UNIVERSITI PUTRA MALAYSIA

MICROCLIMATE MODELLING OF MESUA FERREA L., MIMUSOPS ELENGI L. AND PHELTOPHORUM PTEROCARPUM (DC) K. HEYNE IN UNIVERSITI PUTRA MALAYSIA

MAH CHEN YING

FRSB 2014 20

MICROCLIMATE MODELLING OF MESUA FERREA L., MIMUSOPS ELENGI L. AND PHELTOPHORUM PTEROCARPUM (DC) K. HEYNE IN UNIVERSITI PUTRA MALAYSIA

By

MAH CHEN YING

DOCTOR OF PHILOSOPHY

UNIVERSITI PUTRA MALAYSIA

2014

MICROCLIMATE MODELLING OF MESUA FERREA L., MIMUSOPS ELENGI L. AND PHELTOPHORUM PTEROCARPUM (DC) K. HEYNE IN UNIVERSITI PUTRA MALAYSIA

By

MAH CHEN YING

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

2014

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

MICROCLIMATE MODELLING OF MESUA FERREA L., MIMUSOPS ELENGI L. AND PHELTOPHORUM PTEROCARPUM (DC) K. HEYNE IN UNIVERSITI PUTRA MALAYSIA

By

MAH CHEN YING

2014

Chairman: Associate Professor Noorizan Mohamed PhD
Faculty: Design and Architecture

The Urban Heat Island Effect is a common topic in research literature and newspapers nowadays. The aim of this study is to identify and evaluate the conditions of isolated landscape tree towards microclimate as compared to the open space without tree, as well as the comparison of microclimate under three various popular landscape trees, namely: *Peltophorum pterocarpum* (umbrella form), *Mimusops elengi* (round form), *Mesua ferrea* (conical form). Two sets of watch dog 2000 weather stations are used to collect the solar radiation, air temperature and relative humidity. One set is placed under the tree, another set is placed in the open space without tree. An AccurPAR LP80 is used to collect Leaf Area Index data. The study site is at University Putra Malaysia. The data analysis was conducted using R software (The R Foundation Statistical Computing) and Minitab statistical software. The research hypothesis is to study the microclimate conditions under tree species. The findings reveal that the tree species has a great reduction on solar radiation under tree canopy as compared to open space without tree. The solar radiation for *Mimusops elengi* (reduction 95.55%) is the lowest amongst the three species, *Mesua ferrea* ranked second, *Peltophorum pterocarpum* is third. However, the air temperature and relative humidity have no significantly different effects in ststisticsas compared to open space without tree, but the air temperature has slightly lower and relative humidity has a slight increment under tree canopy. The hypotensis testing

develops the microclimate model which can be used as a tool for predicting the curve and estimating the percentage of decrement or increment of microclimate under the tree species. The trees with an umbrella form and round form are able to provide bigger shade compared to *Mesua ferrea* which has a conical form. The shade is able to intercept sunlight and diminish the solar radiation which affects the comfort of humans. Therfore, the size of canopy area is very important to influence urban heat island effect. The results from this study suggest that the selection of appropriate urban trees by the planners and landscape architects to ameliorate the Urban Heat Island effect in the design approach should also consider the tree species, which can provide bigger shade and higher Leaf Area Index.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doctor of Philosophy

PEMODELAN MIKROCLIMATE BAGI MESUA FERREA L., MIMUSOPS ELENGI L. AND PHELTOPHORUM PTEROCARPUM (DC) K. HEYNE DALAM UNIVERSITI PUTRA MALAYSIA

Oleh

MAH CHEN YING

2014

Chairman: Associate Professor Dr.Noorizan
Faculty: Design and Architecture

Kesan Pulau Haba Bandar (Urban Heat Island Effect) ialah isu yang umum dalam kertas penyelidikan dan akhbar. Tujuan kajian ini adalah untuk mengenal pasti dan menilai prestasi pokok lanskap terhadap cuaca berbanding dengan kawasan terbuka tanpa pokok, Tiga spesis pokok lanskap yang popular telah digunakan iaitu: *Peltophorum pterocarpum* (bentuk payung), *Mimusops elengi* (bentuk bulat) dan *Mesua ferrea* (bentuk kon). 2 set Watchdog 2000 Weather Station digunakan untuk merekod sinaran solar, suhu dan kelembapan udara dengan 1 set diletak di bawah pokok dan 1 lagi diletak di kawasan terbuka. AccuPAR LP80 digunakan untuk merekod data Indeks Keluasan Daun (Leaf Area Index) Kawasan Universiti Putra Malaysia dipilih sebagai tapak kajian. Penganalisis data telah dijalankan dengan menggunakan Perisian R (*The R Foundation Statistical Computing*) dan penganalisis tentang pemboleh-ubah dijalankan dengan menggunakan Generalized Linear Model dalam perisian statistik Minitab. Hipotesis kajian ini adalah membelajari keadaan cuaca di bawah pokok. Keputusan ini menunjukkan sinaran solar di bawah kanopi pokok mempunyai nilai perbezaan yang ketara berbanding dengan kawasan terbuka tanpa pokok. Sinaran solar untuk *Mimusops elengi* (pengurangan 95.55%) adalah paling rendah di kalangan tiga spesis tersebut. Walau bagaimanapun, suhu udara dan kelembapan tidak menunjukkan nilai yang jauh beza berbanding dengan kawasan terbuka tanpa pokok, tetapi ditunjukkan di bahagian bawah kanopi pokok. Hipotesis mencadangkan satu formula yang boleh diguanakan

untuk mengira kenaikan dan keturunan mikroclimate untuk pelbagai spesis pokok daripada kelengkungan graf pada model mikroclimate, Pokok yang berbentuk payung dan bulat dapat memberi naungan yang lebih besar berbanding dengan *Mesua ferrea* yang berbentuk kon. Naungan dapat menghalang cahaya matahari dan mengurangkan radiasi solar yang mempengaruhi keselesaan manusia. Oleh itu bentuk pokok yang memberi naungan besar dan mempunyai Indeks Keluasan Daun yang tinggi perlu diambil kira dalam pemilihan pokok bandar oleh perancang bandar dan arkitek lanskap dalam pendekatan reka bentuk mereka untuk memperbaiki Kesan Pulau Haba Bandar.

ACKNOWLEDGEMENTS

The student is grateful to Dr. Carl Lee, who is the senior faculty research fellow, professor of Statistics, Department of Mathematics, Central Michigan University, who provides valuable advices on statistcal analysis and Dr. Yun-Ming Pong, the Adjunct Professor of College of Bio-Resources and Agriculture, Department of Agronomy, National Taiwan University, who provides useful comments and suggestions on testing. At the same time, I would also like to thank the supervisory committee; Dr Noorizan Bt Mohamed, Dr. Ahmad Ainuddin B Nuruddin, Dr. Christopher Teh Boon Sung and Dr. Osman Bin Tahir. I would also like to thank Loh Gim Hin and Lim Khim Joe who are both students from University Putra Malaysia who contributed a lot of time for field measurements. Lastly, I would like to thank for my beloved wife Lim Lee Fong and son Mah Yih Haur for their support and understanding for the period of studying.

APPROVAL

I certify that an Examination Committee has met on ----12014 to conduct the final examination of MAH CHEN YING on his Doctor of Philosophy thesis entitled "**MICROCLIMATE MODELLING OF VARIOUS ISOLATED TREE SPECIES IN UPM CAMPUS, MALAYSIA"** in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Doctor of Philosophy.

Members of the Examination Committee were as follows:

Name of Chairperson, PhD
Professor
Faculty of Design and Architecture
Universiti Putra Malaysia
(Chairman)

Examiner 1, PhD
Faculty of Design and Architecture
Universiti Putra Malaysia
(Internal Examiner)

Examiner 2, PhD
Faculty of Design and Architecture
Universiti Putra Malaysia
(Internal Examiner)

External Examiner, PhD

NEED TO REPLACE, I KEEP THE COPY PROVIDED BY SGS

_____

SEOW HENG FONG PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 2014

这张 SGS 提供（已排好页码），在我这里，你暂时排上上页码（vi），到时打印时，我换掉。

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Noorizan Bt Mohamed, PhD
Associate Professor
Faculty of Design and Architecture
Universiti Putra Malaysia
(Chairman)

Osman Bin Mohd Tahir, PhD
Associate Professor
Faculty of Design and Architecture
Universiti Putra Malaysia
(Member)

Ahmad Ainuddin Nuruddin, PhD
Professor
Faculty of Forestry
Universiti Putra Malaysia
(Member)

Christopher Teh Boon Sung, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Studies

Date: Augest 2014

DECLARATION

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012:
- there is no plagiarism or data falsification/ fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. This thesis has undergone plagiarism detection software.

Signature: _____ Date: Augest 2014

Name and Matric No.: CHEN YING MAH; GS 16820

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduated Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: _____
Name of Chairman of Supervisory Committee: **Noorizan Binti Mohamed, PhD**

Signature: _____
Name of Chairman of Supervisory Committee: **Osman Bin Mohd Tahir, PhD**

Signature: _____
Name of Chairman of Supervisory Committee: **Ahmad Ainuddin Nuruddin, PhD**

Signature: _____
Name of Chairman of Supervisory Committee: **Christopher Teh Boon Sung, PhD**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Rapid urbanization has resulted in the clearing of vegetation, replacing it with infrastructures such as buildings, roads, paving, drains and bridges thus creating shortage of vegetation such as tree, shrubs and turfs. This situation has reduced the ability to block the solar radiation in the area, thus resulting in a lot of heat being absorbed by the hard surface during day time and released during night time. This has caused serious heat island effects in urban areas and become a common issue emerging everywhere nowadays. Trees play an important role in microclimate (Luxmoore et. al., 2005; Shahidan, 2012; Benz Kotzen, 2003). There are four ways to modify microclimate: modification of wind; relative humidity; solar radiation and terrestrial radiation from the ground and other surfaces (Brown and Gillespie, 1995). Amongst these four ways, the most important aspect is to modify solar radiation and terrestrial radiation from the ground through the creation of shade (Benz Kotzen, 2003). The shade created by the trees is able to modify the solar radiation, which is one of the important factors affecting human comfort, especially in tropical countries which are located in strong solar radiation areas (Brown and Gillespie, 1995).

The important role that trees play in microclimate has been well documented in the literature. Schmidt (1979), in his research mentioned that with solar energy a layer of leaves will generally absorb 80% of incoming visible radiation, whilst reflecting 10% and transmitting 10%. With infrared approximately 20% is absorbed with 50% being reflected and 30% transmitted. More layers of leaves will be more efficient at reducing solar radiation under a tree,(Brown and Gillespie , 1995; Kotzen ,2003). In other words, leaf area index is one of the factors influencing solar radiation and as such, the study of Leaf Area Index of different tree species is important.

The capability of tree in microclimate modification depends on the canopy structure, Shahidan (2011) stated that shade is created by two shading properties: major and minor branching/limbs and leaf cover. However, the percentage of limbs and leaf cover varies across tree species and from tree to tree within the same species. Furthermore, the density of leaf cover also varies from season to season. Therefore, the shade performance of each species is different, and their effectiveness in filtering radiation will influence microclimate modification. He also highlights that it is important to investigate the differences between species to understand the impact of each tree species on outdoor comfort.

According to the “Draft Struktur Kuala Lumpur 2020 (DBKL)” Kuala Lumpur city center is located in a harsh humid tropical country, lacking of greenery

elements and spaces that could give shade & thermal protection for outdoor environments. The lack of both greenery and spaces can be seen quite easily throughout the city center and its immediate surroundings (Shahidan, 2007). Due to matters that are based on the issue of weather, Kuala Lumpur now holds an unwanted world record; it is getting hotter, faster than any other reported city in the world (Davis et al., 2004). The outdoor mean temperature in Kuala Lumpur is increasing by 0.6 degree Celsius per decade, compare to 0.4 degree Celsius for Los Angeles and 0.1 degree Celsius for Shanghai (Jensen, 2002). National Environment Agency (Singapore) stated that the mean yearly temperature for Singapore for the period 1948-2008 shows an increase of 0.25 degree Celsius per decade.

In Malaysia, from my working experience as a landscape architect for the past 29 years, I have noted that most of the street trees in most of the cities and towns such as Kuala Lumpur, Shah Alam, Kajang, Putrajaya, etc., focus primarily on geometrical forms (conical form, topiary plant and palm tree), and as such, palm trees have become one of the popular street trees in some urban areas. For the Putrajaya project, Moser (2010) revealed that the climate is one of the primary challenges to urban designers and architects in Malaysia. He pointed out that one of Putrajaya has failed to achieve climatic design in planning, architecture, and landscape architecture. With great design freedom, an expansive budget, and an explicit goal of creating a "garden city", the designers for Purajaya have missed an important opportunity to advance microclimatic design and create a "green city", cooled passively through design and planting, rather than relying primarily on air conditioning. This claim is consistent with review made by Danby (1986) on the diversification of Islamic architecture in Arabic cities in promoting the passive cooling strategies. Moser (2010) accented that Putrajaya designers failed to reclaim the use of urban microclimatic features that were developed in the Middle East to contradict the effects of intense heat from a constant sun illumination (Hakim, 1994). From my observation, the Putrajaya planting design is largely focused on aesthetic purposes, with trees mainly palm trees, conical shape like *Hopea ordorata; Eugene oleinia; Mesua ferrea,* pagoda form like *Tabebuia pentaphlla; Tabebuia rosea; Bucida buceras,*oblong form like *Bucida buceras*; *Terminalia mantaly; Terminalia mantaly* 'tricolor' and slow growing *trees like Mimusops elengi.* All these trees are without a large canopy to intercept the solar radiation, in other words, they are not able to provide large shade for the hard surface like huge paving and large and tall buildings to mitigate an urban heat island effect. Salleha et al. (2013) suggested that the resolution of Putrajaya Green City 2025 greatly depends on this corrective period; as building and enforcing new green integrated developments can only be complimented if the existing mess and adversity is being rescued and neutralised.

In Shah Alam, the council selects palm tree as the city tree, enforcing all landscape projects to plant palm tree at the project site. This policy causes a more adverse impact on the ecology and microclimate. The preference of landscape architects in Malaysia is to select geometrical trees, such as palm tree, conical form, topiary plant, oblong form , or blossom trees (*Tabebuia rosea*) for their designs. This kind of planting prevalence which focuses on aesthetic perception amongst the landscape may need rethinking. These trees provide very limited shade on the surrounding surfaces (building, road, paving) thus making the urban heat island effect increasingly serious.

The green environment that transpires through many parks and gardens threaded throughout the city, only provide limited power in reducing the heat throughout the day. This is because the greenery areas consist of decorative landscaping features rather than huge canopies or long benches of trees. Not to mention the sidewalks throughout the city have very little vegetative cover at all, even until recent years. (Salleha et al. 2013)

Another problem in Malaysia is that the majority of landscape authority officers tend to reject the proposal of large tree from the landscape consultants; this is my experience from my past projects. Their complaints are that the roots will damage the walkways and drains, and also the high maintenance costs which will make them unable to manage. Whereas we found that the Green City-Singapore plant a lot of large trees everywhere, mainly *Enterolobium saman, Pterocarpus indicus, Ficus species*…etc. They can manage the large trees properly with effective growing systems and effective pruning technology. Putra Jaya is a typical example of planting design to show the perception of street tree design amongst landscape architects in Malaysia. In Malaysia most of the large trees are planted more than 20 years ago. Due to the development and extension of road in urban areas, many large trees with a big canopy and fast growing characteristics (*Enterolobium saman, Ficus benjamina, Ficus retusa, Peltophorum pterocarpum, Pterocarpus indicus,Terminalia catappa*….etc) have been removed and replaced with the slow growing conical trees, topiary trees and palm trees. These trees have a small canopy which is not able to sufficiently provide large effective shade to mitigate solar radiation on the surrounding hard surfaces, causing the urban heat island effect to be more serious day by day. 2 Notwithstanding the fact that urban heat island effects can be mitigated through proper design approach, however, poor design in current urban landscape of hot-humid tropics has been established to be one of the contributing factors that lead to outdoor thermal discomfort (Thani et al. 2012). Hence, the aim of this study is to investigate on microclimate under different species of isolated tree in relation with the tree's geometry.

1.2 Statement of the Problem

Heat Island Effect is a present meteorological problem in most of the cities across the globe. Many studies (Brown and Gillespie, 1995; Shahidan, 2011; Kotzen 2003) revealed that trees play an important role in microclimate, but what kind of tree species can effectively ameliorate microclimate in urban areas, very seldom researchers will conduct field research on this topic in tropical countries. Therefore this research is to evaluate the conditions of a number of isolated tree species in various species in microclimate in UPM campus, Malaysia. Unfortunately, due to time, equipment, and manpower constraints, we can only select three various tree species with three forms for our experiment.

Trees species have different botanical features and percentage of limbs (branching) and leaf cover, they are varies across tree species and from tree to tree within the same species. The density of leaf cover also varies from season to season. Therefore, the microclimate conditions (solar radiation, air temperature and relative humidity) under the trees are different. The tree's leaf angular and spatial distributions have an effect on transmission and absorption of solar radiation through the tree canopy. Therefore, experiments are carried out on the site to understand the conditions of microclimate under tree species.

Jauregui, (1991) stated that a single tree can already moderate the climate well, and is one of the strategies to mitigate the urban island effect. Amongst all the climate amelioration measures, street trees are the most low cost and most effective green elements (Rosenweig et al. 2006). Wong et al. (2007) stated that large green created by the trees can be considered as a green park. Huang et al. (1987) estimates that by increasing the general canopy of trees in various cities cooling loads can be reduced significantly. Computer modelling showed tree planting could reduce maximum surface temperature by between 0.5 ◦C and 2.3 ◦C (Halla et al. 2012).

Shahidan et al. (2010/2011) and Hidayat (2010) pointed out that selection of plant species should be focused on tall (evergreen) trees with wide canopy, massive leaves (Leaf Area Index (LAI) value >5) and dense branches to filter radiation. Shahidan et al. (2010) comments that types, sizes and arrangements of leaves play an important role in improving efficiency in radiation absorption and reflection. They also indicated that the higher the number of trees and the density of their canopies, the greater the temperature decreases.

Tliebard and De Herde, (2005) stated that choice of species is important because the quality of the shade of a tree depends on its density. Thus the foliage of a tree can filter 60 to 90% of solar radiation and crouching vegetation also reduces the solar radiation reflected by the ground.

The above researchers all highlight the importance of trees play the role of ameliorating the microclimate for the mitigation of urban heat island effect. Therefore, I decide this to be my research topic.

1.2.1 Goal

To examine the microclimate modeling under various isolated tree species in Malaysia to mitigate the Heat Island Effect in urban area.

1.2.2 Objectives

1) The evaluation of microclimate conditions within landscape tree.
2) The fitness of microclimate conditions within landscape trees by establishing a microclimate model.

1.2.3 Hypotheses

Hypothesis 1
Ho*: Mesua ferrea, Mimusops elengi* and *Peltophorum pterocarpum* are effective in the reduction of solar radiation, air temperature and increment of relative humidity.

Ha: *Mesua ferrea, Mimusops elengi* and *Peltophorum pterocarpum* are not effective in the reduction of solar radiation, air temperature and increment of relative humidity.

Hypothesis 2
Ho: There are some diference of microclimate conditions amongst *Mesua ferrea*, *Mimusops elengi* and *Peltophorum pterocarpum.*

Ha: There is no difference of microclimate conditions amongst *Mesua ferrea, Mimusops elengi* and *Peltophorum pterocarpum*.

1.2.4 Assumptions and Limitations

1.2.4.1 Assumptions

1) Wind is one of the factors to modify the microclimate, it influences the air temperature, relative humidity and thermal comfort. All the samples are in different locations with different environments, it is impossible to measure the wind velocity in the same condition. Therefore, for this experiment we are assuming that the site has zero influence by wind factor and thus, wind factor is excluded in this experiment. .

2) Ground temperature under tree is not measured, it also has influence on air temperature. But due to the instrument and man power constraint, we will assume that the ground temperature is zero.

1.2.4.2 Limitation.

1) The solar radiation in this study has excluded long wave terrestrial radiation, diffuse and reflected radiation from the sky and other objects.
2) All the samples of the three species should be the same height to compare the microclimate, but due to lack of enough quantity of the trees samples in the campus, it is very difficult to get the samples with same height.

1.2.4.3 Research Problem

The present research topic "microclimate conditions under tree species", especial the isolated trees, most of the researchers used computer simulations, and very seldom conducted actual field measurements in tropical country. Therefore there is a lack of information to refer to.

Trees species have different botanical features and percentage of limbs (branching) and leaf cover, they are varies across tree species and from tree to tree within the same species. The density of leaf cover also varies from season to season. Therefore, the microclimate conditions (solar radiation, air temperature and relative humidity) under the trees are different. The tree's leaf angular and spatial distributions have an effect on transmission and absorption of solar radiation through the tree canopy. Therefore, an experiment is carried on the site to understand the conditions of microclimate under tree species.

Jauregui, (1991) stated that a single tree can already moderate the climate well, as it is one of the strategies to mitigate the urban island effect. Amongst all the climate amelioration measures, street trees are the most low cost and most effective green elements (Rosenweig et al. 2006). Wong et al. (2007) stated that large green creates by the trees can be considered as a green park. Huang et al. (1987) estimate that by increasing the general canopy of trees in various cities cooling loads can be reduced significantly. Computer modelling showed tree planting could reduce maximum surface temperature by between 0.5 ◦C and 2.3 ◦C (Halla et al. 2012). The above researches confirm that the tree species with their botanical features really influence the microclimate under tree canopy, therefore, we need to do further research.

The tree samples always has different environment, it is very difficult to get the samples in same height and same environment. However, I select the samples which all comply the criteria the tree selection.

1.2.5 Research Framework

To achieve the researched goal and objectives, the following works are identified and carried out. The research framework is divided into four steps as follows:

1) The first step consists of information gathered from the literature review to establish pertinent information on the canopy structure and solar radiation modification in urban areas, focusing on the relationship between the trees and the microclimate as well as Heat Island Effect problems. My past 29 years of working experience as a landscape architect practicing in Malaysia always involved planting design and plan submission to local authorities. Identify the problems and research goals and choosing research titile.

2) The second focuses on the research methodology which consists of guidelines for field measurements, choosing the instruments, design the field measurement procedure, instruments testing, recording the results and data analysis. Identify the softwares used for data analysis.
3) The third step is the results and discussion. The results use the selected software to do analysis and comparison, produce the tables, figures and microclimate model. Discuss the results.
4) The fourth and final step is discussion on the subject matter which leads to the development of the conclusion and recommendations pertaining to the subject matter of this paper.

1.2.6 Benefits of the study.

Since 1985, I have been practicing landscape architect in Malaysia and through my observation I have found that most of the landscape architects in Malaysia when conducting street tree selection will mainly focus on aesthetic perception rather than on ecological and microclimate concerns. This prevailing trend is really affecting the heat island effect in urban area. The present popular street trees like the palm tree, topiary plant, conical or pyramidal form tree and slow growing tree which contribute small canopy size, are not able to provide for effective solar radiation deduction, causing urban area's island heat effect to be more serious in Malaysia. This study focuses mainly on big canopy tree which can maximize the shade to mitigate the Heat Island Effect in urban area, therefore to quest for the appropriate tree species and tree forms which can provide enough shade area to intercept the sunlight to improve the Heat Island Effect for our living is a critical issue nowadays. We have to use scientific figures and analysis to support our hypothesis, in order to convince professional experts about the importance of the selection of trees to create thermal comfort for people in urban areas. This study contributes some tree selection criteria for landscape authority, landscape architect, horticulturalist, forester, town planner, and environmental planner for tree planting design in urban area in order to make a comfortable environment for living in Malaysia. The study of isolated

tree species on microclimate is quite seldom done in Asian countries. We hope this study can highlight the intention on this issue to most of the researchers who can then continue to do further research to benefit the people in tropical countries.

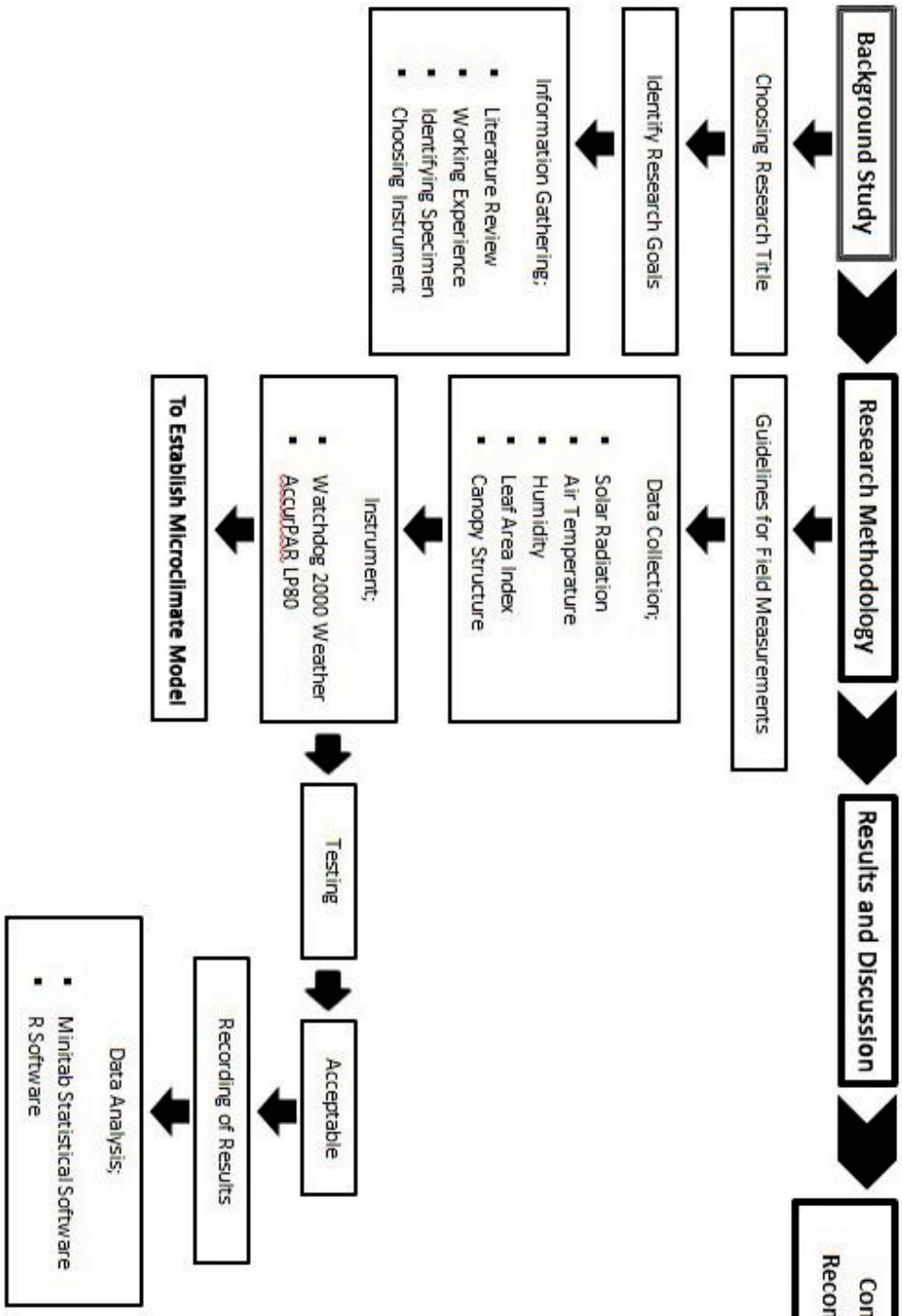

FIGURE 1.1 Research Framework

REFFERENCE

Ahmad, S.S. (2004) PhD. Thesis. *A study on thermal comfort and energy performance of urban multistorey residential buildings in Malaysia*. University of Queensland, Australia.

Ahmed, K.S. (2003) Comfort in urban spaces: defining the boundaries of outdoor thermal comfort for the tropical urban environments. *Energy and Buildings*, Vol 35, pp 103–110

Akbari H, Pomerantz M, Taha H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*; 70: 295-310.

Alamah Misni* (2013). Modifying the Outdoor Temperature around Single-Family Residences: The influence of landscaping. *Procedia – Socia l and Behavioral Sciences* 105 (2013) 664 – 673.

Ali-Toudert F, Mayer H. (2007). Thermal comfort in an east-west oriented street canyon in Freiburg (Germany) under hot summer conditions. *Theor Appl Climatol*; 87:223-37.

Ali-Toudert F, Mayer H. (2007). Effects of asymmetry, galleries, overhanging facades and vegetation on thermal comfort in urban street canyons. *Solar Energy*; 81:742-54.

Armsona, D., Stringerb P, and Ennosa, A.R. (2012). The effect of tree shade and grass on surface and globe temperatures in an urban area. *Urban Forestry & Urban Greening*, Vol 11, pp 245-255.

Armsona P, Stringerb , A.R. Ennosa,. The effect of tree shade and grass on surface and globe temperatures in an urban Area. *Urban Forestry & Urban Greening* 11 (2012) 245– 255

Ayman Hassaan Ahmed Mahmoud. (2011). Analysis of the microclimatic and human comfort conditions in an urban park in hot and arid regions. *Building and Environment* , Vol 46, pp 2641-2656.

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*, 70(3), 295 310.

B. Givoni (1991). Impact of Planted Areas on Urban Environment Quality: A Review. *Atmospheric Environment* Vol. 25B, No. 3, pp 289-299.

Brad B. (2002). *Mitigating the urban heat island with green roof infrastructure. In: Urban heat island summit—mitigation of and adaptation to extreme summer heat*, Toronto; May 1–4, 2002.

Brown, R. D. & Gillespie, T. J. (1995), *Microclimate Landscape Design: Creating Thermal Comfort and energy Efficiency*. New York: John wiley & Sons.

Bowler, D.E., Ali, L.B., Knight, T.M., and Pullin, A.S. (2012). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*, Vol 97, pp 147-155.

Moufidaa,B. and Djamelba, A.(2012). Impact of vegetation on thermal conditions outside, Thermal modeling of urban microclimate, Case study: the street of the republic, Biskra. *Energy Procedia 18*, pp 73 – 84

Chen L. and Ng, E. (2012) Outdoor thermal comfort and outdoor activities: A review of research in the past decade. *Cities, Vol 29*, pp 118–125

Chen Y. and Wong N.H. (2006) Thermal benefits of city parks. *Energy and Buildings*, Vol 38, pp 105–120.

Givonia, B., Noguchi, M., Saaroni, H., Pochter, O., Yaacov, Y., Feller, N. and Becker, S. (2003) Outdoor comfort research issues. *Energy and Buildings* 35, pp 77–86.

Danby, M. (1986). Hakim, Besim Selim," Arabic-Islamic Cities: Building and Planning Principles"(Book Review). *Third World Planning Review, 8*(4), 367.

Davis, M. P., Nordin, N. A., Kamal, M., Yahaya, n., Babjee, S. M. A., Abdullah, A.S., et al. (2004). Thermal Comfort honeycomb Housing for Hot Climates. Paper presented at the Place Making and Sustainable Communities in Urban Development Conference, Kuala Lumpur, Malaysia.

Emmanuel R, Rosenlund H, Johansson E. (2007). Urban shading e a design option for the tropics. *A study in Colombo, Sri Lanka*. Int J Climatol 2007; 27:1995-2004.

Ennos, A. R. (2010). Urban cool. *Physics World*, 23(8), 22–25.

Fahmy M, Sharples S, Yahiya M. (2010). LAI based trees selection for mid latitude urban developments: a microclimate study in Cairo, Egypt. *Build Environment* :345-57.

Fanger, P.O. (1970). *Thermal Comfort: Analysis and Applications in Environmental Engineering*. New York: McGraw Hill.

Yang, F. Stephen S.Y. Lau, Qian F. (2011). Urban design to lower summertime outdoor temperatures: An empirical study on high-rise housing in Shanghai. *Building and Environment* 46, 769-785.

Gartland, L. (2008). *Heat Islands: Understanding and Mitigating Heat in Urban Areas.* Earthscan, London, Sterling VA.

Georgi, N. J., & Zafiriadis, K. (2006). The impact of park trees on microclimate in urban areas. *Urban Ecosystems*, 9, 195–209.

Gill, S. E. (2006). *Climate change and urban greenspace* (Ph.D. Thesis). UK: School of Environment and Development, University of Manchester.

Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: The role of the green infrastructure. *Building and Environment*, 33(1), 115–133.

Grimme FW, Laar M. (2005). Solar radiation and orientation as key information for bio climatic design (retrieved 08.09.05), http://www.tt.fh-koeln.de/publications/ ittpub3001024.pdf; 2005.

Gomez-Munoz, V.M., Porta-Gandara, M.A. and Fernandez, J.L. (2010) Effect of tree shades in urban planning in hot-arid climatic regions. *Landscape and Urban Planning*, Vol 94, pp 149–157.

Yana, H., Wang, X., Hao P.Y. and Donga, L. (2012). Study on the microclimatic characteristics and human comfort of park plant communities in summer. *Procedia Environmental Sciences* 13 (2012) 755 – 765.

Hakim, B.S. (1994). The" URF" and its Role in Diversifying the Architecture of Traditional Islamic Cities. *Journal of architectural and planning research, 11*, 108-108.

Huizenga, C., Hui, Z., & Arens, E. (2001). A model of human physiology and comfort for assessing complex thermal environments. *Building and Environment*, 36(6), 691 699.

Hwang, R.-L., Lin, T.-P., Cheng, M.-J., & Lo, J.-H. (2010). Adaptive comfort model for tree-shaded outdoors in Taiwan. *Building and Environment*, 45(8), 1873-1879

Hwang RL, Lin TP, Matzarakis A. (2011). Seasonal effects of urban street shading on long-term outdoor thermal comfort. *Build Environ* 2011; 46:863-70.

Hwang RL, Lin TP. (2007). Thermal comfort requirements for occupants of semioutdoor and outdoor environments in hot-humid regions. *Archit Sci Rev* 2007; 50:60-7.

Huang Y. J., Akbary H., Taha H. and Rosenfeld A. H. (1987). *The potential of vegetation of deducing summer cooling loads in residential buildings* J. Clim. appl. Met. 26. 1103-1116.

Julia N. Georgi*and Dimitriou, D.(2010). The contribution of urban green spaces to the improvement of environment in cities: Case study of Chania, Greece. *Building and Environment* 45 (2010) 1401–1414

Jusuf, S.K., Wong, N.H., Hagen, E., Anggoro, R., & Hong, Y. (2007). The influence of land use on the urban heat island in Singapore.*Journal of Habitat International*, 31 (2), 232 242

Justine M. Hall, John F. Handley, A. Roland Ennos. (2012). The potential of tree planting to climate-proof high density residential areas in Manchester, UK. *Landscape and Urban Planning* 104 (2012) 410-417.

Ahmed, K.S. (2003). Comfort in urban spaces: defining the boundaries of outdoor thermal comfort for the tropical urban environments. *Energy and Buildings* 35, 103–110.

Kantzioura, A., Kosmopoulos, P. and Zoras, S. (2012) Urban surface temperature and microclimate measurements in Thessaloniki. *Energy and Building*, Vol 44, pp. 63-72.

Kotzen, B. (2003) An investigation of shade under six different tree species of the Negev desert towards their potential use of enhancing micro-climate conditions in landscape architectural development. *Journal of Arid Environments*, Vol 55, No 2, pp 231-274.

Knez I, Thorsson S. (2006). *Influences of culture and environmental attitude on thermal, emotional and perceptual evaluations of a public square*. Int J Biometeorol 2006; 50:258-68.

Kuala Lumpur, D. B. K. (2003). *Buku Draf Pelan Struktur Kuala Lumpur 2020* (First Edition ed Vol. 1). Kuala Lumpur: Dewan Bandaraya Kuala Lumpur, Malaysia.

Kleerekopera,L., Escha, M. and Salcedob, T.B. (2012). How to make a city climate-proof, addressing the urban heat island effect. *Resources, Conservation and Recycling* 64 (2012) 30– 38.

Lemonsu, A., Masson, V., 2002. Simulation of a summer urban breeze over Paris. *Boundary Layer Meteorology* 104, 463–490.

Alain, L. and André, D.H. (2005). *Traité d'architecture et d'urbanisme bioclimatique*. Édition de moniteur. Paris; 2005, P. 139.

Lin T.P., Matzarakis A and Hwang RL. (2010). Shading effect on long-term outdoor thermal comfort. *Build Environ*; 45:213-21.

Lin T.P. and Matzarakis A. (2011).Tourism climate information based on human thermal perception in Taiwan and Eastern China. *Tourism Manag* 2011; 32(3): 492-500.

Lin T.P., De Dear R and Hwang R.L. (2011). Effect of thermal adaptation on seasonal outdoor thermal comfort. *Int J Climatol* 2011; 31:302-12.

Lin T.P. (2009). Thermal perception, adaptation and attendance in a public square in hot and humid regions. *Building and Environment* ; 44:2017–26.

Liu, J., Yao, R.M. and McCloy, R. (2012) A method to weight three categories of adaptive thermal comfort. *Energy and Buildings*, Vol 47, pp 312-310.

L. Shashua-Bar a, M.E. Hoffman.(2000). Vegetation as a climatic component in the design of an urban street An empirical model for predicting the cooling effect of urban green areas with trees. *Energy and Buildings* 31, 221–235

Luxmoore, D.A., Jayasinghe, M.T.R. and Mahendran, M. (2005) Mitigating temperature increases in high lot density sub-tropical residential developments. *Energy and Buildings*, Vol 37, pp 1212–1224.

Makaremi, N., Salleh, E., Jaafar, M. Z., & Ghaffarian Hoseini, A. (2012). Thermal comfort conditions of shaded outdoor spaces in hot and humid climate of Malaysia. *Building and Environment* 48, 7 14.

Mansor, M., Said, I. and Mohamad, I. (2010) Experimential Contacts with Green Instructure's Diversity and Well -being of Urban Community. *Asian Journal of Environment-Behaviour Studies, Volume 1*(No.2), 33 - 48.

Nikolopouloua, M. & Lykoudisb, S.(2006). Thermal comfort in outdoor urban spaces: Analysis across different European countries. *Building and*

Environment 41, 1455–1470.

Mayer (1993). Objective criteria for thermal comfort, *Building and Environment* 28, pp 393 -403.

Mayer H, Holst J, Dostal P, Imbery F and Schindler D. (2008) *Human thermal comfort in summer within an urban street canyon in Central Europe*. Meteorol Z

Mc Pherson E. (1994). Cooling urban heat islands with sustainable landscapes. The ecological city: *Preserving and restoring urban biodiversity*:161–71.

Rautiainena, M., Stenberga, P., Tiit Nilson,T. & Kuusk A. The effect of crown shape on the reflectance of coniferous stands. *Remote Sensing of Environment* 89 (2004) 41–52.

McPherson, E. G., Nowak, D. J., & Rowntree, R. A. (1994). *Chicago's urban forest ecosystem: Results of the Chicago urban forest climate project*. General Technical Report NE-186. Radnor, PA, USA: USDA Forest Service, Northeastern Forest Experiment Station

Mohd Fairuz Shahidan. *Effectiveness of Mesua Ferrea L. And Hura Crepitans as solar radiation filters in outdoor environment*. Master Thesis, Universiti Putra Malaysia, August 2007.

Mohd Fairuz Shahidan, Phillip J. Jones, Julie Gwilliam, Elias Salleh (2012). An evaluation of outdoor and building environment cooling achieved through combination modification of trees with ground materials. *Building and Environment* 58, 245-257.

MOHURD (2006). *Evaluation standard for Green Building*. In: Ministry of Housing andUrbaneRural Development of P.R. China (MOHURD), editor . Beijing: China Architecture and Building Press.

Moufidaa, B. and Djamelba, A. (2012) Impact of vegetation on conditions outside, Thermal modeling of urban microclimate Case study: the street of the Republic, biskra. *Energy Procedia*, Vol 18, pp 73-84.

*Nastaran Makaremi**, Elias Salleh, Mohammad Zaky Jaafar, AmirHosein Ghaffarian Hoseini. Thermal comfort conditions of shaded outdoor spaces in hot and humid climate of Malaysia. Building and Environment 48 (2012) 7-14.

National Environment Agency, Singapore. Weatherwise Singapore. From http://app2.nea.gov.sg/data/cmsresource/20090721544571208250.pdf [accessed 08.09.12].

Ng, E., Chen, L., Wang, Y.N. and Yuan, C. (2012) A study on the cooling effects of greening in a high-density city: An experience from Hong Kong. *Building and Environment*, Vol 47, pp 256-271.

Ng, E. and Cheng, V. (2011) Urban human thermal comfort in hot and humid Hong Kong *Energy and Buildings*

Rabiatul Adawiyah Nasir, Sabarinah Sh Ahmada, Azni Zain Ahmed. Psychological Adaptation of Outdoor Thermal Comfort inShaded Green Spaces in Malaysia. ASIA Pacific International Conference on Environment-Behaviour Studies. Egypt, 31 October 2 November 2012.

Oke T. (1987). *Boundary layer climates*. New York: Routledge; 1987.

Parker, J., 1983. The effectiveness of vegetation on residential cooling. *Passive Solar Journal 2* (2), 123–132.

Parker J. H. (1983). The effectiveness of vegetation on residential cooling. *Passive Solar* J. 2, 123-132.

Paker J. H. (1987). The use of shrubs in energy conservation plantings. *Landscape J*. 6, 132-139.

Paker J H. (1989) The impact of vegetation on air conditioning consumption. Proc., Conf. Controlling the Summer Heat Island. LBL- 27872. pp. 46-52.

Peter Hoppe. Different aspects of assessing indoor and outdoor thermal comfort. *Energy and Building* 34 (2002), pp 601-605.

Peters, E. B., & McFadden, J. P. (2010). Influence of seasonality and vegetation type on suburban microclimates. *Urban Ecosystems*, 13, 443–460.

Peters, E. B., McFadden, J. P., & Montgomery, R. A. (2010). Biological and environmental controls on tree transpiration in a suburban landscape. *Journal of Geophysical Research*, 115 (Article Number: G04006).

Perrot, Pierre (1998). *A to Z of Thermodynamics*. Oxford University Press.

ISBN 0-19-856552-6.

Rautiainena, M., Stenberga, P., Nilsonb, T. and Kuuskb, A. (2004) The effect ofcrown shape on the reflectance of coniferous stands. *Remote Sensing of Environment*, Vol 89, pp 41–52.

Reuy-Lung Hwang a, Tzu-Ping Lin , Ming-Jen Cheng , Jen-Hao Lo. (2010). Adaptive comfort model for tree-shaded outdoors in Taiwan. *Building and Environment* 45 (2010) 1873-1879.

Rizwan Ahmed Memon, Dennis Y.C. Leung □, Chun-Ho Liu (2009). An investigation of urban heat island intensity (UHII) as an indicator of urban heating. *Atmospheric Research* 94, 491–500.

Rosenzweig C, Solecki WD, Slosberg RB. (2006). *Mitigating New York City's Heat Island with Urban Forestry, Living Roofs and Light Surfaces*. New York State Energy Research and Development Authority.

Sanesi, G., Lafortezza, R., Bonnes, M., & Carrus, G. (2006). *Comparison of two different approaches for assessing the psychological and social dimensions of green spaces*. *Urban Forestry & Urban Greening*, 5(3), 121 129.

Santamouris, M., Gaitani, N., Spanou, A., Saliari, M., Giannopoulou, K., Vasilakopoulou, K. and Kardomateas, T. (2012) Using cool paving materials to improve microclimate of urban areas Design realization and results of the flisvos project. *Building and Environment*, Vol 53, pp 128-136.

Schmidt, N. (1979), *Desert Animals-Physiological Problems of Heat and Water*, New York: Dover Publication.

Scudo G. Thermal comfort in green spaces. In: proceedings: the green structures and urban Planning Conference. Milan: 2002.

Shahidan, M.F., Shariff, M.K.M., Jones, P., Saeh, E. and Abdulah, A.M. (2012) A comparison of *Mesua ferrea* L. and *Hura Crepitans* L. for shade creation and radiation modification in improving themal comfort. *Landscape and Urban Planning*, Vol 97, No 3, pp 168-181.

Sham, S. (1990). *Pembandaran dan Iklim, Implikasinya Terhadap Perancangan Bandar di Rantau Tropika Rendah. In Malay*. Penerbit Universiti Kebangsaan Malaysia, Bangi. 16 -18, 46-49

Sharifah Khalizah Syed Othman Thani*, Nik Hanita Nik Mohamad, Sabrina Idilfitri. Modification of Urban Temperature in Hot-Humid Climate through Landscape Design Approach: A review. *Procedia - Social and Behavioral Sciences* 68 (2012) 439 – 450

Shashua-Bar, L and Hoffman M. E. (2000) Vegetation as climatic component in the design of an urban street-An empirical model for predicting the cooling effect of urban green areas with trees. *Energy and Buildings*, Vol 31, pp 221-235.

Siti Aekbal Salleha,*, Zulkiflee Abd.Latifa, Wan Mohd. Naim Wan Mohda, Andy. Factors Contributing to the Formation of an Urban Heat Island in Putrajaya, Malaysia. *Procedia - Social and Behavioral Sciences* 105 (2013) 840 – 850

Solecki, W. D., Rosenzweig, C., Parshall, L., Pope, G., Clark, M., Cox, J., et al. (2005). Mitigation of the heat island effect in urban New Jersey. *Environmental Hazards*, 6, 39–49.

Stathopoulos, T., Wu, H.Q. and Zacharias, J. (2004) Outdoor human comfort in an urban climate. *Building and Environment*, Vol 39, pp 297 – 305.

Taha H. (1997). Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. *Energy Build* 1997; 25:99-103.

The City of Edinburgh Council. (2001) In: Greening the City. A report on the Edinburgh and Craigmillar urban forest projects; 2001.

T. Honjo, T. Takakura. (1990). Simulation of thermal effects of urban green areas on their surrounding areas, *Journal of Energy and Buildings* 15–16, 443–446.

Tran H, Uchihama D, Ochi S, Yasuoka Y. (2006). Assessment with satellite data of the urban heat island effects in Asian mega cities. *Int J Appl Earth Obs* 2006; 8: 34-48.

T. Susca, S.R. Gaffin, G.R. Dell'Osso. (2011). Positive effects of vegetation: Urban Heat Island and green roofs。Environmental Pollution 159, 2119-2126.

T.R. Oke. (1989). *The micrometeorology of the urban forest*, J. Phil. R. Sec. Land. B 324 _1989. 335–349..

Tzu-Ping Lin , Kang-Ting Tsai , Chi-Chang Liao , Ying-Che Huang .Effects of thermal comfort and adaptation on park attendance regarding different shading levels and activity types. *Building and Environment* 59 (2013) 599-611.

Tzu-Ping Lin, Andreas Matzarakis, Ruey-Lung Hwang. Shading effect on long-term outdoor thermal comfort. *Building and Environment* 45 (2010) 213–221.

Vigotti M, Muggeo V, Cusimano R. (2006). The effect of birthplace on heat tolerance and mortality in Milan, Italy, 1980 1989. *Int J Biometeorol* 2006; 50:335-41.

V.M. Gómez-Mu˜noza, M.A. Porta-Gándarab, J.L. Fernándezc. (2010). Effect of tree shades in urban planning in hot-arid climatic regions. *Landscape and Urban Planning* 94, 149–157

Wei Yang*, Nyuk Hien Wong, Steve Kardinal Jusuf. Thermal comfort in outdoor urban spaces in Singapore. *Building and Environment* 59 (2013) 426-435.

Wong NH, Chen Y. (2005). Study of green areas and urban heat island in a tropical city. *Habitat Int* 2005; 29:547-58.

Yan, H., Wang, X., Hao, P.Y. and Dong, L. (2012) Study on the microclimatic characteristics and human comfort of park plant communities in summer . *Procedia Environmental Sciences*, Vol 13, pp 755 – 76

Santamouris M, editor. (2001) Energy and climate in the urban built environment. London:James and James; 2001.