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EFFECTS OF ALTITUDE AND MICROCLIMATE ON THE DISTRIBUTION FERNS IN AND URBAN AREAS

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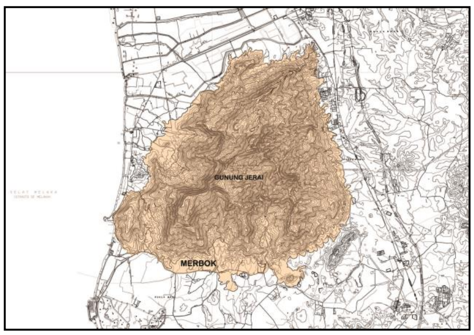
Graphical abstract



Abstract

The aim of the research is to explore the potential of fern species as natural ecological indicator agent to forecast microclimate changes in the urban area. Ferns which also known as pteridophyte are not only valuable in term of its ethno-botanical uses such as food and medicine but also useful in ecological values. Other than that it can be used to treat unhealthy environment such as absorbing methane gas, fertilizing land and treating heavy metal such as arsenic as well as can be used as a potential ecological indicator agent for microclimate changes. In this research, observation and measurement were made at two different environments which are natural environments; Gunung Jerai, Kedah and Lata Jarum, Pahang and manmade setting environments; Hospital Serdang, Serdang and Secret Garden, Kuala Lumpur. Interestingly results from two case studies of natural environments indicated that the distribution and abundance of fern species strongly influenced by differences in altitude. Twelve fern species were found at different elevations at Gunung Jerai, Kedah whereas 20 fern species were found at Lata Jarum, Pahang. Among the species found at Gunung Jerai were *Selaginella willdenowii, Arcypteris irregularis*, *Adiantum caudatum*, *Pityrogramma calomelanos*, *Histiopteris stipulacea, Athyrium cordifolium, Osmund wachellii*, and *Cyathea contaminans.* Whereas the species found at Lata Jarum are *Dicranopteris linearis, Phymatodes scolopendria, Antrophyum callifolium, Arcypteris irregularis, Phymatodes crustachea, Selaginella willdenowi, Angiopteris evecta and Aglaomorpha heraclea.* Another factor that influences the occurrences of the fern species is microclimate particularly atmospheric factor. Results observed from both case studies showed that light intensity, relative humidity and temperature also influenced the distribution of fern species. Therefore fern species are excellent ecological indicator which can be used as phytoindicator for unhealthy environment such as harsh environment or to predict microclimate changes at urban area.

Keywords: Fern species, ecological indicator agent, urban microclimate, climate changes

1.0 INTRODUCTION

Ecological indicators can be defined as a discrete expression or portion of the environment that provides quantitative information on ecological resources reflecting the status of large systems [11].

Ferns are dispersed by small spores and establish new populations in distant localities, they exhibit lower endemism, and less frequent speciation, they have a mostly herbaceous perennial growth form (a few are annuals and or tree-like), need moisture and they have a long evolutionary history [20, 24, 28]. Because of these unique features, patterns of fern and flowering plant richness along an elevational gradient may not be concurrent [6]. There are many studies of plants along elevational gradients have focused on the distribution of terrestrial species; few have focused on epiphytes, and fewer still have compared epiphytic and terrestrial floras [13, 14]. Although there are many studies related to fern ecology, relatively few studies have addressed the change of diversity along elevational gradients [12, 15, 19, 8]. Elevational gradients can serve as an excellent system to evaluate ecological and biogeographical theories of species richness and their relationships to climate [16]. In addition, literature study emphasizes microclimatic factors such as light, temperature, and precipitation as explanations for species richness distributions along elevational gradients. A series of recent studies have added a new consideration for studies of species richness: the influence of geometric constraints [7]

As reported in previous research by Ruokolainen *et al*., (1997) and Vormisto *et al*., (2000) [25, 3], ferns are good indicator for tree species distribution patterns at different spatial scales as well as indicators for disturbance of forest quality where by many species show clear habitat differentiation with regard to light intensity (LI) or relative humidity (RH) in natural setting [5]. This is due to the outer canopy that has the most extreme climatic conditions with a high variation in temperature and air humidity, causing dry and/or cold events. The plant species that grow across different light environments or intensity are able to produce leaves that are morphologically and physiologically suited to a wide range of light environments [4, 34, 17, 27]. LI can influence photosynthetic performance of ferns direct effect on the photosynthetic apparatus and its damage under stress conditions [36, 19, 34] so that the balance between the light energy absorbed and that used for metabolism is critical in photosynthetic organisms [9]. RH is the ratio of the partial pressure of water vapor in the mixture to the saturated vapour pressure of water at a prescribed temperature whereas LI is the amount of light energy transmitted.

Fern species also can be survive in the urban atmosphere. Urban areas are closely related to climate changes. It represent a major modification of the urban climatic condition such as the modification of radiation, energy, and energy exchanges resulting from the built form of the city, together with the emission of heat, moisture, and pollutants from human activities.

Recently the World Health Organization's (WHO) stated that over 77, 000 people death in the Asia Pacific Region per year caused by climate changes [25]. European studies of urban climates also identified changes in humidity, wind speeds and radiation within the larger cities [18].

The effect of Green House Gasses (GHG) is eminent which caused by global warming reaction where the important gases; carbon dioxide which emitted in energy production and transportation being released into the atmosphere. Consideration of upgrading the public health where co-benefits action in protecting health by reducing the GHG emissions through building, industry, agriculture, transport, energy supply and conversion and waste management should be emphasized.

This study is subject to discuss the potential of fern species as ecological indicator agent for urban climate changes at different altitude. The urban climate changes are usually caused by the phenomenon of 'urban heat island' (UHI). These UHI usually consign to the 'urban heat-island intensity', which the maximum temperature difference between the city and the surrounding area [2]. For example, street temperature possesses a simpler causality than air temperature, which is coupled to the thermal state of the adjacent surfaces but is also subject to advective influences [3, 29]. It is perhaps this simplicity that has permitted successful hardware and numerical simulation modelling of the street surface UHI under calm, night-time conditions, when solar shading is absent and turbulent interactions between street, air and advective fluxes are minimal [21, 1, 11, 22, 30]. Data compiled from various sources show that heat-island intensity can be as high as 15°C [26].

2.0 MATERIALS AND METHOD

2.1 Plot Sampling

Nineteen different plots were identified along the trail of Gunung Jerai in Kedah and Lata Jarum in Pahang in order to establish the plots, locations and information of fern as shown in Figure 1 and 2.

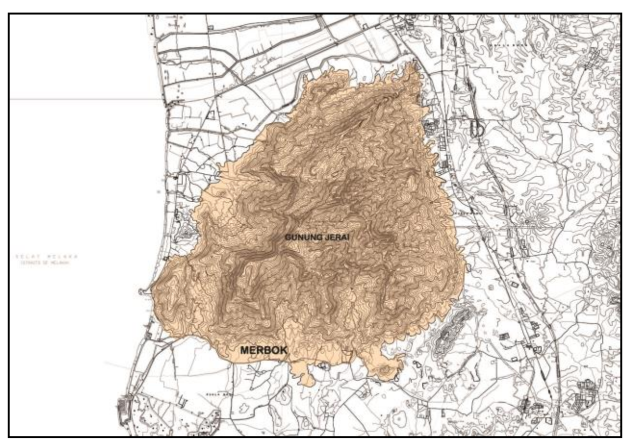


Figure 1 Location map of Gunung Jerai

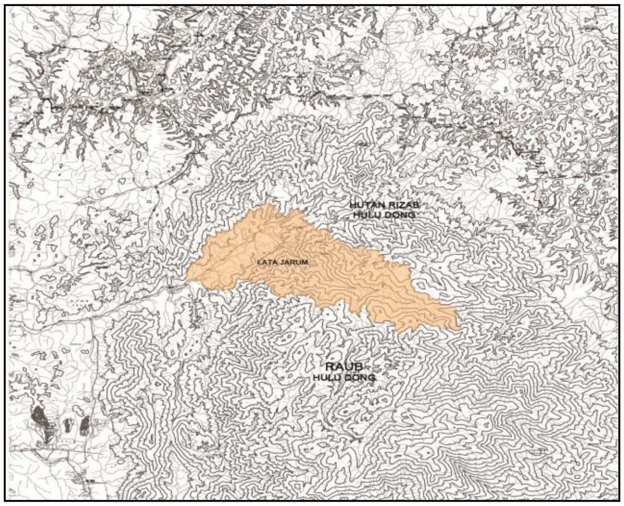


Figure 2 Location map of Lata Jarum

At both this site, square plots were located, and were bordered by tape and stakes. All plots were established in mature forests around Gunung Jerai that showed less signs of recent human intervention, at the least distance from each other of 500 m. In each plot, all ferns species data were recorded and collected. To make this study more comprehensive, the photograph of the fern species and the sample of leaves were taken for herbarium specimen collection as further described by Duque *et al*. (2005).

2.2 Climate Variable

Two different environments which are natural environments; Gunung Jerai, Kedah and Lata Jarum, Pahang and manmade setting environments; Hospital Serdang, Serdang and Secret Garden, Kuala Lumpur were selected as case studies. Time of sampling for both areas is the same. All the climate variables were measured during 10 a.m. till 5 p.m. At Gunung Jerai, the climate variables were measured from 0-100 m up to 500 m elevation from the sea level. Whereas for Lata Jarum, the observation started from 200-300 m up to 500 m due to topography variation factor. As for hospital Serdang and One Utama Shopping Complex the observation started from 0-200 m elevation due to building height variation. Light intensity was taken using 'Extech EA30 EasyView™ Light Meter' whereas for temperature and relative humidity the data was taken using 'Testo 625 Hygrometer With Probe'. Climate variable data's were used to identify possible associations between the probability of occurrence of the fern species and climatic characteristic.

3.0 RESULTS AND DISCUSSION

3.1 Analysis of Temperature, Relative Humidity and Light Intensity of Different Altitudes at Natural and Manmade Setting Environments

Based on the study, the urban microclimate (manmade setting area) is indicated as hotter than the surroundings. The temperature is slightly higher, the RH is lower and the LI is higher due to the rapid development of built environment, lack of vegetations planted at the area and lack of evaporating methods from the source of water at urban area. However, Table 1 shows that, at elevation 0-100 m, the temperature is 25.90°C (Gunung Jerai) and 31.23°C (urban area), the RH is 79.40% (Gunung Jerai) and 66.80% (urban area) and the LI are 355.50 lux (Gunung Jerai) and 730.88 lux (urban area). As for elevation of 101-200 m, the temperature is 25.33°C (Gunung Jerai) and 31.94°C (urban area), the RH is 81.08% (Gunung Jerai) and 56.88% (urban area) and the LI are 371.17 lux (Gunung Jerai) and 1541 lux (urban area).

It shows that the microclimate condition of natural and manmade setting is apparently different. The manmade setting area has a hotter microclimate whereas the microclimate at natural area is more conducive than the urban area.

Table 1 Analysis of temperature, relative humidity and light intensity of different altitudes at natural and manmade setting environments (T: Temperature, RH: Relative Humidity, LI: Light Intensity)

Elevation (m)	**Gunung Jerai**			**Lata Jarum**			**Urban area**		
	T (°C)	RH (%)	LI (lux)	T (°C)	RH (%)	LI (lux)	T (°C)	RH (%)	LI (lux)
0-100	25.90 ± 1.53	79.40 ± 10.74	355.50 ± 50.94	No data	No data	No data	31.23 ± 1.11	66.80 ± 4.27	730.88 ± 580.31
101-200	25.33 ± 0.79	81.08 ± 4.04	371.17 ± 158.43	No data	No data	No data	31.94 ± 1.94	56.88 ± 4.41	1541.00 ± 04.17

3.2 Potential Fern Species to Forecast Microclimate at Urban Area

Based on this research, there are few species recommended based on observation made at Lata Jarum and Gunung Jerai to be applied at urban high-rise setting area. The species are as in Table 2.

Table 2 Recommended fern species as ecological indicator agent to forecast climate chages at urban area. (There are no data for elevation of 0-200 m due to the habitat is found above 200 m of elevation)

Elevation (m)	Gunung Jerai	Lata Jarum	Urban area
001-100	*Arcypteris irregularis, Selaginella willdenowii*	No data	Applied as recommended by Gunung Jerai data
101-200	*Adiantum Caudatum, Pityrogramma calomelanos*	No data	Applied as recommended by Gunung Jerai data

3.3 Ferns at Different Elevations of Gunung Jerai and Lata Jarum

Referring to these results as shown in Figure 3, at Gunung Jerai, it can be concluded that there are altogether 12 different fern species can be found while as shown in Figure 4, the remaining 20 other species can be found at Lata Jarum. The fern species at Gunung Jerai are *Arcypteris irregularis, Selaginella willdenowii, Adiantum caudatum, Pityrogramma calomelanos,* unknown species, *Athyrium cardifolium, Osmund wachellii, Histopteris stipulaceae, Cyathea contaminans, Lygodium circinnatum* and *Histiopteris stipulace*.

While fern species at Lata Jarum are *Dicranopteris linearis, Cyathea contaminans, Asplenium nidus, Arcypteris irregularis, Selaginella willdenowii, Phymatodes scolopendria, Aglamorpha heraclea, Arcypteris irregularis, Selaginella willdenowi, Antrophyum capillifolium, Angiopteris evecta, Phymatodes crustachea, Adiantum latifolium Osmunda wachellii, Angiopteris evecta, Arcypteris irregularis, Selaginella plana, Athyrium cordifolium* and *Cyathea contaminans*. The results are shown in Figure 3 (Gunung Jerai) and Figure 4 (Lata Jarum).

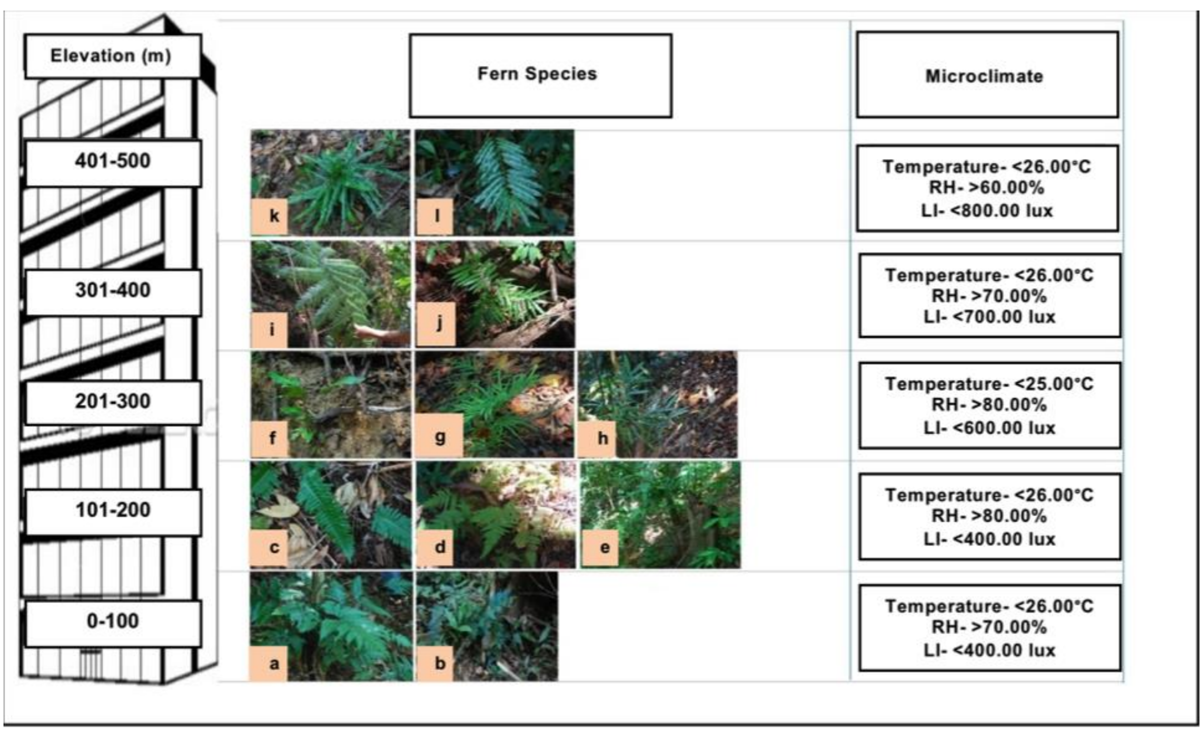


Figure 3 Fern distribution at Gunung Jerai

Table 3 Fern species at Gunung Jerai according to elevation

Elevation (m)	Fern species
0-100	(a)*Arcypteris irregularis,* (b) *Selaginella willdenowii,*
101- 200	(c)*Adiantum caudatum,* (d) *Pityrogramma calomelanos,* (e) unknown species
201-300	(f) *Athyrium cordifolium,* (g) *Osmund wachellii,* (h) *Histiopteris stipulacea*
301- 400	(i)*Histiopteris stipulacea,* (j) *Cyathea contaminans*
401-500	(k) *Lygodium circinnatum* (l) *Histiopteris stipulacea,*

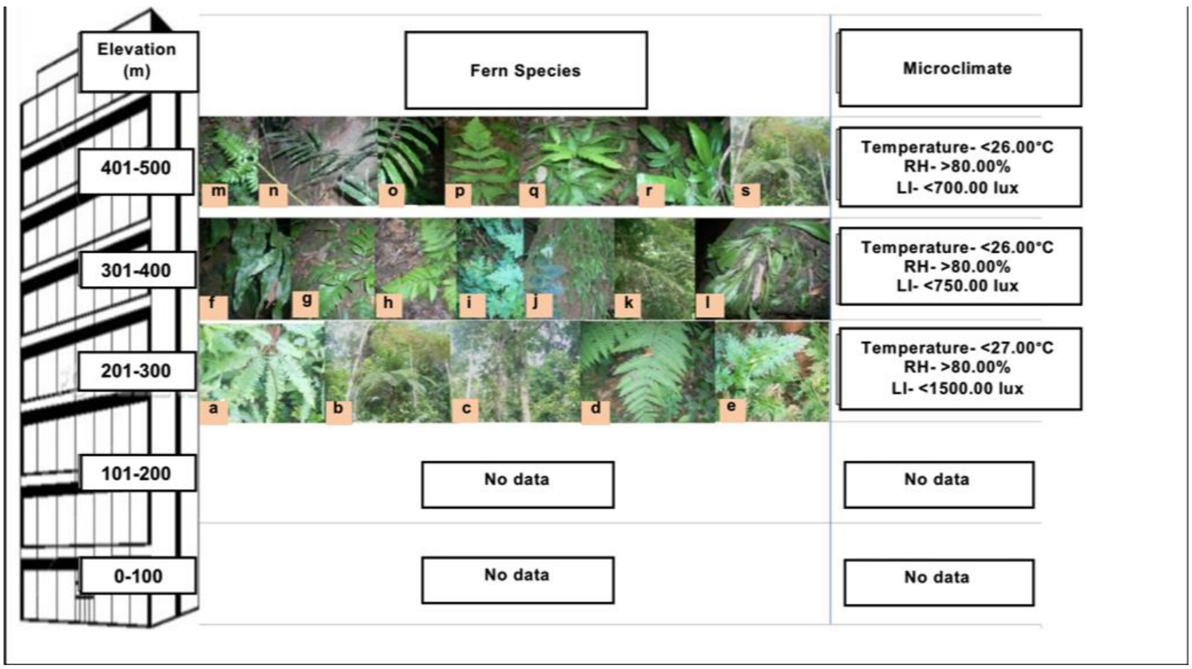


Figure 4 Fern distribution at Lata Jarum (There are no data for elevation of 0-200 m due to the habitat is found above 200 m of elevation)

Table 4 Fern species at Lata Jarum according to elevation

Elevation (m)	Fern species
0-100 101-200	No data for elevation 0-200 m
201-300	(a)*Dicranopteris linearis,* (b) *Cyathea contaminans,* (c) *Asplenium nidus,* (d) *Arcypteris irregularis,* (e) *Selaginella willdenowii,*
301-400	(f) *Phymatodes scolopendria,* (g) *Aglaomorpha heraclea,* (h) *Arcypteris irregularis,* (i) *Selaginella willdenowi,* (j) *Antrophyum capillifolium,* (k) *Angiopteris evecta,* (l) *Phymatodes crustachea,*
401-500	(m) *Adiantum latifolium,* (n) *Osmunda wachellii,* (o) *Angiopteris evecta,* (p) *Arcypteris irregularis,* (q) *Selaginella plana,* (r) *Athiyrium cordifolium,* (s) *Cyathea contaminans.*

According to the data obtained from Gunung Jerai (refer Table 3) and Lata Jarum (refer Table 4), at the lowest elevation, there are *Arcypteris irregularis* and *Selaginella willdenowii.* Whereas at the highest elevation, the species which can be found are *Lygodium circinnatum* and *Histiopteris stipulacea* (Gunung Jerai) and *Adiantum latifolium, Osmunda wachellii, Angiopteris evecta, Arcypteris irregularis, Selaginella plana, Athiyrium cordifolium,* and *Cyathea contaminans* (Lata Jarum). From the data, the most common species found at Gunung Jerai and Lata Jarum are *Arcypteris irregularis, Selaginella willdenowii, Adiantum caudatum,* and *Cyathea contaminans*. The result of this study is in accordance with the majority of the previous research which stresses that the distribution and abundance of fern species are strongly influenced by differences in altitude [12, 15, 20, 8] and relationship with the climate changes [16]. These species richness also can be identified as species that inhabitat in all condition of light intensity, humidity and temperature.

Due to UHI and rapid development at these manmade setting environments, the fern species cannot survive in urban climate. For that reason, this research were conducted to discover and understand the microclimate within the city centre which to know the percentage heat contribution towards the urban heat island and also to applied fern species in urban area to forecast micro clima changes. The fern species that found in the ecological area also can be applied to the urban environment to detect the surrounding microclimate changes. Accordingly, the fern species can be applied in line with the elevation of the height of building and the altitude. At different altitude, there are only certain species can survive. This will indicate that the climate at the area not conducive. Therefore, a suitable mechanism is required to act as forecaster for microclimate changes at urban area. It is normal when the scientific mechanism is used to forecast the microclimate. However, it is not common to use plant as a phyto-technology agent to indicate the climate changes. In this study, the uses of fern as ecological indicators as well as phyto-technology agent for micro climate changes will be revealed for microclimate changes. It is because fern species are sensitive with temperature, low relative humidity [19], and amount of sunlight. The increasing in relative humidity can reduce the temperature of the surrounding area especially for high-rise building such as balcony and rooftop garden. A high relative humidity or moisture climate, and low temperature also can be a suitable habitat for fern species.

Thus, any changes in growth of fern species can detect any changes in microclimate surrounding, because the growth of fern species are related with temperature, relative humidity as well as light intensity. Most of the fern species are categorized as semi-shade and full shade plants. Shade elements applied as protection from sun light to reduce the temperature. In urban context, shaded element can be adopted by planting foliage vegetation, implement the head top elements such as pergola and canvas, and planting vinery such *Vallaris glabra* to cover the head-top element. Besides, shady and low temperature area is also suitable habitat for fern species. Thus, any changes in growth of fern species can detect any changes in microclimate surrounding, because the growth of fern species are related with the temperature. So, the raises issues that associated with this study are to make use the fern species as the ecological indicator to forecast the microclimate changes at the urban area.

4.0 CONCLUSION

In conclusion, even within natural environment, there are different levels and types of microclimate. It indicates that the distribution of fern species varies according to microclimate and elevation. In urban area, the microclimate requirements differ from the lower elevation up to the higher elevation. This is due to urban heat island temperature and the height of the elevation as well. Therefore, there are few species which have potential to forecast the microclimate changes but it needs some consideration of adaptability towards respective species in according to specific location. Result of this research suggested the suitable fern species and its ideal microclimate to be applied. The recommended ideal environment for windy urban area located near by the sea would be the fern species from Gunung Jerai whereas in a dense urban area, fern species from Lata Jarum accommodate the best.

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