ASPECTS OF TREES AND THEIR INFLUENCE IN REDUCING SOLAR RADIATION PENETRATION TO THE GROUND

Aniza Abu Bakar[1]*, Nurhayati Abdul Malek[1], Amira Nadhirah Mohamad[1], and Noor Aziah Mohd. Ariffin[2]

[1*]*Dept. of Landscape Architecture, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia Kuala Lumpur, Malaysia*
aaniza@iium.edu.my / anizaab@gmail.com
[2]*Dept. of Architecture, Kulliyyah of Architecture and Environmental Design, International Islamic University Malaysia Kuala Lumpur, Malaysia*

Abstract

Vegetation plays an important role in modifying the climate in urban areas. Apart from its function that is to provide shade, the absorption of high proportion of the solar radiation by the dark green leaves, the cooling effect from the evaporation of water from the leaves and the potential of reducing glare are among the roles of vegetation in modifying the microclimate. Not only providing the screening effect to reduce the solar penetration on the ground and walls, the existence of trees in clumps also has the potential in reducing the ambient temperature. However, the potential of trees in addressing the above mentioned functions are yet to be empirically investigated. This study is intended to investigate the aspect of trees: which are the trunk height, crown height, diameter of the canopy as well as the foliage density, and their effect in screening the solar radiation from penetrating and heating the ground. The data collection was done within the campus of the International Islamic University Malaysia (IIUM) due to the availability of various types of trees. Conducted in July 2013 this study involved 89 trees from four case study sites. Solar radiation readings were taken at human level of about 1.5m from the ground underneath the canopies of the investigated trees, between 11am to 3pm. The initial results show significant reduction of the quantity of solar radiation penetrating the canopies from the different tree aspects. These findings are hoped to guide designers in choosing appropriate trees in achieving their design intentions especially when addressing the thermal comfort of users and in mitigating the urban heat island effect.

Keywords: solar radiation, tree aspects – trunk height, crown height, canopy diameter, foliage density

1. Introduction

"*One of the main reasons for considering microclimate in landscape design is to create thermally comfortable habitats for people*"
Brown and Gillespie [1]

Studies on the urban microclimate has been emphasizing on the importance and influence of vegetation in moderating the thermal environment. Lansdberg regarded vegetation as the main and first planning factor of a town in his "utopian meteorologically planned city" (*see* [2]), while 'urban greening' has been suggested as a strategy to mitigate the adverse impact of increased temperatures that results from the climate change [3][4]. Hence, vegetation, thermal environment and its impact on the people have been the interest on many in improving the quality of life.

However, it can be said that studies that focus on the detailed physical aspect of trees in modifying the impact of solar radiation within tropical region is limited [5] and yet to be further explored and expanded. Tropical regions where the sun can be said as constantly positioned high in the sky are experiencing intense solar radiation throughout the year. The urban areas where less vegetation is found are the most impacted areas which lead to the investigations of the urban heat island phenomenon (among others) [5][6].

This study focuses on physical aspect of trees to observe empirically their potential in screening the solar radiation from reaching the ground.

in relation to the screening effect of the trees in an attempt to create a thermally comfortable outdoor environment for the people. Hence, investigations on the tree variables such as the trunk height, crown height, diameter of the canopy as well as the foliage density were conducted in an attempt to identify the most effective tree species in screening the solar radiation as a means to 'control' the microclimate.

2. Vegetation and Microclimate

The influence and impact of vegetation on urban thermal performance or microclimate have resulted in several researches [7][8][9], leading to the identification of specific functions of vegetation as follows (among others):

i. to minimize the effect of solar radiation,
ii. to provide shadowed area, and
iii. to provide cooler air.

Vegetation is said as among the natural landscape element that have remarkable influence to the urban thermal island intensity as it has the edge effect influence to the ambient temperature [6].

2.1 The microclimatic effect of trees

Realising the importance of its impact on creating conducive urban environment, vegetation are always proposed to be planted in urban squares, green spaces, pedestrian shopping, pedestrian network, bicycle routes and vehicular routes [10]. The United States Department of Energy has also produced a manual showing how to mitigate urban heat island through vegetation and the use of light-coloured surfaces [11].

The work of Avissar on the inter-relationship between vegetation coverage, with gradient of sensible heat flux and latent heat flux indicated that the higher the vegetation coverage the lower are both the heat fluxes, as shown in Table 2 [12].

Table 2: Effect of vegetation coverage on heat flux (source: Avissar, 1996)

Vegetation coverage (%)	Gradient of sensible heat flux (W/m^2)	Latent heat flux (W/m^2)
0	450	500
33	250	300
67	125	150
100	0	0

Dimoudi and Nikolopoulou investigated on the physiology of plants and the thermal impact of vegetation and effect of a park on the urban block scale using the Computational Fluid Dynamic (CFD) analysis [13]. They suggested several processes were involved in the microclimatic effect of trees such as the reduction of heat gains through effects of shading and cooling effect through evapotranspiration processes. Based on their research, they concluded that increasing the size and density of the green area reduces the ambient temperature and keeps it relatively local. The effect of orientation is also pronounced through the influence of wind but there is no significant effect between vegetation with low or high evapotranspiration upon the ambient temperatures.

2.2 The screening potentials of trees in reducing the penetration of solar radiation to the ground

Studies have been conducted in investigating the potentials of trees in screening the solar radiation penetration to the ground. Shashua-Bar and Hoffman [8] discovered a reduced penetration of solar radiation on the ground, as well as on walls, due to the increased partial shaded area. According to Padmanabhamurty [14], temperature is reduced by 2.5°C with the existence of forest cover. Sham [15] discovered lower maximum temperatures in the more established settlements with mature trees. Murakami et al. [16] in their study using CFD also discovered that plant canopies can reduce ground surface temperature by 2-4°C. Shahidan et al. [5] compared the effectiveness of two types of tree species which are *Messua ferra L*. and *Hura crepitans L*. in shade creation and radiation modification within hot and humid environment by employing computer simulation and field measurement. They concluded that *Messua ferra L.* is an effective thermal radiation filter due to its canopy properties – thicker branching with higher volume of leaf cover. In addition, a study on the microclimate under three types of shrubs namely *Porlieria chilensis* (zygophyllaceae), *Proustia cuneifolia* (asteraceae) and *Adesmia bedwellii* (papilionaceae) within semiarid environment was conducted throughout seasons of the year (2004-2005) [17]. The microclimate under the shrubs was also further compared with the microclimate away from the canopy of the shrubs The results indicated that generally the air temperature under shrubs was lower than away from canopies. The greatest difference between air temperature and relative humidity reading under shrub is demonstrated by *Porlieria chilensis (with highest average Plant Area Index – PAI)* followed by *Proustia cuneifolia* and *Adesmia bedwellii (with generally the lowest PAI)*.

de La Torre and Serra [18] investigated the role of vegetation in the environmental control of outdoor urban spaces in Barcelona, Spain on a street and a square. They concluded that, in terms of urban microclimate, vegetation has the most evident effects on solar radiation. Their results show that vegetation obstructs, absorbs and reflects a high percentage of solar radiation. Thus, it controls radiant temperature by preventing surfaces from heating up and emitting long wave radiation. Simulation conducted by Picot [19] also confirms that tree foliage has screening potential with the direct effect of reducing solar radiation absorbed under a tree canopy. The work of Fahmy et al. [20] however, cautioned on selection of trees, as trees with high leafs density might trap long-waved radiation by their canopies.

Based on the previous researches, it is thus concluded that apart from the close correlation between urban morphology and its microclimate, vegetation indeed plays a very important role in 'controlling' the thermal performance of the urban area as further clarified by Kurn et al (*see* [21]) as "*Vegetation mitigates the heat island not by cooling the air but by warming the air less*".

A study conducted in several plazas in Putrajaya, Malaysia in 2011 [22] provided the empirical evidence and gave the indication on the influence of landscape setting on the microclimate of the investigated plazas. The best plaza surface material was found to be lighter coloured and finer textured with better performance under the cover of trees than exposed. It was also indicated that colour seems to be an influencing factor that enhances the material's heat absorbing capability more than texture. Another research findings also suggested that ambient temperature can be reduced by up to 3^{o}C while surface temperature can be reduced by up to 8^{o}C by adopting passive cooling techniques such as cool materials, solar control and additional vegetation [23]. In Bahrain, researchers establish that there is a significant improvement in thermal comfort level in areas with more water bodies and vegetation as compared to areas with concrete and asphalt [24].

The purpose of mitigating the Urban Heat Island is not only to solve the urban-scape temperature issue but also would help in reducing energy consumption in buildings within the area. In Singapore, a study had been carried out on the impact of the surrounding urban topography on energy consumption of a building within the urban-scape. The research concluded that the existence of greenery gave the most significant impact to the building energy saving of up to 4.5% reduction in energy consumption [25].

3. Methods of Data Collection

This study was conducted at four case study sites at the International Islamic University Malaysia (IIUM).The aim of this study is to quantify the influence of the tree aspects on solar radiation penetration to the ground with focus on typical trees that can be found in the designed outdoor settings in Malaysia. This study would also lead to defining the thermal comfort of the outdoor spaces. The four sites were categorized into two types of open spaces: green and exposed, as shown in Table 1.

Table 1: The four case study sites in the IIUM and their categorization.

Category	Test sites	Specific site criteria
Green space (GS)	Riverside (RS)	Plenty of trees and shrubs with a stream flowing within the site
	Rector's house (RC)	On a hill top, surrounded with greeneries and plenty of trees
Exposed space (ES)	Mahallah Aminah (MA)	Wide turfed open field with small amount of trees, and partially surrounded by buildings
	Helipad (HP)	Wide tarmac area with small number of trees at the perimeter

The following figure 1 shows the location of these sites within IIUM.

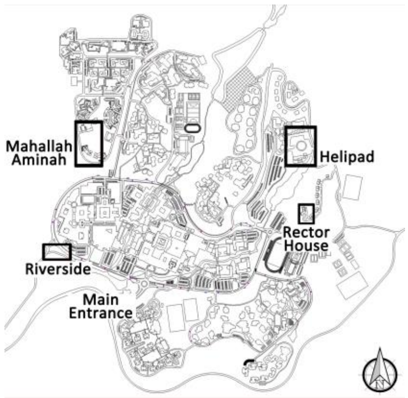

Fig 1: The layout of IIUM with indications on the four sites

The process of data collection was conducted at the end of June and early July 2013 where the position of the sun is considered quite low in the Kuala Lumpur's sky, which was identified using the online tools [26]. It is intended that further investigation will be conducted in the months where the sun's position is the highest in the sky as to compare and contrast the outcome for more meaningful results.

3.1 Identification of area of study

The investigated trees are located at the four test sites as mentioned previously. These sites were identified based on two general categories which are green space and exposed space. "Green space" is referring to space with a lot of big and mature trees as well as being well turfed, while "exposed space" reflected a space that has small amount of trees which caused it to be exposed directly to the sun. Besides that, the ground surface materials are also taken as among the factors considered in selecting the sites for that research [27].

3.2 Trees selection and the process of inventory

Basically all trees within the four sites were identified by their common and scientific names. The trees were examined, measured and inventoried in advanced prior to measuring the solar radiation underneath the tree canopy which was conducted on separate days. Small trees (below 1 meter high) were not included as to standardized the height of the equipment to record the reading for the solar radiation underneath the tree canopy which is at human level of 1.5 meter from the ground. This is also to ensure that the equipment is positioned well to allow its sensor to capture the solar radiation reading while allowing the reading to be read and recorded. The aspects of trees that were measured and inventoried are the trunk height (**TH**), crown height (**CH**), diameter of the canopy (**CD**) as well as the foliage density (**FD**). Based on field observation and adoption of the Likert scale, generally the foliage density can be categorised into three which are loose density, medium density and dense, and these categories are numbered as (1), (2) and (3) accordingly for the purpose of analysis. Figure 2 shows the examples of trees and their foliage densities of these three classifications.

(1) (2) (3)

Fig. 2: Types of foliage density: (1) loose density, (2) medium density & (3) dense
Top - side view/elevation and below - canopy view from underneath

Figure 3 shows the equipment used in the process of the measurement (100 meter measuring tape and staff).

Fig 3: The process and equipment used to measure in the inventory the tree aspect

In order to speed up the process, three enumerators were engaged to measure and record the dimensions while identifying the category of foliage density of each tree. Whenever the trees were higher than the staff used (more than five meters) – approximation by ratio method was applied.

3.3 The process of solar radiation measurement

Following the analysis on daily mean solar radiation data for Kuala Lumpur obtained from the Meteorology Department, Malaysia, the process of solar radiation measurement were decided to be conducted between 11am until 3pm due to the high reading of solar radiation observed with an average reading beyond 400 Wh/m^2 (1 year data) [28]. The period of time for recording the solar radiation readings is shown in Table 3. Each site has different number of trees where RC has the biggest number followed by MA, RS and HP, hence it affects the period of recording the data.

Table 3: The date and time of solar radiation data collection

	Date	Start Time
RS	2 July 2013	11.30 am - 12.15 pm
RC	13 July 2013	12 noon - 1.30 pm
HP	13 July 2013	2 pm - 2.30 pm
MA	14 July 2013	12 noon - 1.30 pm

Two units of solar meter model ISO-TECH ISM 410 were used – refer Figure 4. The accuracy level is ±5%.One unit was located stationary under the direct sunlight with readings taken three times throughout the period for each site – at the beginning (1), half way through (2) and towards the end (3) of the period of the process (Table 5). As for the readings underneath each tree canopy, they were taken for three times consecutively at human level (about 1.3 meters from the ground). The interval between each reading was one minute. These readings were then averaged, and further compared with those taken under the direct sunlight

Fig. 4: The solar meter used and the process to measure solar radiation

4. Analysis on tree aspects and solar radiation penetration

In order to analyse the data, the trees are first identified by their common and scientific names. Then they are grouped solely based on the tree species. These trees are further analysed based on the trunk height (TH), crown height (CH), diameter of canopy (DC) and foliage density (FD) according to species.

4.1 The classification of trees based on common & scientific names – the tree types

There are 6 types of trees species with 89 numbers being investigated as shown in Table 4.

Table 4: The classification of the investigated trees following their location, common and scientific names, and quantity (nos)

Location	Scientific Name	Common Name	
RS, MA, HP	*Samanea Saman (SS)*	Rain tree	18
MA, RC	*Cinnamomum Verum (CV)*	Cinnamon	18
RS, HP	*Lagerstomia Speciosa (LS)*	Pride of India	10
MA	*Phoenix Roebelenii (PR)*	Dwarf date palm	12
MA	*Mangifera indica Linn. (MIL)*	Mango	7
RC	*Hopea Odorata (HO)*	Merawan siput jantan	24
		Total number of trees	**89**

4.2 The analyses on the amount of solar radiation penetrating the tree canopy in relation to the tree aspects studied

In analysing the data, it is hypothesised that smaller trunk height (TH) dimension, bigger crown height (CH) dimension and denser foliage would give lower solar radiation (SR) reading, while the crown density (CD) might not have significant effect to the SR reading underneath the tree canopy. Table 5 indicates the three solar radiation readings recorded under direct sunlight for each and every site during the measurement process.

Table 5: The three solar radiation readings recorded under direct sunlight throughout the measurement process

Site	W/m^2		
	1	2	3
MA	1020.0	932.9	497.4
HP	388.0	398.9	453.4
RC	730.2	801.2	821.0
RS	837.5	1020.6	938.9

Referring to Table 5, it can be seen that in general the range of reading is the highest for Riverside while Helipad showed the lowest range. The range for Mahallah was very wide between nearly 500 W/m^2 and 1020 W/m^2.

Table 6 indicates the approximation of range of solar radiation readings (minimum and maximum) underneath every type of investigated tree.

Table 6: The approximation of range of solar radiation readings (minimum and maximum) underneath every type of investigated tree

Tree Type	W/m^2	
	min	max
SS	50	750
CV	100	350
LS	100	340
PR	180	340
MIL	110	210
HO	283	565

When compared between Table 3, 4, 5 and 6, it can be suggested that generally the tree aspects influence the penetration amount of solar radiation. It is observed that reduced amount of solar radiations readings are recorded underneath those investigated tree canopies as compared to the higher range of solar radiation which are recorded under the directly sunlight.

The following analysis is strategized where these six types of tree species are studied according to their types (intra-species) - the tree aspects of the intra-species trees (CD, TH, CH & FD). They are then being cross-examined with the averaged recorded reading of the solar radiation underneath the trees.

i. Samanea Saman

There are 18 nos of *samanea saman* being investigated. The following Figures 5, 6 and 7 indicate the physical character of these tree species, their classification of foliage density and averaged solar radiation readings respectively, followed by Table 7 that sums up the analysis on *samanea saman*.

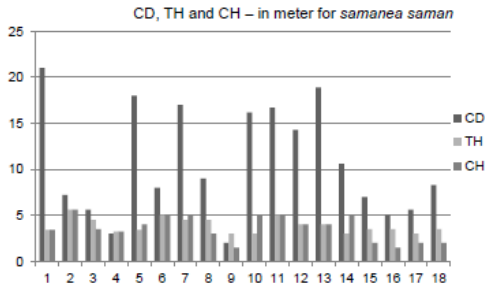

Fig. 5: Dimensions of canopy diameter (CD), trunk height (TH) and crown height (CH) of 18nos.of samanea saman

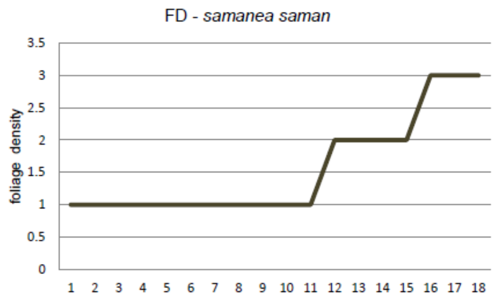

Fig. 6: Categories of foliage density (FD) for 18 nos. of samanea saman

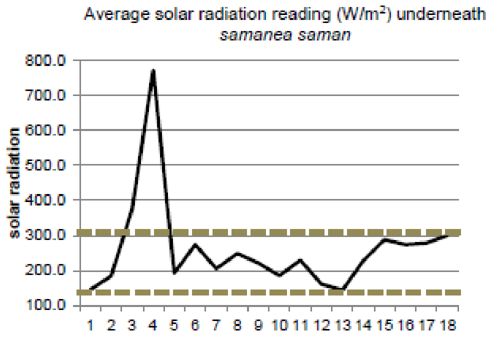

Fig. 7: Average solar radiation readings (W/m^2) underneath 18 nos.of samanea saman

Table 7: The physical analysis of *samanea saman* and general range of solar readings (W/m^2)

Range of TH (m)	3.0 - 5.6	
Range of CH (m)	1.5 - 5.6	
	Ratio	**Nos**
Ratio of CH/TH	= 1.0	7
	< 1.0	7
	> 1.0	4
Ratio of CD/CH	= 1.0	0
	<1.0	1
	>1.0	17
FD*	1	11
	2	4
	3	3
General range of solar readings underneath tree (W/m^2)	150-300	

* 1: least dense; 2: medium dense; 3: dense

ii. Cinnamomum Verum

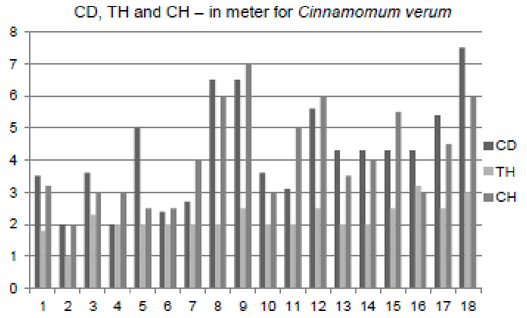

Fig. 8: Dimensions *of canopy diameter (CD), trunk height (TH) and crown height (CH) of 18 nos. of cinnamomum verum*

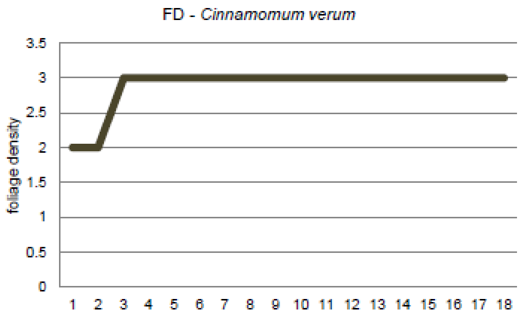

Fig. 9: Categories of foliage density (FD) for 18 nos. of cinnamomum verum

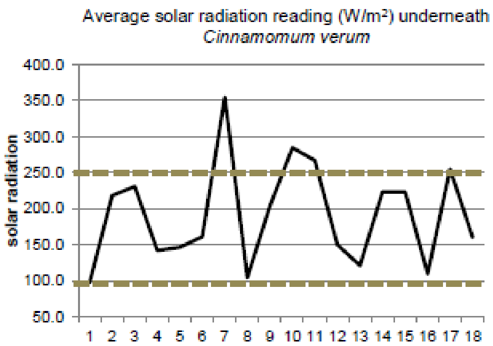

Fig. 10: Average solar radiation readings (W/m^2) underneath 18 nos.of cinnamomum verum

Table 8: The physical analysis of *cinnamomum verum* and general range of solar readings (W/m^2)

Range of TH (m)	1.0 – 3.2	
Range of CH (m)	2.0 – 7.0	
	Ratio	**Nos**
Ratio of CH/TH	= 1.0	0
	< 1.0	1
	> 1.0	7
Ratio of CD/CH	= 1.0	1
	< 1.0	6
	> 1.0	11
FD*	1	0
	2	2
	3	16
General range of solar readings underneath tree (W/m^2)	100-250	

* 1: loose density; 2: medium density; 3: dense

iii. Lagerstomia Speciosa

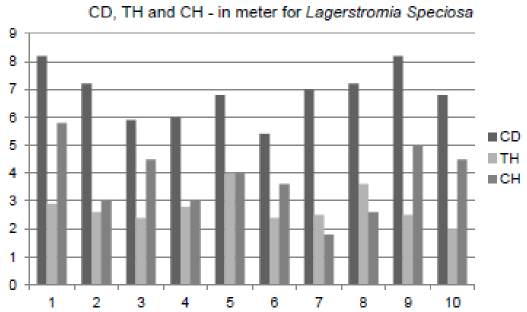

Fig. 11: Dimensions of canopy diameter (CD), trunk height (TH) and crown height (CH) of 10 nos. of lagerstromia speciosa

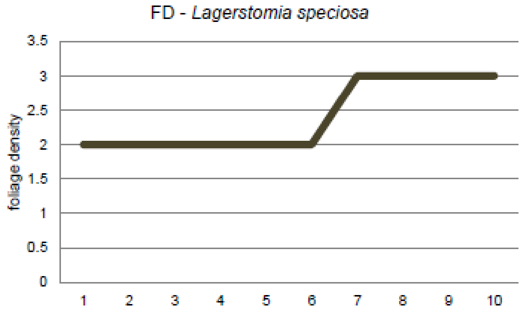

Fig. 12: Categories of foliage density (FD) for 10 nos. oflagerstromia speciosa

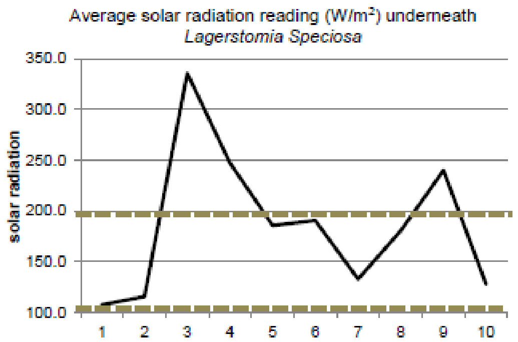

Fig. 13: Average solar radiation readings (W/m^2) underneath 10 nos. of lagerstromia speciosa

Table 9: The physical analysis of *lagerstomia speciosa* and general range of solar readings (W/m^2)

Range of TH (m)	2.0 – 3.6	
Range of CH (m)	1.8 – 5.8	
	Ratio	**Nos**
Ratio of CH/TH	= 1.0	1
	< 1.0	2
	> 1.0	7
Ratio of CD/CH	= 1.0	0
	< 1.0	0
	> 1.0	10
FD*	1	0
	2	6
	3	4
General range of solar readings underneath tree (W/m^2)	100-200	

* 1: loose density; 2: medium density; 3: dense

iv. Phoenix Roebelenii

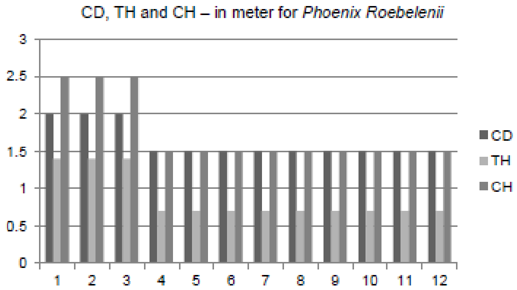

Fig. 14: Dimensions of canopy diameter (CD), trunk height (TH) and crown height (CH) of 12 nos. of phoenix roebelenii

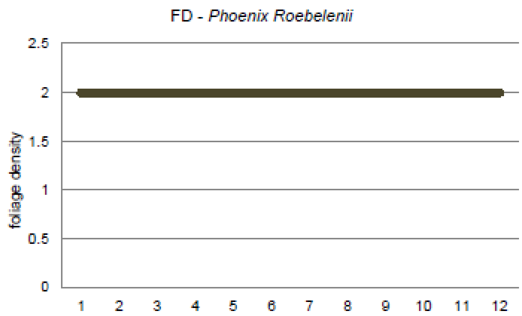

Fig.15: Categories of foliage density (FD) for 12 nos. of phoenix roebelenii

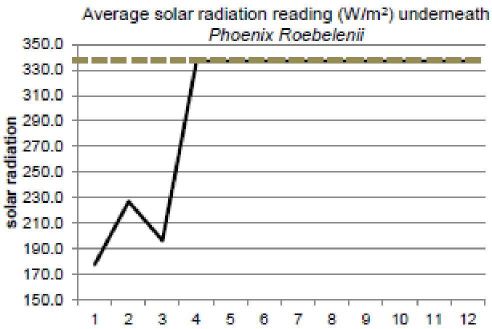

Fig. 16: Average solar radiation readings (W/m^2) underneath 12 nos.of phoenix roebelenii

Table 10: The physical analysis of *phoenix roebelenii* and general range of solar readings underneath the tree (W/m^2)

	Ratio	Nos
Range of TH (m)	0.7 – 1.4	
Range of CH (m)	1.5 – 2.5	
	Ratio	**Nos**
Ratio of CH/TH	= 1.0	0
	< 1.0	0
	> 1.0	12
Ratio of CD/CH	= 1.0	0
	< 1.0	3
	> 1.0	9
FD*	1	0
	2	12
	3	0
General range of solar readings underneath tree (W/m^2)	±337	

* 1: loose density; 2: medium density; 3: dense

v. Mangifera Indica Linn

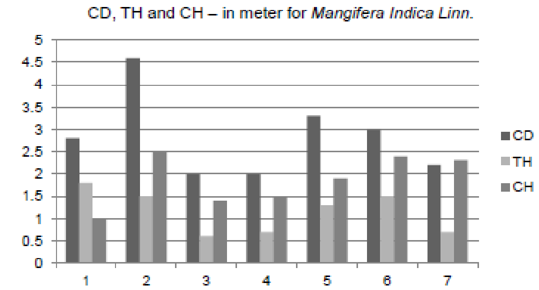

Fig. 17: Dimensions of canopy diameter (CD), trunk height (TH) and crown height (CH) of 7 nos.of mangifera indica linn.

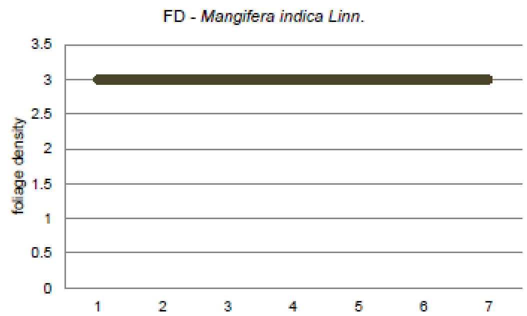

Fig. 18: Categories of foliage density (FD) for 7 nos. of mangifera indica linn.

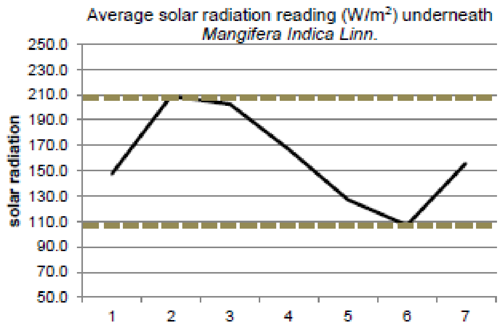

Fig. 19: Average solar radiation readings (W/m^2) underneath 7 nos.of mangifera indica linn.

Table 11: The physical analysis of *mangifera indica linn.*and general range of solar readings underneath the tree (W/m^2)

	Ratio	Nos
Range of TH (m)	0.6 – 1.8	
Range of CH (m)	1.0 – 2.5	
	Ratio	**Nos**
Ratio of CH/TH	= 1.0	0
	< 1.0	1
	> 1.0	6
Ratio of CD/CH	= 1.0	1
	< 1.0	0
	> 1.0	6
FD*	1	0
	2	0
	3	7
General range of solar readings underneath tree (W/m^2)	107-209	

* 1: loose density; 2: medium density; 3: dense

vi. *Hopea Odorata*

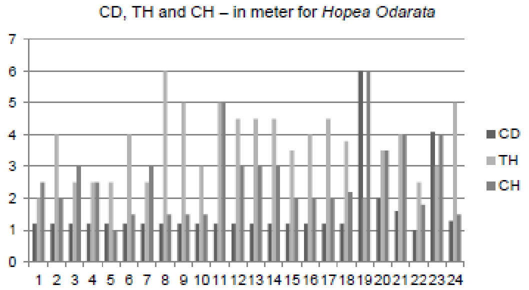

Fig. 20: Dimensions of canopy diameter (CD), trunk height (TH) and crown height (CH) of 24 nos. of hopea odorata

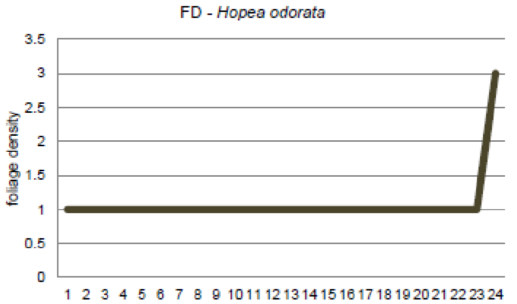

Fig. 21: Categories of foliage density (FD) for 24 nos. of hopea odorata

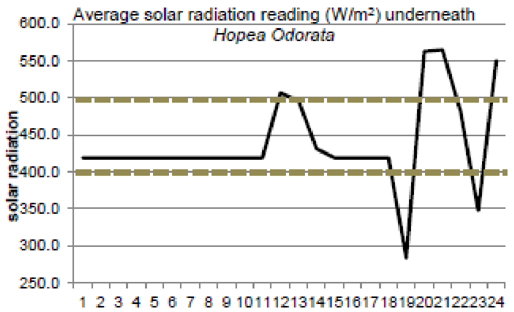

Fig. 22: Average solar radiation readings (W/m^2) underneath 24 nos. of hopea odorata

Table 12: The physical analysis of *hopea odorata* and the general range of solar readings underneath the tree (W/m^2)

Range of TH (m)	2 - 6	
Range of CH (m)	1 - 6	
	Ratio	**Nos**
	= 1.0	0
Ratio of CH/TH	< 1.0	1
	> 1.0	6
	= 1.0	1
Ratio of CD/CH	< 1.0	0
	> 1.0	6
	1	23
FD*	2	0
	3	3
General range of solar readings underneath tree (W/m^2)	400-500	

* 1: loose density; 2: medium density; 3: dense

The following Table 13 indicates the best tree species in screening the solar radiation from penetrating to the ground.

Table 13: An attempt to rank the tree types that best screen solar radiation penetration

Tree types	Range underneath the tree (W/m^2)	Location – Nos.	Rank
SS	150-300	RS - 8 MA - 5 HP – 5	4
CV	100-250	MA - 6 RC -12	3
LS	100-200	RS - 9 HP – 1	1
PR	330	MA - 12	5
MIL	107-209	MA - 7	2
HO	400-500	RC - 24	**6**

In an attempt to identify and rank the tree types that best screen solar radiation penetration to the ground, cross-analysis was conducted and examined between the time and dates when the measurement was conducted (Table 3), the sites with types of tree species (Table 4), the range of solar readings recorded under direct sunlight throughout the measurement process (Table 5), and the range of solar radiation readings underneath tree (Table 7 until Table 12). The tree types are then ranked as such. *Lagerstromia speciosa* is suggested as the best solar radiation screener while *hopea odorata* seems to be the worst among these six tree types.
Therefore, the physical aspects of tree which are the CD, TH, CH and CD for these two tree species are further analysed. When compared and contrasted, the followings are found:

Table 14: Analysis on the physical aspects of *hopea odorata* (HO) and *lagerstromia speciosa* (LS)

	HO	LS
Dimension of CH bigger than TH	9 (38%)	7 (70%)
Dimension of CH smaller than TH	15 (62%)	2 (20%)
Dimension of CH = TH	0 (0%)	1 (10%)
Dimension of CD smaller than CH and TH	21*	0

*the dimensions of CD, TH and CH for the other 3 are:
i – 1.2m,2.5m, 1.0m
ii – 6.0m, 2.0m, 6.0m
iii – 4.1m, 3.0m, 4.0m

Referring to Table 14, it can be said that generally for *lagerstromia speciosa* its crown height is bigger than its trunk height, and the dimension of its diameter of the canopy is bigger than its crown height and trunk height – while *hopea odorata* is otherwise. Hence, it can be suggested that trees with bigger dimension of crown height than trunk height, with bigger dimension of diameter of canopy than that of crown height & trunk height seem to screen the solar radiation penetration to the ground better. Looking into the foliage density, as for *lagerstromia speciosa* it falls within medium dense (6/10 – 60%) and dense (4/10 – 40%); while for *hopea odorata* it can be categorized as least dense as 96% (23/24) falls under least dense (1/24 of was identified as dense).

5. Conclusion and Recommendation

The field investigation has provided some insight on the influence of tree aspects of the typical Malaysian trees investigated on the amount of solar radiation that can penetrate to the ground. It can be concluded that *lagerstromia speciosa* is the best tree out of the six trees investigated in screening the solar radiation penetration to the ground. Hence, the results of this investigation seem indicate that tree aspects influence the amount of solar radiation penetration to the ground.

Thus, the analysis and result may provide some guidelines to the designer in choosing appropriate tree species and its characters (tree aspects – crown diameter, trunk height, crown height and foliage density) towards controlling the microclimate of the space to be designed.

Based on this investigation, there are many rooms for improvement identified. Due to the unavailability of localised weather station, it was quite difficult to monitor the macro and direct solar radiation. It is hope such data is available in the future. For future investigation, based on the data and result obtained, selected trees can be studied further by collecting and analysing data on the air temperature and relative humidity underneath the tree canopy (human level) – as to see how the tree aspects influence the micro-climate there. Other than that, the data can be further re-analysed as to see the significance level of each aspect studied towards influencing the penetration of solar radiation to the ground. This would perhaps lead to rank the tree aspects that have great influence. More tree species that are commonly found in the context of Malaysian landscape can be included too in the future investigations.

6. Acknowledgements

This study is funded by the International Islamic University Malaysia, EDW-B11-271-0749.

7. References

1. Brown, R.D., and Gillespie, T.J., (1995), *Microclimatic landscape design: creating thermal comfort and energy efficiency*. New York: John Wiley & Sons.
2. Wilmers, F., (1990/91), Effects of vegetation on urban climate and buildings, *Energy and Buildings*, Vol. 15-16, pp. 507-514.
3. Bowler, D.E., Buyung-Ali, L., Knight, T.M., and Pullin, A.S., (2010), Urban greening to cool towns and cities: A systematic review of the empirical evidence, *Landscape and Urban Planning*, Vol. 97, pp. 147-155.
4. Gago, E.J., Roldan, J., Pacheco-Torres, R., and Ordóňez, J., (2013), The city and urban heat islands: A review of strategies to mitigate adverse effects, *Renewable and Sustainable Energy Reviews*, Vol. 25, pp. 749-758
5. Shahidan, M.F., Mohd. Shariff, M.K., Jones, P., Salleh, E., and Abdullah, A.M., (2010), A comparison of Messua ferra L. and Hura crepitans L. for shade creation and radiation modification in improving thermal comfort, *Landscape and Urban Planning*, Vol. 97, pp. 168-181
6. Zhang, Y., Yiyun, C., Qing, D. and Jiang, P., (2012), Study of urban heat island effect based on ormalized difference vegetated index: A case study of Wuhan City, Procedia Environmental Sciences, Vol. 13, pp. 574-581
7. Shashua-Bar, L., Tzamir, Y., and Hoffman, M.E., (2004), Thermal effects of building geometry and spacing on the urban canopy layer microclimate in a hot-humid climate in summer, *International Journal of Climatology*, Vol. 24, pp. 1729-1742.
8. Shashua-Bar, L., and Hoffman, M.E., (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*, Vol. 31, pp. 221-235.
9. Shashua-Bar, L., and Hoffman, M.E., (2003), Geometry and orientation aspects in passive cooling of canyon streets with trees, *Energy and Buildings*, Vol. 35, pp. 61-68 .
10. de Schiller and Evans, (1998), Sustainable urban development: design guidelines for warm, humid cities. *Urban Design International* 4, 165-184.
11. Oke, T.R., Johnson, G.T., Steyn, D.G., & Watson, I. D. (1991). Simulation of surface urban heat island under 'ideal' conditions at night Part 2: Diagnosis of causation. *Boundary-Layer Meteorology,* 56, 339-358.
12. Avissar, R., Potential effects of vegetation on the urban thermal environment, *Atmospheric Environment* 30 (3) (1996) 437–448.
13. Dimoudi, A., and Nikolopoulou, M., (2003), Vegetation in the urban environment: microclimatic analysis and benefits, *Energy and Buildings*, Vol. 35, pp. 69-76
14. Padmanabhamurty, B., (1991), Microclimates in tropical urban complexes, *in:Energy and Buildings*, Vol. 15-16, Elsevier Sequoisa S.A., Lausanne, Switzerland, pp. 83-92.
15. Sham, S., (1990/91), Urban climatology in Malaysia: an overview, *in:Energy and Buildings*, Vol. 15-16, Elsevier Sequoisa S.A., Lausanne, Switzerland, pp. 105-117.
16. Murakami, S., Ooka, R., Mochida, A., Yoshida, S. and Kim, S., (1999), CFD analysis of wind climate from human scale to urban scale, *Journal of Wind Engineering and Industrial Aerodynamics*, Vol. 81, pp. 57-81.
17. Tracol, Y., Gutiérrez, J.R. and Squeo, F.A., (2011), Plant Area Index and microclimate underneath shrub species from a Chilean semiarid community, *Journal of Arid Environments*, Vol. 75, pp. 1-6.
18. de La Torre, J.M.O., and Serra, R., (1998), *Microclimatic analysis of some urban scenarios*, In: Environmentally friendly cities - Proceedings of PLEA '98, Lisbon, Portugal, June 1998, London, James & James (Science Publishers) Ltd., pp. 159-162.
19. Picot, X., (2004), Thermal comfort in urban spaces: impact of vegetation growth – case study: Piazza della Scienza, Milan, Italy, *Energy and Buildings*, Vol. 36, pp. 329-334.

20. Fahmy, M., Sharples, S. and Yahiya, M., (2010), LAI based trees selection for mid latitude urban developments: A microclimatic study in Cairo, Egypt, Building and Environment, Vol. 45, pp. 345-357.
21. Shashua-Bar, Hoffman, M.E., and Tzamir, Y., (2006), Integrated thermal effects of generic built forms and vegetation on the UCL microclimate, *Building and Environment*, Vol. 41, pp. 343-354.
22. Abu Bakar, A. and Mohd. Ariffin, N.A., (2012), *The effect of ground surfaces – material, color & texture towards the adjacent thermal environment: a case study of plazas in Putrajaya, Malaysia*, in: IIUM-Toyo Joint Symposium 2012. Sustainable Built Environment: lesson learned from Malaysia and Japan, 15 November 2012, Tokyo, Japan
23. Fintikakis, N., Gaitania, N., Santamourisa M., Assimakopoulosa, M., Assimakopoulosa, D.N., Fintikaki, M., Albanisb, G., Papadimitrioub, K., Chryssochoidesb, E., Katopodib, K. and Doumasb, P., (2011) Bioclimatic design of open public spaces in the historic centre of Tirana, Albania, *Sustainable Cities and Society*, Vol. 1, 54-62.
24. Radhi, H., Fikry, F., and Sharples S., (2013) "Impacts of urbanisation on the thermal behaviour of new built up environments: A scoping study of the urban heat island in Bahrain", Landscape *and Urban Planning*, Vol. 113, 47-61.
25. Wong, N.H., Jusuf, S.K., Syafii, N.I., Chen, Y., Hajadi, N., Sathyanarayanan, H., and Manickavasagam, Y.V., (2011), Evaluation of the impact of the surrounding urban morphologyon building energy consumption, *Solar Energy*, Vol. 85, 57-71.
26. http://www.sunearthtools.com/dp/tools/pos_sun.php
27. Abu Bakar, A., Mohamad, A.N., and Sanusi, A.N.Z. (2013), *The impact of the landscape setting on the hot-humid outdoor microclimate towards mitigating the urban heat island – A preliminary investigation*, in: International Conference of Architecture and Built Environment 2013, 7 and 8 November 2013, Kuala Lumpur
28. Abu Bakar, A. (2007), *User response to thermal comfortof outdoor urban spaces in hot-humid region*. PhD thesis, University of Nottingham, United Kingdom.