UNIVERSITI PUTRA MALAYSIA

EFFECTIVENESS OF 'PENAGA LILIN' (MESUA FERREA L.) AND 'PAYUNG INDONESIA' (HURA CREPITANS L.) TREES AS THERMAL RADIATION FILTERS IN OUTDOOR ENVIRONMENT

MOHD. FAIRUZ SHAHIDAN.

FRSB 2007 3

EFFECTIVENESS OF 'PENAGA LILIN' *(MESUA FERREA L.)* AND 'PAYUNG INDONESIA' *(HURA CREPITANS L.)* TREES AS THERMAL RADIATION FILTERS IN OUTDOOR ENVIRONMENT

By

MOHD FAIRUZ SHAHIDAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In Fulfilment of the Requirements for the Degree of Master of Science

December 2007

DEDICATION

This thesis is dedicated to my parents, Shahidan bin Mat Doud and Hasidah binti Awang. Thank you for all your love, patience and sacrifice. To my brothers and sisters, thanks for all your support. Finally, Alhamdullillah to Allah S.W.T for this success.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fullfilment of the requirement for the degree of Master of Science

EFFECTIVENESS OF 'PENAGA LILIN' *(MESUA FERREA L.)* AND 'PAYUNG INDONESIA' *(HURA CREPITANS L.)* TREES AS THERMAL RADIATION FILTERS IN OUTDOOR ENVIRONMENT

By

MOHD FAIRUZ SHAHIDAN

DECEMBER 2007

Chairman: **Professor Mustafa Kamal bin Mohd Shariff, PhD**

Faculty: **Design and Architecture**

In tropical climates, outdoor open spaces are highly exposed to solar radiation, resulting in uncomfortable conditions for pedestrians and other users. This influences the outdoor energy budget, leading to consequential thermal effects on the overall urban environment and contributing to the urban heat island effect. However, trees and other vegetation can play a significant role in reducing the effects of thermal heat in open spaces by filtering the incoming solar radiation before it reaches the ground.

This study compares the effectiveness of two types of tree structural forms in filtering the thermal radiation. The trees are *Mesua ferrea L.* and *Hura crepitans L.*, representing roundhead trees and horizontal shape species respectively. This study focuses on three variables that influence on solar radiation filtration, namely, transmissivity, leaf area index and shade form. Two evaluation methods were employed in this study; (i) a field measurement programme using a modified net radiometer and other related instruments, and (ii) Ecotect - a computer-based sun-shading analysis.

Results from this study indicated that both *Mesua ferrea L.* and *Hura crepitans L.* contribute significantly to direct thermal radiation modification below their canopies. The average heat filtration under tree canopy for *Mesua ferrea L.* was found to be 93% with 5% canopy transmissivity, 6.1 of leaf area index, and 35% of shade area. Meanwhile for *Hura crepitans L.* the average heat filtration under canopy was 79% with canopy transmissivity of 22%, leaf area index of 1.5 and 52% of shade area. Therefore, the study found that *Mesua ferrea L.* was better in filtering thermal radiation than *Hura crepitans L.* (93% and 79% respectively). This was attributed to the denser foliage cover and branching habit of *Mesua ferrea L.* with Leaf Area Index of 6.1 and allowing only 5% transmissivity as compared to *Hura crepitans L.* foliage density and branching system with Leaf Area Index of 1.5 and allowing for 22% transmissivity. Finally, the study also found that tree canopy characteristics of both species significantly influence thermal radiation filtration.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

KEBERKESANAN POKOK PENAGA LILIN *(MESUA FERREA L.)* DAN PAYUNG INDONESIA *(HURA CREPITANS L.)* SEBAGAI PENYARING RADIASI TERMAL DALAM PERSEKITARAN LUARAN

Oleh

MOHD FAIRUZ SHAHIDAN

DISEMBER 2007

Pengerusi: **Profesor Mustafa Kamal bin Mohd Shariff, PhD**

Fakulti: **Rekabentuk dan Senibina**

Di dalam iklim tropika, kawasan lapang sangat terdedah kepada radiasi solar. Ini menimbulkan rasa kurang selesa kepada pejalan kaki dan pengguna lain. Ini juga memberi pengaruh terhadap keperluan tenaga, dimana ianya mengakibatkan kesan termal kepada keseluruhan persekitaran bandar yang menyumbang kepada kesan kepulauan haba. Dalam konteks ini, pokok dan tumbuhan lain memainkan peranan penting dalam mengurangkan haba termal di kawasan lapang dengan bertindak sebagai penyaring radiasi solar yang memancar ke kawasan lapang sebelum ia tiba ke permukaan tanah.

Kajian ini membandingkan keberkesanan dua jenis bentuk pokok dalam menyaring radiasi thermal. Spesies pokok-pokok tersebut adalah *Mesua ferrea L.* (Penaga Lilin) dan *Hura crepitans L.* (Payung Indonesia) yang mewakili spesies pokok berkanopi bentuk bulat dan berkanopi bentuk rendang. Kajian ini hanya menumpu kepada tiga pembolehubah yang mempengaruhi saringan radiasi solar iaitu kadar ketelusan kanopi, nisbah keluasan daun (NKD) dan bentuk teduhan. Kajian ini menggunakan

dua kaedah penilaian (i) program pengukuran ditapak menggunakan alat *net radiometer* yang diubahsuai dan alatan lain yang berkaitan; dan (ii) Ecotect - perisian komputer bagi analisis teduhan.

Hasil kajian mendapati bahawa kedua-dua pokok *Mesua ferrea L.* dan *Hura crepitans L.* menyumbang penuh terhadap pengubahsuaian radiasi termal di bawah kanopi kedua-dua pokok berkenaan. Secara purata haba yang disaring di bawah kanopi pokok *Mesua ferrea L.* adalah sebanyak 93% dengan 5% kadar ketelusan kanopi, 6.1 nisbah keluasan daun (NKD) dan 35% bagi keluasan teduhan. Manakala bagi *Hura crepitans L.* pula, purata haba yang disaring adalah sebanyak 79% dengan 22% kadar ketelusan kanopi, nisbah keluasan daun (NKD) sebanyak 1.5 dan 52% bagi keluasan teduhan. Oleh demikian, kajian mendapati bahawa kedua-dua pokok *Mesua ferrea L.* dan *Hura crepitans L.* adalah penyaring radiasi termal yang efektif. Walaubagaimanapun, pokok *Mesua ferrea L.* terbukti menjadi penyaring radiasi termal yang lebih baik daripada *Hura crepitans L.* (93% dan 79% masing-masing). Ini adalah disebabkan oleh tabiat keluasan daun, dahan serta ranting pokok *Mesua ferrea L.* yang padat dengan 6.1 nisbah keluasan daun (NKD) dan hanya membenarkan 5% ketelusan kanopi jika dibandingkan sistem kepadatan daun, dahan dan ranting pokok *Hura crepitans L.* iaitu dengan nisbah keluasan daun (NKD) sebanyak 1.5 dan membenarkan 22% ketelusan kanopinya. Akhir sekali, kajian ini juga mendapati bahawa karektor fizikal pokok kedua-dua species pokok ini sangat mempengaruhi penyaringan radiasi termal.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and sincere thank to my main supervisor, Associate Professor Dr. Mustafa Kamal Mohd Shariff, for the persistent guidance, assistance, support and understanding throughout the study period.

Gratitude and thanks are also extended to all members of the graduate committee, Profesor Ar. Dato' Elias bin Salleh and Associate Professor Dr. Ahmad Makmom Hj. Abdullah for their constructive comments, advice and guidance.

Special thanks are also due to Dr. Mohd Haniff bin Harun from Malaysian Palm Oil Board (MPOB) for his support and guidance in providing instruments for this research. Thanks are also extended to Dr. Jusang Bolong from the Faculty of Modern Languages and Communication and Associate Professor Dr Ahmad Ainuddin Nuruddin, Deputy Director Rainforest Academy, Universiti Putra Malaysia for his advice and providing useful information.

Much appreciation is dedicated to the Landscape Architecture and Architecture Department staffs and my deepest appreciation to all my colleagues and best friends that support me from time to time. Last but not least, the utmost gratitude goes to my beloved mother, father, brothers and sisters for their wise advices, patience, understanding, sacrifices, and tolerance during the course of my study.

I certify that an Examination Committee has met on 5th December 2007 to conduct the final examination of Mohd Fairuz bin Shahidan on his Master of Science thesis entitled "Effectiveness of 'Penaga Lilin' (*Mesua ferrea* L.) and 'Payung Indonesia' (*Hura crepitans* L.) Trees as Thermal Radiation Filters in Outdoor Environment" 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 degree of Master of Science.

Members of the Examination Committee were as follows:

Osman Mohd Tahir, PhD
Lecturer
Faculty of Design and Architecture
Universiti Putra Malaysia
(Chairman)

Ahmad Ainuddin Nuruddin, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Internal Examiner)

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

Ismail Said, PhD
Associate Professor
Faculty of Design and Build
Universiti Teknologi Malaysia
(External Examiner)

HASANAH MOHD. GHAZALI, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 21 February 2008

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

Mustafa Kamal Mohd Shariff, PhD
Professor
Faculty of Design and Architecture
Universiti Putra Malaysia
(Chairman)

Elias b. Salleh, PhD
Professor
Faculty of Design and Architecture
Universiti Putra Malaysia
(Member)

Ahmad Makmom Hj. Abdullah, PhD
Associate Professor
Faculty of Environmental Studies
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

MOHD FAIRUZ BIN SHAHIDAN

Date: 20th May 2008

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES IN APPENDIX

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Trees are one of the natural elements that have its own special potential that exist to give a significant impact in minimizing environmental conflict such as thermal problems. In concerning plants and the environment, canopy is one major component that can contribute in giving such impact towards microclimatic environment. Shades that form by canopy have their own correlation by their foliage geometry form that react significantly towards microclimate indicators such as solar radiation and wind velocity (Steven *et al.*, 1986). Physical aspects such as form, height, density and branching structure; and leaf covers are the main components that create shade as well as filtration shelter system (Brown and Gillespie, 1995 and Kotzen 2003).

According to Oke (1987), in country such as France, some micro-climatologists have studied the use of vegetation as a form of microclimatic control in outdoor environment. Vegetation such as tree can be planted in four different structures: covering vegetation, isolated trees, groves or lines of trees. Many studies have been performed in the microclimatic performance of these green configurations based on planting design and principles in outdoor surrounding environment (Oke, 1987).

In addition, many studies have been conducted to measure and evaluate on tree design aspect in such a way it can give some extraordinary impact to landscape character as

well as temperature control (Heisler, 1985; Scott *et al.*, 1999; Streiling and Matzarakis, 2003; Rosdi and Ainuddin, 2004; Picot, 2004; and Kotzen, 2003). Tree physical aspect is one major factor that should be considered in giving a good ambient towards microclimatic surrounding. Picot (2004) in his study proved that tree growth could give impact towards users' comfort. It shows that physical aspect of trees may influence the character and the ambient of micro surrounding.

Tree canopy creates shade by its foliage geometry. Crown of tree that was created by branches, leaves and twigs can provide shade and reduce wind speed. The shade cast by trees can reduce glare and block the diffuse light reflected from the sky and surrounding surfaces, thereby altering the heat exchange between the building and its surroundings. During the day, tree shading also reduces heat gain in buildings by reducing the surface temperature of the surroundings (Akbari *et al.*, 2001).

According to Kotzen (2003), the shade indicates a reduction in downward energy flow, particularly of visible light and solar infrared. This shade is created by two elements, namely major and minor branching/limbs as well as leaf covers. The percentage of limbs and leaf cover varies from tree species to tree species, from tree to tree within the species and the density of leaf cover also varies from season to season.

Based on the above statements, we know that the tree canopy physical character can contribute in enhancing microclimate underneath the canopy. The tree that creates shade by its canopy character would give a different quality impact in reducing the surface temperature as well as microclimatic surroundings. However, the value of heat reduction

create by the canopy character should be analysed to enhance the effectiveness of tree as a natural solar radiation filter.

1.2 Problem Statement

In tropical climates, outdoor open spaces are highly exposed to solar radiation. This influences the outdoor energy budget, leading to consequential thermal effects on the overall urban environment (Scott, 1999; Akbari, 2001; Scudo, 2002; Streiling, 2002; Picot, 2004). The heat generated can also lead to the formation of heat islands in urban areas (Akbari, 2001). One way of improving urban microclimate is by using shade trees and green structures in minimizing energy use and reducing thermal effects to the overall surrounding (Akbari, 2001; Streiling, 2002).

Tree canopies and vegetation can play a significant role in reducing the effects of heat in open outdoor spaces by filtering the incoming solar radiation before it reaches the ground surface (Brown and Gillespie, 1995). Shades formed by tree canopies have their own correlation to foliage geometry that significantly influences microclimate indicators such as solar radiation and wind velocity (Steven, 1986). Physical aspects such as form, height, density and branching structure, and foliage cover are the main components that create shade as well as filtration shelter system (Brown and Gillespie, 1995; Kotzen, 2003).

According to Brown and Gillespie (1995p. 97), trees can modify microclimatic elements such as wind velocity, relative humidity, solar radiation and terrestrial radiation. However, it is most effective in modifying solar radiation and terrestrial radiation.

Therefore, trees can react towards all microclimate indicators but most of it is through radiation control.

In fact, tree canopy characteristics such branching, twigs and limbs, foliage cover and tree shape are the main components that contribute to the quality of shade, amount of radiation filter, number of temperature changes underneath the canopy and the microclimate ambient influenced by the canopy (Heisler, 1985; Brown and Gillespie, 1995; Akbari, 2001; Streiling, 2002 and Kotzen, 2003).

Trees that have a horizontal spreading canopy or round shaped canopies can give ample shade and moderate temperatures (Darwin and Saufi, 1980, Said *et. al*, 2004). Horizontal shaped canopy with many spreading branches and round shape canopy with thick and overlapping branching provide shade that reduces evaporation from the asphalt or hard surface thereby reducing the radiant heat underneath the canopy (Darwin and Saufi, 1980; Brown and Gillepie, 1995; Scott, 1999 and Kotzen, 2003).

The main research question that needs to be addressed is how effective are trees with spreading horizontal and roundhead canopies function as an effective thermal radiation filters based on their canopy characteristics?

1.3 Research Question

This study revolves around the question of whether trees of certain species can become an effective thermal radiation filter and therefore can contribute towards reducing thermal heat in urban areas.

1.4 Research Goal and Objectives

The goal of this study is to determine the effectiveness of selected tree species as thermal radiation filters to ameliorate thermal heat in outdoor environment.

To achieve this goal, the following objectives are formulated:

i) To identify tree species with suitable structural form and physical characteristics that can be effective thermal radiation filters;

ii) To evaluate and compare thermal radiation and daylight intensity outside and underneath tree canopy of selected species;

iii) To evaluate and compare leaf area index of selected species;

iv) To evaluate and compare the influence of canopy form of selected species on the amount of shade provided.

1.5 Hypothesis

Hypothesis 1

Ho: *Mesua ferrea L.* is not significantly difference from *Hura crepitans L.* as thermal radiation filter

Ha: *Mesua ferrea L.* is significantly different from *Hura crepitans L.* as thermal radiation filter

Hypothesis 2

Ho: *Mesua ferrea L.* is effective as thermal radiation filter in outdoor environment.

Ha: *Mesua ferrea L* is not an effective thermal radiation filter in outdoor environment.

Hypothesis 3

Ho: *Hura crepitans L.* is effective as thermal radiation filter in outdoor environment.

Ha: *Hura crepitans L.* is not an effective thermal radiation filter in outdoor environment.

1.6 Operational definition of terminologies

In this study, there are operational definitions of terminologies to be determined such as:

i) Microclimate modification can be defined as manipulating or changing the energy of microclimate component by blocking or transmitting or adjusting the partitioning to balance between energy supplied and the energy that need by the consumers. It that can significantly modified through an object elements in landscape in achieving a small outdoor thermally comfortable environment.

ii) Solar radiation can be defined as radiation from the sun whilst Terrestrial radiation is radiation emitted by objects on earth. Solar radiation consists of variety of wavelengths, from very short ultraviolet wavelengths, visible wavelengths and solar infrared wavelengths.

iii) Thermal radiation can be defined as electromagnetic radiation emitted from heat or light source as a consequence of its temperature. It consists essentially of ultraviolet, visible and infrared radiations.

iv) Thermal radiation filtration can be defined as blockage of solar radiation through branches and leaves of a tree by the process of absorption, reflection and transmission in shortwave radiation (consists of infrared, visible light and ultraviolet wavelength) that reduces the energy reaching the ground.

v) Wind factor is the movement of air from one place to the next. However, this factor in not included and measured in the study.

vi) Relative humidity is a term used to describe the quantity of water vapour that exists in a gaseous mixture of air and water.

vii) Temperature is defined as a physical property of a system that underlies the common nations of hot and cold or; a measure of how hot or cold something is.

viii) Tree canopy is defined according to tree characteristic that is constructed by tree trunk, branches, twigs and limbs that formed the shape of the tree. It also consists of leaves that structured and arranged by combination of branching elements and character. Root structure is not considered in this study.

ix) Amount of shade cover is defined as the total shadow that is sheltered from the heat and glare of sunlight created by branching or limbs as well as foliage cover from the tree canopy form. It depends on the tree shape according to tree existing character.

x) Branching is a part of a woody plant such as tree, shrub, or vine. It is any woody structural member that is usually connected to but not part of the central trunk. A large or main branch is sometimes called limb or bough, while very small branches are called branchlets or twigs.

xi) Transmissivity of plants can be defined as the light that is being transmitted after it has been blocked, absorbed and reflected by canopy structure due to the density of branching, twigs and foliage covers character. It can be determined by percentage value (Brown and Gillespie, 1995).

xii) Leaf cover or foliage cover can be defined as the fraction of the ground covered by foliage density. Foliage density can be defined as the amount of leaf in a tree canopy.

xiii) Leaf Area Index (LAI) is index value in estimating leaf density by measuring leaf area per unit ground area. It determines the foliage density of a tree.

xiv) Crown form can be defined as the form of tree that made up and influence by branch, twigs and leaf features formation. It forms an individual