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ABSTRACT

The aims of this research were (i) to examine changes in plant diversity along an urbanization gradient in Ipoh, Perak, (ii) to relate plant traits (tree height, specific leaf area (SLA), and dispersal) with the urbanization intensity, and (iii) to relate environmental conditions (ambient temperature, air humidity, and light intensity) with urbanization intensity. The urbanization intensity was determined based on the percentage of built-up area within a $1km^2$ area using Geographical Information Systems (GIS). A total of 12 sampling plots sized $1km^2$ were constructed to represent different urbanization intensities. In each plot, 40 subplots were randomly selected to form a total sampling area of 0.1 hectares, and any plants with ≥5cm diameter at breast height were identified at the species level. The plant height and SLA were measured while the dispersal mode was identified based on literature. The environmental data were collected during midday for three times at each plot. The findings revealed that there were 96 plant species belonging to 71 genera and 42 families in the 12 plots. Species diversity ($r= -0.781$; $p= 0.003$), richness ($r= -0.842$; $p= 0.001$), and evenness ($r= -0.901$; $p< 0.001$), declined significantly as urbanization intensity increased. The number of native species and plant height decreased with increasing urbanization intensity. Meanwhile, for SLA, the outcome demonstrated that there was no significant relationship between SLA and urbanization intensity. Endo-zoochory, hemerochory, and myrmechory were the most important dispersal modes in urban areas. The three environmental factors were also significantly associated with increasing urbanization intensity. In conclusion, environmental conditions vary with urbanization and urbanization reduces plant diversity. However, plant trait is only partially associated with urbanization. The findings from this research could help town planners in designing urban environments to achieve more sustainable development.

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PERUBAHAN DALAM KEPELBAGAIAN TUMBUHAN, CIRI-CIRI TUMBUHAN DAN PEMBOLEH UBAH PERSEKITARAN SEPANJANG KECERUNAN PEMBANDARAN DI IPOH, PERAK

ABSTRAK

Tujuan penyelidikan ini untuk (i) mengkaji perubahan kepelbagaian tumbuhan sepanjang kecerunan pembandaran di Ipoh, Perak, (ii) mengaitkan ciri tumbuhan (ketinggian pokok, luas daun tertentu (SLA), dan penyebaran) dengan intensiti pembandaran, dan (iii) mengaitkan keadaan persekitaran (suhu ambien, kelembapan udara, dan keamatan cahaya) dengan intensiti pembandaran. Intensiti pembandaran ditentukan berdasarkan peratusan kawasan binaan dalam kawasan 1km^2 menggunakan Sistem Maklumat Geografi (GIS). Sebanyak 12 plot persampelan bersaiz 1km^2 telah dibina untuk mewakili intensiti pembandaran yang berbeza. Dalam setiap plot, 40 subplot telah dipilih secara rawak untuk membentuk jumlah kawasan persampelan seluas 0.1 hektar, dan mana-mana tumbuhan dengan diameter ≥5cm pada ketinggian paras dada telah dicamkan pada peringkat spesies. Ketinggian pokok dan SLA diukur manakala mod penyebaran dikenal pasti berdasarkan literatur. Data sekitaran dikutip pada waktu tengahari sebanyak tiga kali pada setiap plot. Dapatan kajian mendapati terdapat 96 spesies tumbuhan yang tergolong dalam 71 genera dan 42 famili dalam 12 plot. Kepelbagaian spesies ($r= -0.781$; $p= 0.003$), kekayaan species ($r= -0.842$; $p= 0.001$), dan kesamarataan species ($r= -0.901$; $p< 0.001$), menurun dengan signifikan apabila intensiti pembandaran meningkat. Bilangan spesies asli dan ketinggian tumbuhan berkurangan dengan peningkatan intensiti pembandaran. Sementara itu, bagi SLA, keputusan menunjukkan bahawa tidak terdapat hubungan yang signifikan antara SLA dan intensiti pembandaran. *Endo-zoochory*, *hemerochory*, dan *myrmechory* ialah mod penyebaran yang paling penting di kawasan bandar. Ketiga-tiga faktor persekitaran juga berkait secara signifikan dengan peningkatan intensiti pembandaran. Kesimpulannya, keadaan persekitaran adalah berbeza mengikut pembandaran dan pembandaran mengurangkan kepelbagaian tumbuhan. Walau bagaimanapun, ciri tumbuhan hanya sebahagiannya berkait dengan pembandaran. Dapatan daripada penyelidikan ini dapat membantu perancang bandar dalam mereka bentuk persekitaran bandar untuk mencapai pembangunan yang lebih mampan.

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LIST OF ABBREVIATION

APG	Angiosperms Phylogeny Group
FRIM	Forest Research Institute Malaysia
GIS	Geographical Information System
IPA	Important Plant Area
IUCN	International Union for Conservation of Nature Red List
IVi	Important Value Index
SDG	Sustainable Development Goals
SLA	Specific Leaf Area
UNHCR	United Nations High Commissioner for Refugees

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Urbanization is the process of becoming urban, the movement of people or processes to expand the urban areas. An urbanized society is a new and significant evolutionary stage for humanity since majority of the population lives in towns and cities (Hussain & Imitiyaz, 2018). In the next 40 years, urbanization is expected to increase to 65 percent of the global population (Ali, Bakhsh & Yasin, 2019). The advantages of urbanization appear to be numerous, including a better quality of life and more opportunities for social interaction (Zhao, Shi & Nu 2014). However, Petersen, Speed, Grøtan & Austrheim (2021) mentioned, urbanization may have substantial environmental repercussions. Urbanization also generates challenges for the environment such as shifting land-use patterns (Yang, Li & Lu, 2019a). Even more worrying is that a rapid urbanization process can cause significant ecological damage to the natural environment (Newbold et al. 2015; Trisos et al. 2020; Vellend et al.,

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2013). Therefore, one of the most serious concerns today is how to balance urbanization while maintaining biodiversity (Wigginton et al., 2016).

Urbanization has increased significantly in Malaysia, making it one of the world's most densely populated regions (Nabilla et al., 2019; Kanniah & Ho, 2017). Moreover, Malaysia's urban population increased from 70.91 percent to 77.2 percent between 2010 and 2021, as shown by figure 1.1. According to Trisos et al. (2020), urbanization and population increase devastate the natural environment to meet the needs of human population. In addition, the western half of Peninsular Malaysia has the most people living there because of the growth in the area (Bin, 2011). Examining the environmental impacts of urbanization towards our biodiversity, especially tropical plants is critical and urgent to give knowledge and recommendations for urban planning and policy development that can assist to prevent possible severe environmental ramifications (Delphin, Escobedo, Abd-Elrahman & Cropper 2016; Grimm et al., 2008; Li et al., 2017) since environment does affect plants survival (Petersen, Speed, Grøtan & Austrheim, 2021).

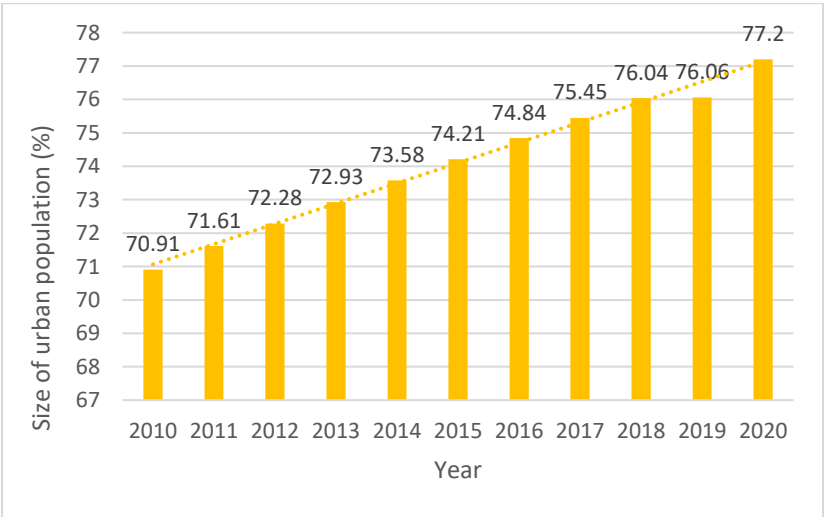

Figure 1.1. Percentage of urban population in Malaysia from 2010 until 2021. Source: World Bank, (2021)

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An important objective of the Sustainable Development Goals (SDG) is to promote sustainable cities and communities around the world (UNHCR, 2017). Moreover, the Malaysian government has implemented new policies and plans to promote sustainable urbanization and green growth (Twelfth Malaysia Plan, 2021). Thus, Malaysian industry development must be guided towards sustainable urbanization (Mitchell Gelber et al., 2019). Prime Minister has stated that a green development agenda will be prioritized in Malaysia Twelfth Plan (2021), therefore, environmental sustainability is an important consideration in the country's growth plans. A more comprehensive strategy will be undertaken with the involvement of the commercial sector, civil society organizations, and the public. This strategy will be able to mitigate the effects of urbanization-related climate change while also conserving the country's biodiversity assets for present and future generations.

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Urbanization is still necessary to enhance the quality of life, but this endeavor will be difficult to complete due to environmental changes as urbanization grows (Petersen, Speed, Grøtan & Austrheim, 2021). Therefore, this study aims to examine how biodiversity vary along the urbanization gradient by using plants as the model organisms. Plants play a critical role in maintaining the environments however, warmer temperatures, low air humidity and increasing light intensity, will impact plant productivity (Hatfield & Prueger, 2015; Szymańska, Ślesak, Orzechowska & Kruk, 2017). Due to their incapacity to withstand extreme conditions, plants will eventually become extinct. A plant's functional traits are the characteristics of an organism that are deemed important in determining how well it responds to the environment (Díaz & Cabido, 2001). This is because, the functional qualities of organisms that allow plants to adapt to a changing environment, as well as the factors driving the success of

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different species in different environments (Funk et al., 2017; Schroeder-Georgi et al., 2016). Changing environmental conditions, such as those caused by urbanization, will frequently be mitigated by selecting plants that have specific traits (Song et al., 2019; Zirbel et al., 2017). Furthermore, three traits (plant height, SLA, and dispersal mode) can be used to forecast how plant establishment, persistence, and dispersal affect the distribution and abundance of a plant, hence these factors were influence the diversity of plants (Zirbel et al., 2017; Weiher et al., 1999). It would also be beneficial to analyzes the traits associated with plants' tolerance to environmental change in order to uncover plant ecological approaches and plant adaptations to urbanization.

Pattern analysis of plant diversity is essential to study for maintaining vegetation (Zisadza-Gandiwa et al., 2013). In Malaysia, urbanization's impact on plant diversity has been studied mostly in urban settings, even though different levels of urbanization may have varied effects on local biodiversity. The impacts of urbanization on biodiversity can be explored most effectively through investigations along the urbanization gradients (Donihue & Lambert, 2015; Johnson et al., 2015; McDonnell et al., 1997; McKinney, 2002), this is because the spatial change in environmental factors along the gradient may replicate temporal variations in these scenarios (Cochard et al., 2019). Moreover, study along the urbanization gradient allows for comparisons across studies, irrespective of exact species composition. Previous research also used the urbanization gradient approach to examine how human-induced environmental changes affect the plant diversity along the urbanization gradient (McDonnell et al., 2008; Vakhlamova et al., 2014; Wang et al., 2020b). Therefore, the percentage of the built-up area was used in this study to define an urbanization gradient.

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To produce an urbanization gradient, Geographic Information System (GIS) was utilized to quantify the percentage of built-up area. Thus, four main types of urbanization gradient (urban, suburban, rural, and wild land), were identified based on Marzluff et al. (2001). Modern GIS with image processing scanning and simulation technologies were principally used in the inquiry to keep tabs on urban growth (Mansour et al., 2020; Singh et al., 2015). Therefore, a clear image of how to control urban sprawl while promoting sustainable urban expansion and proper land management can be gained from such studies (Mansour et al., 2020). Thus, as urbanization increase, this study's findings may help better comprehend plant diversity along the urbanization gradient (Yang et al., 2021), in determining conservation and management priorities for the future (Li et al., 2020b). An additional benefit of this research is that it aligns with the goal of sustainable urbanization in the Twelfth Malaysia Plan (2021).

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1.2 Problem Statement

Within three decades, Malaysia's population is predicted to increase, which is more than 20% greater than global norms (New Straits Times, 2018). Marzuki and Jais (2020) found that, due to the rapid growth of this heavily populated area, urban sprawl has exceeded municipal boundaries and occupied significant land areas while also lowering natural areas and food security. Combined with habitat depletion and fragmentation (Aronson et al., 2014; Cheng et al., 2019; Wang et al., 2020b), urbanization exacerbates and intensifies the reduction of habitat quality (Li et al., 2020b) hence allowing only a few plant species to survive and favoring specific plant species to colonize the region

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(Petersen, Speed, Grøtan & Austrheim, 2021) because of environmental changes (Reshi et al., 2020). As a result of this rising awareness, research on urban biodiversity has arisen in Malaysia recently.

According to previous studies, the influence of urbanization on plant diversity has produced uneven and conflicting results. Even though urbanization is predicted to affect plant diversity production (Aronson et al., 2015; Wang et al., 2009) yet plant diversity patterns vary significantly from study to study (Wang et al., 2020b). However, only a few research have employed a defined definition to determine the urbanization gradient, which will make it tough to distinguish data from other studies and derive broad implications. Hence, more significant research on how plant diversity responds to urbanization is necessary especially in tropical region (Thaweepworadej & Evans, 2022).

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Previous literature does document and assess the changes in plant diversity along a transect from the city center to the outskirts or endeavoring to identify the patterns of plant species diversity relative to the "distance from urban center" (Dallimer et al., 2012b; McDonnell et al., 2008; Vakhlamova et al., 2014) or access road across metropolitan centers (Tian et al., 2015; Zhang et al., 2016). Referring to Li et al. (2020a), the single-factor effect intensities of distance from the city centre were the weakest, and the association between "distance from city centre" method and plant species diversity is not consistent across landscapes, therefore mixed results are obtained. Most of this research used a range of wide urbanization measures and criteria. However, future improvements in the field will necessitate establishing some broad standardized measures to make comparisons easier hence, it is necessary to fill in this gap of current acknowledgment so that all the fields can attain their maximum potential.

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In Malaysia, a study by Rahmad & Akomolafe (2018), investigated the impact of urban development on tropical plants; however, the study used visual observation and perception to categorize the study sites which can lead to biased result. Meanwhile, Kanniah (2017a), Kanniah & Ho (2017b) and Nabilla et al. (2019) does study the impact of urbanization on green areas; however, the research only focuses on densely populated urban areas such as Kuala Lumpur, Malaysia. Different levels of urbanization may have distinct effects on local biodiversity and the urbanization gradient may be a valuable measure for analyzing such alterations (Donihue & Lambert, 2015; Johnson et al., 2015; McDonnell et al., 1997; McKinney, 2002). The knowledge of how different urban settings influence biodiversity is still scarce in this country; hence, this assessment aims to investigate the pattern of plant diversity along an urbanization gradient. Additionally, according to Wang et al. (2020b), the essential urbanization metric is the percentage of urban dwellers or proportion of urban land use, reflecting the amount of impermeable surface area. Therefore, in this study, spatial modelling and simulation were employed to answer the research questions, together with an analytical procedure using a Geographic Information System (GIS).

Analyzing plant traits along an urbanization gradient could reveal plant ecological strategies and reactions to urbanization (Song et al., 2019; Petersen, Speed, Grøtan & Austrheim, 2021). hence, a study of plant response will be quite beneficial (Williams et al., 2015). In addition, environmental changes may facilitate the selection of plant species with specific traits that will enable them to thrive in new habitats, and these traits will also serve as indicators of plant responses towards environmental changes (Liu & Ma, 2015). Considering that urbanization is expected to act as a filter for plant species with different functional traits (Petersen, Speed, Grøtan & Austrheim,

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2021), an assessment of plant traits would be advantageous to learn more about and comprehend what plants are doing in response to urbanization since this study remains unexplored (Song et al., 2019). Since urbanization does cause environmental changes (Petersen, Speed, Grøtan & Austrheim, 2021). Therefore, three factors were chosen which are ambient temperature, air humidity and light intensity. This is because, these three factors do affect the plant diversity and the development of plants (Hatfield & Prueger, 2015; Szymańska, Ślesak, Orzechowska & Kruk, 2017; Tito et al., 2020)

In order to ensure that biodiversity is conserved despite rising urbanization, it is necessary to understand plant diversity and how plants adapt to their surroundings; therefore, the south of Perak was chosen because it has the potential to develop into a "regional city," with Ipoh serving as the regional capital (van Grunsven & Benson, 2020). Hosni et al. (2020) revealed that in Ipoh, Perak, the development, and construction area has expanded by 157.12 hectares. Ipoh is an excellent location for investigating the impacts of urbanization on plant diversity since Ipoh also known as phytogeography ally unique area as mentioned by Wong (1998) and Ashton (1992). Therefore, this study aimed to assess the diversity of plants, examine the plant functional traits, and evaluate environmental factors along an urbanization gradient.

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1.3 Research Questions

This study was carried out based on the questions below:

1. How plant species diversity changes along an urbanization gradient in Ipoh, Perak?

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2. What is the relationship between plant traits to the urbanization gradient in Ipoh, Perak?

3. What is the relationship between environmental conditions to the urbanization gradient in Ipoh, Perak?

1.4 Research Objectives

This study covers three main objectives:

1. To investigate the changes plant species diversity along the urbanization gradient in Ipoh, Perak

2. To analyze the relationship between plant traits and urbanization gradient in Ipoh, Perak.

3. To determine the relationship between environmental conditions and urbanization gradient in Ipoh, Perak.

1.5 Research Hypotheses

1. There is a significant trend of plant species diversity along an urbanization gradient in Ipoh, Perak.

2. There is a significant relationship between the urbanization gradient in Ipoh, Perak, and plant traits.

3. There is a significant relationship between the urbanization gradient in Ipoh, Perak, and environmental conditions.

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1.6 Research Significance

Malaysia has experienced substantial urban population expansion and the construction of numerous skyscrapers during the last few decades (Kanniah and Ho, 2017). Increased human population and urbanization, on the other hand, demolish the natural landscape (Trisos et al., 2020) in an attempt to reach the ever-increasing needs and provide a more comfortable life for the human population. Therefore, investigating the adverse effects of urbanization is vital and urgent to give awareness and recommendations for town planning and policy development to alleviate their potential adverse environmental repercussions (Delphin, Escobedo, Abd-Elrahman & Cropper 2016; Grimm et al., 2008; Li et al., 2017). Despite Malaysia's rapid urbanization, we still need to be concerned regarding our environmental resources, and thereby, this research aims to meet human needs while sustaining the ecosystems. Alternatively, this type of research is critical because it will enhance our perception of urbanization.

Considering plants are necessary for various ecological systems and processes, they must be adequately maintained and protected. Furthermore, species diversity research is an integral part of strategic urban planning (Li et al., 2020b). An earlier study on the influence of urbanization on plant diversity, on the other hand, produced inconclusive and contradictory results. Despite the fact that urbanization is projected to have a negative impact on plant diversity (Aronson et al., 2015; Wang et al., 2009) yet plant diversity patterns differ significantly between study to study, leaving plant diversity explorations and the association involving urbanization gradient and plant diversity unclear and questionable (Wang et al., 2020b). On that account, there is still a need to research how tropical plant species respond to urbanization, especially given

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the region's fast urbanization, as this research is still scarce in our country. This research may also contribute to a better knowledge of plant diversity and its relationship to human activities and serve as a guide for urban development in this country.

Other than that, the information generated may support the city planners and administrators by provide holistic understanding of the species composition and abundance for a further selection of adaptive species and vegetation management practices to conserve the existing green space and contribute towards sustainable urban planning. Moreover, this study might help as a guideline for adoption of green element in urban development, and it aligns with the goal of sustainable urbanization in the 12th Malaysia Plan (2021) and Sustainable Development Goals (SDGs). For each city, may also develop a detailed green corridor plan. This is because there are still habitats and travel routes for the various bird and animal species that live there. Moreover, to prevent from species extinct especially native. In addition, for high-rise structures like multi-story buildings, apartments, or condominiums, regulations are enforced to require planners to offer a fixed percentage of green space. Last but not least, planting fit and well-chosen plants, particularly native ones, in urban settings. To summarize, more buildings and infrastructure will be built in the coming years. By collaborating with those who will design the areas where humans live, ecologists can help modify and develop locations where urbanization occurs while lowering threats to plant diversity.

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1.7 Scope of Study

Recent studies have discovered a complex set of filters that are believed to affect tree species diversity changes as urbanization rises (Walker et al., 2009; Williams et al., 2009). Despite the extreme consequences of urbanization, scientists have been driven to elucidate better the context whereby urban environments affect species diversity, which has resulted in substantial growth in the number of urban ecological research.

As a result of this growing awareness, research on urban biodiversity has developed in Malaysia in recent years. However, only a few research have employed defined criteria to determine the urbanization gradient of study sites. The inconsistency of biodiversity patterns along the urbanization gradient could be due to a lack of clarity in the characterization of distinct urban contexts. This could lead to communication issues and make it difficult to draw broad conclusions from several investigations. In addition, most of this research focused on biodiversity trends in densely urbanized areas (Kanniah, 2017; Nabilla et al., 2019) regardless of the fact that the along urbanization gradient might well have different consequences on local biodiversity.

In this study, the urbanization gradient was quantified using the ArcGIS software and the Ipoh land use map issued by Malaysia's Federal Department of Town and Country Planning. In addition, GIS is advanced software that can be utilized for investigating the implication of urbanization on the environment since GIS software can generate spatiotemporal information of both human settlement and natural environments (Herold et al., 2003; Serra et al., 2008). Moreover, the most fundamental urbanization metric is the percentage of urban land use, which also reflects the impervious surface area (Wang et al., 2020a).

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This research is focused on plant diversity, functional traits, and environmental factors as they change along an urbanization gradient. Plant traits concepts are also beneficial for assessing community formation and ecological processes during rehabilitation (Zirbel et al., 2017); therefore, three plant traits were chosen as coverage of this study on plant functional traits, namely, plant height, specific leaf area (SLA), and dispersal mode. The functional traits of identified species from sampling locations were quantified using a standardized method by Cornelissen et al. (2003) and Pérez-Harguindeguy et al. (2013), (2016). Moreover, the fact that environment has an impact on plant distribution and abundance; hence, environmental variables were also included in this study (Weiher et al., 1999), and the most significant feature of experimental research is the ability to monitor changes in biotic interactions and their effects (Tito et al., 2018). However, this study only focused on ambient temperature, air humidity, and light intensity to investigate their impact on plant diversity along an urbanization gradient.

Present study area is covered in Ipoh, Perak since it serves as the primary urban centre (van Grunsven & Benson, 2020). Based on Masron et al. (2012), the preponderance of cities in Peninsular Malaysia are concentrated in the West Coast states, and the development core has changed significantly between 1957 and 2000. Ipoh also is a good location for exploring the effects of urbanization on plant diversity. This is due to the fact that Ipoh is a phytogeography unique place with a diversity element of plants. The unique elements of flora and rapid urbanization that occur in Ipoh currently hence it making Ipoh is an excellent place to study the impact of urbanization on plants diversity. In conclusion, this study will offer conservation techniques to recoup future biodiversity loss and a new framework for sustainable urban

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planning for Malaysian cities. Due to the rapid urbanization in this country, more buildings and infrastructure will be built within the next several years. Therefore, this kind of study may contribute and improve city planning ideas in this country while minimizing the threat and damage to the flora by engaging with those who construct and design the urban areas. Such efforts and actions will improve biodiversity prospects even though urbanization still keeps developing as it is crucial in comforting people's lives.

1.8 Limitation of Research

This study has potential limitation. Ipoh, Perak, is the only location where this research was conducted. Ipoh does have quite distinct characteristics of plant compared to other areas in Malaysia. For example, Wong (1998) mentioned that Ipoh was covered with limestone floras, and only selected areas in Malaysia that also consists of limestone flora. Ipoh also high with endemic species. Moreover, in this study, only 40 subplots were selected as a study area. Yang, Lam & Su, (2019b) said that to assess plant diversity, a rectangular plot of 0.05-0.1 ha is recommended for the research project location to obtain the plant sample. Hence, this study's overall sample area is 0.1 ha, and it is still within the range of aspect ratios specified by Yang, Lam & Su (2019b). Despite that, this research has potential limitations since this study only covered in Ipoh area; therefore, it is impractical to extrapolate the research findings to the entirety of Malaysia.

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Another limitation for this study is distance factor. Distance between plot was inevitable. As an example, for this study, the urban plot and suburban plot are somewhat quite near to one another in distance. By using the land use map of Ipoh, Perak, and Geographical Information System (GIS) software, we managed to view the plot for the whole Ipoh. Hence, the selection of study plot was done randomly. However, there are few problems arises once we went to the study plot. Amongst some of the issues that developed are, few of the plot study was restricted from any visitors, and some of the plot that is covered by a huge, electrified fence. Due to this, we decided to change the plots. As a result, the research plot used in this project is the most reliable.

Another limitation in this study is, for objective two, we select dispersal mode in order to study the dispersal mechanism for every species that found in the study area. However, to determine the dispersal mode of each species, literature review from past studies were used instead of making site observation. Different literature review coming from different countries and other region; hence it does not represent the dispersal types for our species especially from tropical regions.

In this study also stated hypotheses suggested to explain the effect of urbanization on plant height. The ideas for hypotheses 1 and 2 came from studies in the temperate region. In order to test the hypotheses in the context of tropical region, further experiments are required using the plant species found in the current research. However, this is not part of the scope of this study. Therefore, such studies have been included the suggestions for future studies.

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In conclusion, the findings of this study are only reliable for the conditions and parameters discussed above; it is an observational study (simply to study the pattern) and not to explore too deeply into the underlying causes of plant height, SLA, and dispersal mode. As a result, the empirical findings presented should be viewed with some limitations in consideration, which may be addressed in future studies.

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