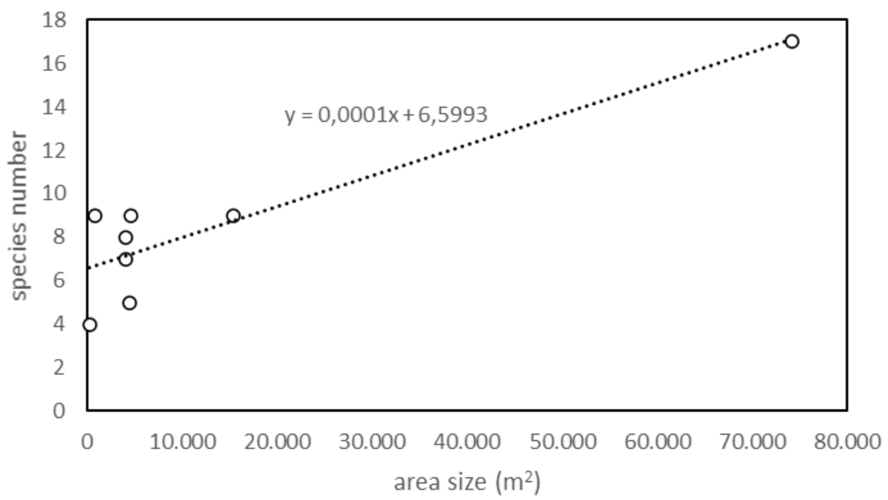

Figure 3. The area-species relationship of the fern community in 8 urban parks in Slawi. Trendline in dash line.

in a reasonable size to shelter many more urban spontaneous species. In Slawi, only 2 parks with size exceeded 1 ha (GOR Trisanja Park, 74,174.81 m^2 and Alun-Alun Hanggawana Park, 15,426.18 m^2), while a study advised that an affective park size in attracting biodiversity is about 1.08 ha (Yao et al. 2022). This is because, as a rule, the larger the anthropogenic island, as any other functional islands, the more species it can shelter.

CONCLUSION

The species of spontaneous ferns in 8 urban parks in Slawi are composed of 24 species. The species composition arranged in similarity clustering showed that species number and composition is important in defining parks uniqueness. The relationship between NDVI and species number is non-significant, while area-species is significant. This indicates that the fern species richness in urban parks is highly determined by the area size, as a biogeographical measure. To further invite more native biodiversity, it is advisable for park managements and designers to take account of species uniqueness and area size of a park into important design and management decision-making.

AUTHOR CONTRIBUTION

AS designed the research, wrote the manuscript, and supervised all the process. NP, A and MW collected field data, satellite imagery and literature collection. MIN is charged with data analysis, while LM is responsible for photo and specimen identification.

ACKNOWLEDGEMENT

We wish to thank all the keepers and field staff of 8 urban parks in Slawi, whose support always cheers us up in the field: *matur nuwun, Pak*. We thank fellow students who were involved in field research, whose discussions were very valuable in this study. We thank M. Muhaimin of BRIN for his assistance in pre-identifying some Slawi fern photographs. We thank Reni Indrayanti and Yulia Irnidayanti of UNJ for administrative assistance in this research.

CONFLICT OF INTEREST

We wish to declare that there is no conflict whatsoever among authors regarding this research and research funding.

REFERENCES

Agatha, S.M. et al., 2019. *Panduan lapangan paku-pakuan (Pteridofita) di Taman Margasatwa Ragunan*, Jakarta: Laboratorium Biologi FMIPA Universitas Negeri Jakarta.

Andayaningsih, D., Chikmawati, T. & Sulistijorini, S., 2013. Keanekaragaman Tumbuhan Paku Terestrial di Hutan Kota DKI Jakarta. *Berita Biologi*, 12(3), pp.297–305.

Anjum, S. et al., 2014. Ecological observations on the Fern Flora of Thannamandi District Rajouri, Jammu & Kashmir, India. *Indian Forester*, 140(12), pp.1235–1244. doi: 10.36808/if/2014/v140i12/55290

Böhnert, T. et al., 2016. Effects of land-use change on vascular epiphyte diversity in Sumatra (Indonesia). *Biological Conservation*, 202, pp.20–29. doi: 10.1016/j.biocon.2016.08.008

Brown, C. & Grant, M., 2005. Biodiversity and human health: What role for nature in healthy urban planning? *Built Environment*, 31(4), pp.326–338. doi: 10.2148/benv.2005.31.4.326

Budiana, A. & Sukarsa, 2012. Diversitas tumbuhan paku epifit di Kebun Raya Baturaden lereng selatan G. Slamet. In *Ekologi Gunung Slamet*. Jakarta: LIPI Press, pp.71–79.

Dassler, C. & Farrar, D., 2001. Significance of gametophyte form in long-distance colonization by tropical, epiphytic ferns. *Brittonia*, 53(2), pp.352–369. doi: 10.1007/BF02812705

Desmet, P. & Cowling, R., 2004. Using the species–area relationship to set baseline targets for conservation. *Ecology and Society*, 9(2), 11.

Gessesse, A.A. & Melesse, A.M., 2019. Chapter 8 - Temporal relationships between time series CHIRPS-rainfall estimation and eMODIS-NDVI satellite images in Amhara Region, Ethiopia. In *Extreme Hydrology and Climate Variability*. Elsevier, pp.81–92. doi: 10.1016/B978-0-12-815998-9.00008-7.

Gleditsch, J.M. et al., 2023. Contemporizing island biogeography theory with anthropogenic drivers of species richness. *Global Ecology and Biogeography*, 32(2), pp.233–249. doi: 10.1111/geb.13623

De Groot, G.A. et al., 2012. Diverse spore rains and limited local exchange shape fern genetic diversity in a recently created habitat colonized by long-distance dispersal. *Annals of Botany*, 109(5), pp.965–978. doi: 10.1093/aob/mcs013.

Holttum, R.E., 1966. *Flora of Malaya Volume II. Ferns of Malaya* 2nd ed., Singapore: Government Printing Office.

Jannah, M., Prihanta, W. & Susetyorini, E., 2015. Identifikasi pteridophyta di Piket Nol Pronojiwo Lumajang sebagai sumber belajar biologi. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 1(1), pp.89—98.

Johansen, B. & Tømmervik, H., 2014. The relationship between phytomass, NDVI and vegetation communities on Svalbard. *International Journal of Applied Earth Observation and Geoinformation*, 27, pp.20–30. doi: 10.1016/j.jag.2013.07.001

Lehnert, M. et al., 2013. Taxonomic and ecological notes on the Alsophila hornei complex (Cyatheaceae-Polypodiopsida), with the description of the new species A. phlebodes from New Guinea. *Systematic Botany*, 38(4), pp.875–886. doi: 10.1600/036364413X674788

MacArthur, R.H. & Wilson, E.O., 1963. An equilibrium theory of insular zoogeography. *Evolution*, pp.373–387.

MacArthur, R.H. & Wilson, E.O., 1967. *The theory of island biogeography*, Princeton, New Jersey: Princeton University Press.

Morajkar, S., Sajeev, S. & Hegde, S., 2015. Ferns: A Thriving Group of Urban Dwellers. *Bionature*, 35(1&2), pp.13-21.

Muhaimin, M., 2017. Adiantum latifolium Lam. (Pteridaceae); A newly naturalized fern in Java, Indonesia. *Floribunda*, 5(6), pp.220-225. doi: 10.32556/floribunda.v5i6.2017.177

Neigel, J.E., 2003. Species–area relationships and marine conservation. *Ecological Applications*, 13(sp1), pp.138–145. doi: 10.1890/1051-0761(2003)013[0138:SARAMC]2.0.CO;2

Oldekop, J.A. et al., 2012. Co-occurrence patterns of common and rare leaf-litter frogs, epiphytic ferns and dung beetles across a gradient of human disturbance. *PLoS One*, 7(6), e38922. doi: 10.1371/journal.pone.0038922

Ossola, A. & Niemelä, J., 2017. *Urban biodiversity: from research to practice*, London: Routledge.

Partomihardjo, T., Eizi, S. & Junichi, Y., 2004. Development and distribution of vascular epiphytes communities on the Krakatau Islands, Indonesia. *South Pacific Studies*, 25(1), pp.7–26.

Pau, S., Gillespie, T.W. & Wolkovich, E.M., 2012. Dissecting NDVI–species richness relationships in Hawaiian dry forests. *Journal of Biogeography*, 39(9), pp.1678–1686. doi: 10.1111/j.1365-2699.2012.02731.x

POWO, 2022, 'Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew', in *POWO*, viewed 21 October 2022, from http://www.plantsoftheworldonline.org/

Praptosuwiryo, T.N., 2013. The rare pteridophytes of Mt. Slamet with three species new records for Java. *Floribunda*, 4(6), pp.138—146. doi: 10.32556/floribunda.v4i6.2013.103

Proctor, M.C.F., 2012. Light and desiccation responses of some Hymenophyllaceae (filmy ferns) from Trinidad, Venezuela and New Zealand: poikilohydry in a light-limited but low evaporation ecological niche. *Annals of botany*, 109(5), pp.1019–1026. doi: 10.1093/aob/mcs012

QGIS.org, 2023, 'QGIS 3.10 Geographic Information System', in *QGIS*, viewed 4 August 2023, from http://www.qgis.org

R Core Team, 2023, 'R: A language and environment for statistical computing', in *R: The R Project for Statistical Computing*, viewed 2 June 2023, from https://www.R-project.org/

Robinson, S.L. & Lundholm, J.T., 2012. Ecosystem services provided by urban spontaneous vegetation. *Urban Ecosystems*, 15, pp.545–557. doi: 10.1007/s11252-012-0225-8

Salamah, Z., Sasongko, H. & Novida, R., 2020. The Diversity of Ferns (Pteridophyta) at Pundong Japanese Cave, Bantul, Yogyakarta. *Proceedings of the International Conference on Biology, Sciences and Education (ICoBioSE 2019)*, pp.185–191. doi: 10.2991/absr.k.200807.038

Sato, T., 1982. Phenology and wintering capacity of sporophytes and gametophytes of ferns native to Northern Japan. *Oecologia*, 55(1), pp.53–61. doi: 10.1007/BF00386718

Savard, J.-P.L., Clergeau, P. & Mennechez, G., 2000. Biodiversity concepts and urban ecosystems. *Landscape and urban planning*, 48(3–4), pp.131–142. doi: 10.1016/S0169-2046(00)00037-2

Sedayu, A., Saraswati, R.A. & Astuti, Y.P., 2022. Light preferences in two landscape managements and ontogenic light requirements of terrestrial ferns in Kebun Raya Baturraden, Central Java. *Reinwardtia*, 21(1), pp.25–33. doi: 10.55981/reinwardtia.2022.4265

Seto, K.C. et al., 2004. Linking spatial patterns of bird and butterfly species richness with Landsat TM derived NDVI. *International journal of remote sensing*, 25(20), pp.4309–4324. doi: 10.1080/0143116042000192358

Sungkono, J., Widiawati, Y. & Chasanah, S., 2012. Persebaran jenis tumbuhan paku Dennstaedtiaceae di hutan Gunung Slamet jalur pendakian Baturraden. In *Ekologi Gunung Slamet*. Jakarta: LIPI Press, pp.81–87.

Taylor, T.N., Kerp, H. & Hass, H., 2005. Life history biology of early land plants: deciphering the gametophyte phase. *Proceedings of the National Academy of Sciences of the United States of America*, 102(16), pp.5892–5897. doi: 10.1073/pnas.0501985102

USGS, 2022, 'Landsat-8 image courtesy of the U.S. Geological Survey', in *USGS*, viewed 21 October 2022, from https://earthexplorer.usgs.gov/

Watkins, J.E., Holbrook, N.M. & Zwieniecki, M.A., 2010. Hydraulic properties of fern sporophytes: Consequences for ecological and evolutionary diversification. *American Journal of Botany*, 97(12), pp.2007–2019. doi: 10.3732/ajb.1000124

Watkins, J.E.Jr. et al., 2007. Ecological and evolutionary consequences of desiccation tolerance in tropical fern gametophytes. *New Phytologist*, 176, pp.708–717. doi: 10.1111/j.1469-8137.2007.02194.x

Whittaker, R.J. & Fernández-Palacios, J.M., 2007. *Island biogeography: ecology, evolution, and conservation*, Oxford University Press.

Williams-Linera, G., Palacios-Rios, M. & Hernández-Gómez, R., 2005. Fern richness, tree species surrogacy, and fragment complementarity in a Mexican tropical montane cloud forest. *Biodiversity & Conservation*, 14, pp.119–133. doi: 10.1007/s10531-005-4053-5

Yao, X. et al., 2022. How can urban parks be planned to mitigate urban heat island effect in "Furnace cities"? An accumulation perspective. *Journal of Cleaner Production*, 330, 129852. doi: 10.1016/j.jclepro.2021.129852

Appendix1. The list of ornamental angiosperms in all 8 parks in Slawi, Tegal, Central Java.

No	Species	GOR Trisanja Park	Poci Roundabout Park	GBN Park	Alun-Alun Hanggawana Park	Railway tunnel Park	Bungah Park	SMA 1 Slawi Crossroad Park	Taman Rakyat Slawi Park
1	*Acalypha siamensis* Oliv. ex Gage	0	1	0	0	0	0	1	1
2	*Albizia chinensis* (Osbeck) Merr.	0	0	0	1	0	0	0	0
3	*Anacardium occidentale* L.	0	0	0	1	0	0	0	0
4	*Annona muricata* L.	0	0	1	0	0	0	0	0
5	*Averrhoa carambola* L.	0	1	1	1	0	0	0	0
6	*Bambusa bambos* (L.) Voss	0	0	0	0	0	1	0	0
7	*Bougainvillea spectabilis* Willd.	0	1	0	0	0	0	0	0
8	*Casuarina junghuhniana* Miq.	0	0	0	0	0	0	1	1
9	*Chrysalidocarpus lutescens* H.Wendl	1	0	0	1	0	1	1	0
10	*Dialium indum* L.	0	0	0	0	1	0	0	1
11	*Dracaena sanderiana* Mast.	0	0	1	0	0	0	0	0
12	*Erythrina crista-galli* L.	0	0	0	1	0	0	0	0
13	*Eugenia uniflora* L.	0	0	0	0	0	1	0	0
14	*Euphorbia tirucalli* L.	0	1	1	0	0	0	0	0
15	*Ficus benjamina* L.	0	0	1	1	0	1	0	0
16	*Handroanthus chrysotrichus* (Mart. Ex DC.) Mattos	0	0	0	0	0	1	0	0
17	*Heptapleurum arboricola* Hayata	0	0	0	0	0	1	0	0
18	*Hevea brasiliensis* (Willd.ex A.Juss.)	0	0	0	0	0	1	0	0
19	*Ixora* L.	0	0	0	0	0	1	0	0
20	*Lantana camara* L.	0	0	0	0	0	1	0	0
21	*Lilium superbu*m L.	0	0	1	1	0	1	0	0
22	*Magnolia champaca* (L.) Baill.ex Pierre	0	0	0	0	0	1	0	0
23	*Mangifera indica* L.	0	0	0	1	0	0	0	1
24	*Manilkara zapota* (L.) P.Royen	0	0	0	1	0	0	0	0
25	*Melaleuca leucadendra* (L.) L	0	0	1	1	0	0	0	0
26	*Mimusops elengi* L.	0	0	0	0	0	1	0	0
27	*Monoon longifolium* (Sonn.) B.Xue & R.M.K Saunders	0	1	1	1	1	0	0	1
28	*Mussaenda pubescens* Dryand.	0	0	0	0	0	0	1	0
29	*Nerium oleander* L.	0	0	0	0	0	0	1	0
30	*Phyllanthus acidus* (L.) Skeels	0	1	0	0	0	0	0	0

Appendix1. Contd.

No	Species	GOR Trisanja Park	Poci Roundabout Park	GBN Park	Alun-Alun Hanggawana Park	Railway tunnel Park	Bungah Park	SMA 1 Slawi Crossroad Park	Taman Rakyat Slawi Park
31	*Plumeria rubra* L.	0	1	0	1	1	0	0	0
32	*Pometia pinnata* J.R.Forst.&G.Forst	0	0	1	0	0	0	0	0
33	*Psidium guajava* L.	0	0	1	0	0	0	0	0
34	*Pterocarpus indicus* Willd.	0	0	0	1	0	1	0	0
35	*Roystonea regia* (Kunth) O.F.Cook	0	0	0	0	0	0	0	0
36	*Ruellia tuberosa* L.	1	1	1	0	1	1	0	0
37	*Samanea saman* (Jacq.) Merr.	1	0	1	0	0	0	0	0
38	*Spondias dulcis* Parkinson	0	0	1	0	0	0	0	0
39	*Streblus asper* Lour.	1	0	1	1	0	1	0	0
40	*Swietenia mahagoni* (L.) Jacq	0	0	0	1	0	0	0	1
41	*Syzygium borbonicum* J.Gueho & A.J.Scott	0	1	0	1	0	0	0	0
42	*Syzygium cumini* (L.)	0	1	0	0	0	0	0	0
43	*Tabebuia heterophylla* (DC.) Britton	0	0	0	0	0	1	0	0
44	*Tabebuia rosea* (Bertol.) DC.	1	1	0	1	0	1	0	0
45	*Terminalia catappa* L	0	0	1	0	0	0	0	0
46	*Terminalia neotaliala* Capuron	1	1	1	1	1	1	1	1
47	*Wrightia religiosa* (Teijsm.&Binn.) Benth. Ex. Kurz	0	0	1	0	0	1	0	0
48	*Yucca gloriosa* L.	0	0	1	0	0	0	0	0
	TOTAL SPECIES	6	12	18	18	5	19	6	7

Note: 0 = absent; 1 = present