Effects of Green Spaces on Urban Microclimate in Residential Areas in Hot and humid Climates

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Specially dedicated to

God and my Family

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ABSTRACT

Urbanization diminishes and fragments green spaces. Thus, it contributes to the degradation of the environment. Urbanization also contributes to the creation of urban heat islands. Housing schemes should have green spaces that are capable of mitigating urban heat islands. Nowadays, a terraced housing neighbourhood is the major type of housing scheme in Malaysia. However, the measurable influence of green spaces is hard to quantify. The aim of the research is to quantify the cooling effects of urban green spaces in a residential area in a tropical region. In consideration of a location, layout, landscape component and built year, Bukit Indah, Johor is chosen as a study area. The study focuses on the layout, land use coverage ratio, and cooling intensity of green spaces by using the three-dimensional microclimate model ENVI-met. A review of the literature in this field identified basic information about urban heat islands and mitigation methods and tools. Three focus areas with a dimension of 240 x 240 metre are chosen for detail comparison analysis in a neighbourhood scale within the study area. Those three areas contain different types of green space layout and coverage ratio, specifically, neighbourhood park, play field, play lot, recreational yard, and road side plantings as a parameter. Through the comparative study based on the different combination of parameters, it is concluded that urban green spaces in the study area mitigate urban heat islands by 1°C. In this case, a better cooling effect is found with interconnected green spaces, and terraced housing blocks should be aligned parallel with the prevailing wind. This is because the cooling effectiveness is limited beyond the boundary of the green spaces but the wind can cool the area approximately 1°C. The result can contribute to zoning, building and landscape law where urban planners, architects, and landscape architects use climatological data as a basis for landscape design in a residential area.

ABSTRAK

Urbanisasi mengurangkan kawasan hijau dan menyebabkan perpecahan susunan kawasan hijau. Malah, urbanisasi menyumbang kepada penurunan kualiti alam sekitar, lantasan ia juga menyumbang kepada pulau haba. Kini, perumahan teres merupakan skim perumahan yang utama di Malaysia. Di setiap perumahan ini terdapat kawasan hijau yang berupaya mengatasi masalah pulau haba. Namun begitu, penilaian kesan kawasan hijau ini sukar dikira. Tujuan kajian ini ialah mengkaji kesan penyejukan kawasan hijau di kawasan tropika khususnya di perumahan Bukit Indah, Johor. Dengan mengambil kira lokasi, susun atur perumahan, komponen landskap dan tahun dibina, maka Bukit Indah, Johor dipilih sebagai lokasi kajian. Kajian dilakukan dari segi susun atur kawasan hijau, nisbah permukaan dan intensiti penyejukan kawasan hijau menggunakan ENVI-met yang merupakan model mikro iklim tiga dimensi. Sorotan kajian telah dilakukan untuk mendalami ilmu pulau haba dan cara mitigasinya. Tiga kawasan tumpuan yang berdimensi 240 x 240 meter telah dipilih untuk perbandingan analisis secara terperinci dengan skala kejiranan. Ketiga-tiga kawasan mempunyai kawasan hijau dan nisbah permukaan yang berlainan seperti taman kejiranan, padang permainan, lot permainan, laman rekreasi dan ruang tepi jalan sebagai parameter. Untuk mencapai matlamat kajian, maka perbincangan tentang suhu, kelembapan relatif dan kelajuan angin dilakukan. Kesimpulannya kawasan hijau di perumahan teres boleh mengurangkan suhu pulau haba sebanyak 1°C di kawasan kajian. Didapati bahawa kawasan perumahan dengan kawasan hijau yang bersambungan adalah lebih baik, di mana kesan penyejukannya dan blok perumahan direka selari dengan arah angin utama. Ini disebabkan keberkesanan penyejukan kawasan hijau adalah terhad selepas sempadan kawasan hijau, di mana kawasan hijau tersebut mempunyai suhu sekata iaitu 1°C. Hasil kajian ini boleh digunakan sebagai panduan untuk perancang bandar, arkitek dan arkitek landskap untuk membuat akta-akta berkaitan dengan pengezonan, bangunan dan landskap di mana penggunaan maklumat klimatologi dititikberatkan. Maka, kajian terperinci tentang kesan jenis dan taburan kawasan hijau perlu dilakukan pada masa depan.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia is located between 1° and 7° north of the equator and between 100° and 119° east (Sani, 1998). Malaysia is a tropical country with warm-humid equatorial climate, and the average air temperature is between 22°C and 32°C (Abdullah, 1994). The growth of urban zones is reducing the natural areas and fragmenting the green spaces, leading to the degradation of the environment. Malaysia has a fast rate of development, which seems to forget the fundamental needs of human thermal comfort especially in the context of housing development. The current problem of housing in Malaysia is the lack of attention to the climatic sensitivity, which has become an issue in building design and urban planning (Givoni, 1998; Chen and Ng, 2011).

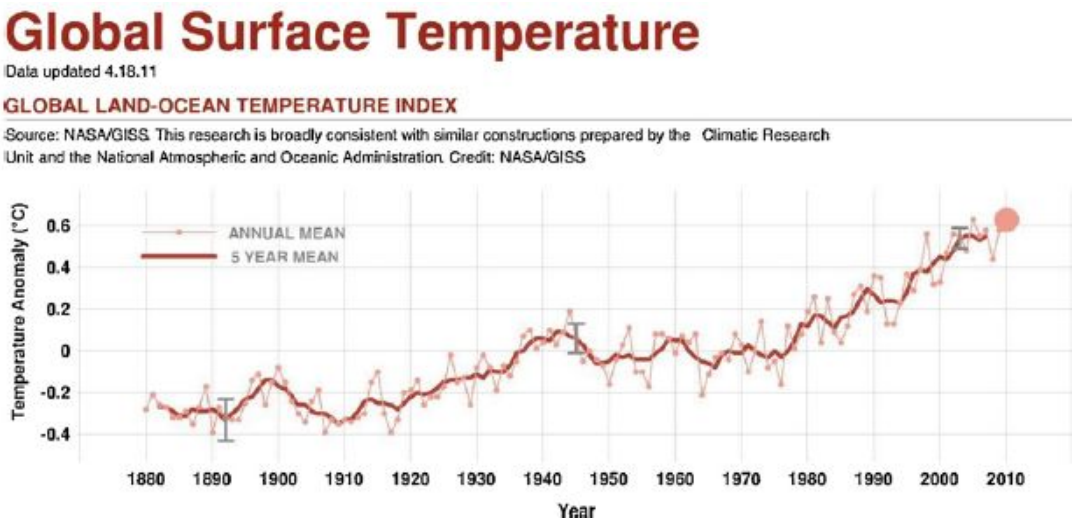

Figure 1.1: Global temperature variation (Vijaya Venkata Raman et al. 2012)

As shown in Figure 1.0, global warming has occurred since the 1880s, but the warmest years have occurred in the past 30 years (Vijaya Venkata Raman et al. 2012). It is important to use climatic information as a design basis because there is still a lack of any application of climatic knowledge in land use and urban planning (Oke 1988; Eliasson 2000). As stated by Yeang (2006), it is important to research the climatic characteristics of the site. Since the 1980s, the role of green spaces and vegetation in cities has been understood, but the beneficial climatic effect of taking into account issues such as the urban climate and green spaces during urban planning has been overlooked (Mathey et al. 2011). Bruse and Fleer (1998) posited the importance of computer simulation to study the climate in urban design. Saito et al.'s (2010) research showed the necessity of a research focus on the relationship between design methods and the natural physical environment of outdoor spaces on a micro-scale in tropical countries. However, it is important to rethink the existing terraced house planning that uses landscape resources to optimize the quality of the living environment.

The lack of detailed information about the benefits of vegetation as a mitigation method is currently preventing the green infrastructure approach from progressing (Mathey et al. 2011). For example, cooling effects are exceptionally high in large parks or areas of woodland, but combining the patches of green space into an interconnected green infrastructure means the impact of cooling will be much greater, and it also functions recreationally, ecologically and socially. As Memon et

al. (2008) commented, there is a need to develop a method to solve urban heat islands using design and planning parameters.

Therefore, knowing the relationship between the microclimate and green spaces means that the types of green space that can mitigate urban heat island can be identified. The method was tested in a computerized simulation using a GIS-based climatic mapping system to facilitate the planning process (Wong and Jusuf, 2008).

This chapter will explain the contents of this research. Firstly, section 1.1 introduces this study while section 1.2 is a discussion of the problems as it is crucial to understand the problem before doing the research to find a solution. Section 1.3 presents the research aims and objectives that guide this research. The hypothesis of this research is given in section 1.4. In order to understand the research method, section 1.5 discusses the research scope and limitation. Meanwhile, section 1.6 considers the research methodology, and section 1.7 discusses the significance of the research. Finally, section 1.8 provides a summary of this chapter.

1.2 Problem Statement

Urbanization in tropical countries has been increasing significantly in the past 60 years; the rapid urbanization has caused changes in the climate, for example, urban heat islands (Yu and Hien, 2006). Indeed, the temperature in the urban area of Singapore has increased by 1°C (Wong and Chen, 2009). Thus, these higher temperatures are causing air and water pollution (Yu and Hien, 2006). Heat affects human health, and as Grimmond et al. (2010) pointed out, in the future, a warmer climate will lead to a dramatic increase in heat-related deaths. Urban heat islands also can affect the living environment, increase energy consumption, and create a chain reaction of effects on the environment and the economy (Memon et al. 2008).

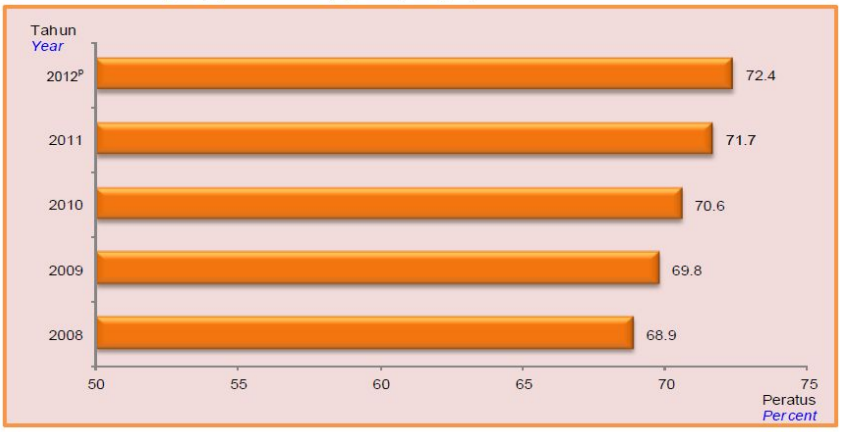

Figure 1.2: Proportion of urban population in Malaysia as percentages, 2008-2012 (Department of Statistics Malaysia, 2013)

As the table shows, the urban population in Malaysia has increased from 71.7% in 2011 to 72.4% in 2012. This situation will lead to an increase in the number of urban neighbourhoods, which in turn, will affect the temperature. Figure 1.3 shows that (Kubota and Ossen, 2009) found that the urban-rural temperature difference can be as much as 2°C due to the effects of anthropogenic heat. They also found that relatively large green areas scattered in between the built-up areas have the potential to lower the air temperature. Thus, there is the need to explore the temperature reduction effects caused by green areas (Kubota et al. 2005).

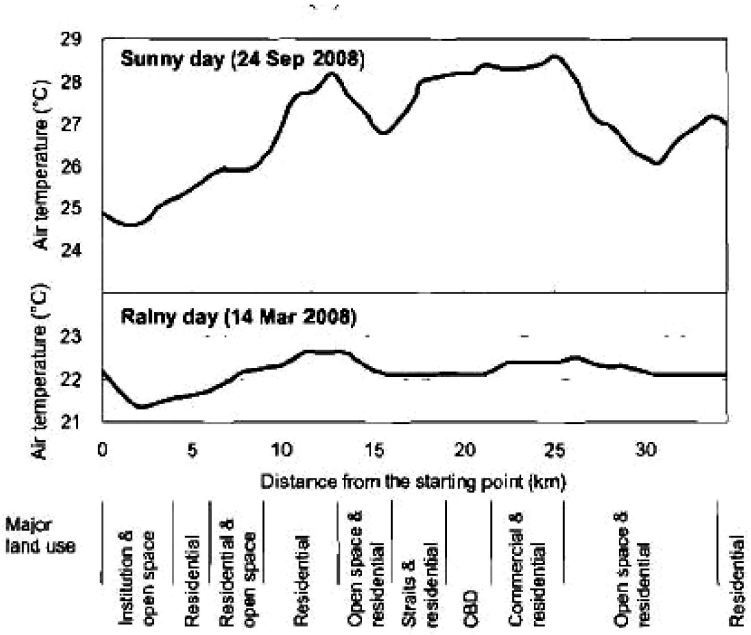

Figure 1.3: Urban-rural temperature differences due to different land use (Kubota and Ossen, 2009)

Cities in Southeast Asia experience a hot and humid climate all year round. Hence, urban heat islands in this region would cause a significant increase in urban energy consumption (Kubota and Ossen, 2009).

However, there is some doubt regarding how a park can affect the urban heat island phenomenon as it is posited that the cooling effect depends on the size of the park and the seasonal radiation condition. In addition, there no linear relationship has been identified between the size of the park and the intensity of the cooling effectiveness (Gago et al. 2013). According to Gago et al. (2013), various measures can be applied to mitigate the heat island effect; however, success depends on a broad range of factors, some of which can be incorporated into planning strategies, while others are outside the scope of the use and geometry of spaces.

Grimmond et al. (2010) reported there must be some data requirement to allow the translation of research findings to urban guidelines in different climate zones and different classes of urban land use. Wong and Chen (2009) and Rohinton (2005) stated that urban planners try to incorporate the knowledge of urban morphology and urban microclimatology into their plans, but there is a knowledge gap in climate sensitive design, especially in tropical urban design. The urban climatic map is a tool to give information and evaluate urban climatic factors in planning by creating climatic phenomena and problems translated into a two-dimensional spatial map (Ren et al. 2011). In a recent study by Seto and Shepherd (2009), regional land-use and land-use change shows that it is spatially correlated with urban heat islands. Ng et al. (2011) stated there must be a detailed investigation into the positioning and grouping of tree plantings in a microclimate neighbourhood setting. Particularly relevant to this research, Saito et al. (2011) confirmed that terraced housing developments in Malaysia have neglected the local environment aspect; they found out that the wind velocity in areas of terraced housing is lower than in areas of detached housing, where it is below 0.6m/s; this means that terraced housing is hotter than detached housing. However, there is still a lack of research into the quantitative analysis, and the assessment of outdoor environment and the effectiveness of greenery to reduce the temperature of micro-neighbourhoods using GIS and computerized simulation in South East Asia.

Southeast Asia needs planning and action to mitigate and tackle global warming (Kubota et al. 2005). Wong and Yu (2009) found out that vegetation cover is the best way to mitigate urban heat islands; however, as stated by Saito et al. (2011), greenery has still not been considered as an effective mitigation method in terraced housing. Mathey et al. (2011) posited that the distribution, connection, and dimensions of urban vegetation structure types can vary in urban green space systems, but that this topic is still to be investigated. To solve the problem, one recommendation is the integration of space in areas of housing using green spaces to improve the situation so that people can benefit from a healthy living environment in terms of mitigating the temperature.

The environmental regulatory bodies have come up with more specific guidelines so that the projects will not lead to an overall excessive increase in outdoor temperatures (Tso, 1996). However, most of current policies, strategies, and regulations are barriers to "green" design and green management practices so they should be removed or updated to encourage creativity and the implementation of sustainable practices (Hostetler et al. 2011). In this case, graphics are used to present practical information to show the outcome and so increase the chance of fostering mutual understanding among communities and planners (Kleerekoper et al. 2011).

1.3 Research Question

The following are the research questions of this study:

i. How much does the microclimate environment differ in terms of air temperature, relative humidity, and wind speed after combination modification has been made?
ii. How will the layout affect the cooling effectiveness in neighbourhood areas?
iii. How can ground surface's albedo and types be modified and combined to promote a significant optimum cooling effect?

1.4 Hypothesis

The hypothesis of this research is that green spaces can mitigate urban heat islands

I. different layouts and different coverage ratios of green spaces can mitigate the effects of urban heat islands.

II. ground surface's albedo and types can be modified and combined to promote a significant optimum cooling effect.

1.5 Research Objectives

The study aims to identify the green space characteristics in Malaysia's terraced neighbourhood area that can best mitigate the microclimate. Thus, the research aims are as follows:

1. to identify different types of urban heat island mitigation methods

2. to understand the characteristic of green spaces in terraced housing areas in mitigating urban heat islands on a local scale

3. to assess the cooling effectiveness of different urban green spaces in neighbourhood areas in Malaysia by examining the green space layout, the land use coverage ratio, and the cooling intensity of green spaces by using the three-dimensional microclimate model ENVI-met.

1.6 Research Scope and Limitations

This research focuses on green spaces in hot and humid neighbourhood areas in Malaysia. The assessment of the simulation result is analyzed during the daytime according to the atmospheric temperature, relative humidity, and wind speed. These parameters will depend on the green spaces characteristic, that is, size of green space,

land use type, and the layout and distribution of green space. The characteristics of green spaces focus only on the shape and type of coverage. However, this study excludes the thermal comfort level of human; subsequently, this study examines only the cooling intensity of green spaces.

A limitation of this research is that ENVI-met software does not support an undulating surface; thus, it is assumed that the topography is flat. The topography is excluded because, as Oke (2006) stated the simulation is assumes as typical spatial form of urban climate distributions.

Furthermore, the plant database is based on plantings suitable to temperate countries; however, the selection of the plants is made in accordance with the similarity to tropical plants. Furthermore, the details of how to solve this limitation will be discussed in Chapter 3.

1.7 Research Methodology

In order to test the hypotheses, the research will explore the use of green spaces (independent variable) as a way to mitigate the microclimate (dependent variable) in a terraced housing environment. There are several stages to the research:

1. definition and identification of green spaces

2. synthesis of criteria for characteristics of green spaces that can mitigate the microclimate of terraced housing environment

3. site surveys and data collection

4. mapping and simulation of green spaces in terraced housing environment

5. documentation of findings of the green spaces that enhance the terraced housing environment

The simulation incorporates urban green spaces and built-up areas. This makes it possible to specify the entire vegetation inventory of the city in both quantitative and qualitative terms. Thus, based on these detailed data, various methods of climate modelling can be adopted to determine and describe the climatic regulatory effects of single types of urban vegetation structure (Bruse and Fleer, 1998; Manthey, 2011).

1.8 Significance of Research

The findings can be viewed as forming a basis for a framework for spatial planning and for comfortable and better cooling effectiveness for terraced housing environments using green space in Malaysia. This framework can be used in the planning process by town planners, landscape architects, or architect. Subsequently, the expected findings can mitigate the effects of urban heat islands on a local scale.

1.9 Summary

However, it will be interesting to provide a quantitative assessment of green spaces to determine and select the most promising method for the implementation of urban design and planning decisions. As McPherson (1994) stated, designers are questioning where and how to manage vegetation in parks, streets, and residential areas to improve climate change.

The controllable factors are the design and planning as these can be controlled by humans to a significant extent; meanwhile, the uncontrollable factors are environmental and nature- related, and these are beyond human control (Memon et al. 2008).

The study will provide a framework for the use of green spaces in terraced housing areas in a tropical climate. This framework can be used as a reference in other places but consideration must be taken of the local microclimate and the simulation must be redeveloped to give a result that is authentic to the site and suitable to the locality. The next chapter discusses the literature review as a basis for this study.

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