

COOLING EFFECTS OF TWO TYPES OF TREE CANOPY SHAPE IN PENANG, MALAYSIA

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ABSTRACT: Shade trees provide a cooling effect by blocking sunlight, increased ambient air humidity and provide shade during the day. All trees cannot offer relief from the heat in the same amount. This study compared the shading effectiveness of two types of canopy shape (rounded and spreading) in the landscape of Universiti Sains Malaysia, Penang. There are four species selected for this study. Field measurement of microclimate conditions under the tree canopy and open spaces were repeated on a sunny day. The effect of trees shade on air temperature, surface temperature, relative humidity, solar radiation and solar transmission were also compared and related to the leaf area index (LAI). It was found that the air temperature under the canopy could be reduced between 0.67 °C to 2.55 °C, while the surface-soil temperature can be reduced between 3.23 °C to 8.15 °C. Tree species with higher LAI values, *Swietenia macrophylla* (Big leaf mahogany) and *Tabebuia rosea* (Tecoma) provide significantly more cooling than the other species. Reduction of surface temperature is positively correlated with leaf area index. This study shows that shade tree in tropical climates are helpful in improving the outdoor thermal comfort, cooling ground surface by encouraging more latent heat and reduces air temperature by encouraging more evapotranspiration. Thus, the selection of tree species with higher leaf area index value can maximize the benefits they provide to the surrounding area.

Keywords: Shade trees, Tree canopy, Microclimate, Cooling effect, Heat island mitigation

1. INTRODUCTION

Shade tree planting is one of strategy to reduce heat islands and improve community comfort in three ways such as through shading, evapotranspiration and wind shielding [1][2]. Trees in the urban environment have great potential with many functions such as modulating the microclimate, reducing air and noise pollution, providing a habitat for urban wildlife and improving aesthetic values of urban area. In hot humid climate, high intensity of solar radiation and low wind velocity are the problems experienced by users of open space. Tree can provide relief from high temperature at two spatial scales. Firstly at the microscale through a direct shading effect below canopy, where by incoming solar radiation is intercepted by the canopy and may be either absorbed or reflected. Secondly at the local scale through evaporative cooling, where energy is used for dominated by larger scale warmer and drier surroundings [3].

Many studies have been reported about the measurement and evaluation to tree design aspects in providing significant impact to landscape character, improving the microclimatic performance of built environments, adapting patterns to climate change, and reducing energy consumption and temperature control [4][5][6][7][8]. During the day, shade trees also indirectly reduce heat gain in buildings by altering

terrestrial radiation and ultimately reducing ground surface temperatures [9][10][11]. Previous study it was found that constant tree shade can reduce mean radiant temperatures by 5°C – 7°C and concrete surface shaded permanently by a bank of trees can be cooled by up to 20°C in the summer in Manchester, UK [12]. Study by numerical simulations suggest that increasing tree cover by 25% would reduce summer temperature by 3.3°C - 5.6°C in Sacramento and Phoenix [13]. A single layer of leaves allow some visible and infrared radiation to be absorb 50%, whilst reflecting 30% and transmitting the other 20%. Meanwhile, all trees can filter approximately 80 - 90% of incoming radiation, referring on their leaf density, arrangement and type of leaf [14]. Study reported a comparison of two type of tropical tree species found that the average heat infiltration of *Messua ferrea L.* is 97% whilst that of *Hura crepitans L.* is 86% [14]. Thus, this will affect comfort of people sitting or walking in the shade, namely that most affects a person's thermal comfort as quantified by measures such as their perceived or physiologically equivalent temperature (PET) [15].

The effect of shade trees on urban microclimate can divided in five major effects such as shading effect, ground temperature effect, surface temperature effect, wind effect and reflection effect [16]. Vegetations that have more density value have a greater heat infiltration value [14]. Shading effect of shade trees depends on tree

characteristic and configuration. Physical aspects such as geometry of the canopy, height, density and branching structure, colour of tree leaves and leaf covers are the main components that create shade as well as moderate the microclimate [7][17][18][19]. Moreover for roundhead and pyramidal canopy have a greater shade area than columnar [16]. Shade effectiveness is also related to the leaf area index (LAI), which is defined as a dimensionless value of the leaf area per unit ground area. It is the key measure used to understand and compare plant canopies [20]. The shade performance of each species is different, and their effectiveness in filtering radiation will influence microclimate modification. Thus, it is important to investigate the differences between species to understand the impact of each tree species on outdoor comfort [7][17][19].

This study is set out to evaluate the differences in cooling effect of two types of tree canopy shape trees in Penang, Malaysia and to investigate how physical characteristics of trees might affect their performance on a sunny day. The objective of the study are to evaluate the relationship between physical characteristic (tree height, crown height, crown area, crown diameter and LAI) of tree, and observed differences in microclimate conditions under the tree canopy and open space.

2. METHODS

2.1 Tree and Site Selection

One of criteria for the choice of species was those among the most used in tree planting programs by the city council in Penang, Malaysia. The study focused on two types of tree canopies such as roundhead and spreading canopy. All data on trees within the Universiti Sains Malaysia campus were gathered according to tree selection criteria. The selection parameters were divided into two parts, (i) tree physical characteristic and (ii) microclimate condition. The first part comprises several sub parts considered in defining the parameters; tree types, foliage and structural geometry, tree crown and tree maturity. Second part for microclimate condition divided to sub parts namely; site condition with equal environment, ground surfaces and no shading by other trees or buildings.

There four species were identified these were divided into two categories of shape; two species of roundhead, i.e., *Swietenia macrophylla* (big leaf mahogany) and *Filicium decipiens* (fern tree), and two species of spreading canopy, i.e., *Tabebuia Rosea* (tecoma) and *Dalbergia oliveri* (tamalan) (Fig. 1). All tree samples were selected based on the following criteria which is similar height, tree size (medium size), age ranging from 10 to 20

years, evergreen, similar microclimatic condition, ground space cover at least 60-70% turf and 30-40% other materials and open space and not interfered by shade of any buildings.

The trees studied were localized at the Universiti Sains Malaysia, Gelugor, Penang, Malaysia (latitude 5.3569°N, longitude 100.3014°E) (Fig. 2). Samples of the selected *S. macrophylla* were located at an open space near to the Desasiswa Tekun building. These trees were 10-15 years old and planted randomly. The location of the selected *T. Rosea* species was at a green space near to the Dewan Tuanku Syed Putra, Lecturer Theatres S, T, U & V and the School of Biological Sciences buildings. The trees were 10-15 years old and planted in row. Meanwhile, samples of the selected *F. decipiens* were located at an open space near to the Desasiswa Restu building. The trees were 10 years old and planted in a row. Lastly, the location of the selected *D. oliveri* species was along Desasiswa Tekun Avenue. The trees were 10 years old and planted in row. The groups of the tree samples are shown in Fig. 3.

All measurements were carried out for each tree at 10.00 am, 12.00 pm and 14.00 pm during the stated period. Only five samples for each type of tree were used and a total tree for measurement was about 20 samples. All measurements were taken over a four day period, namely 14th and 28th of February and 3rd and 5th of March 2015.

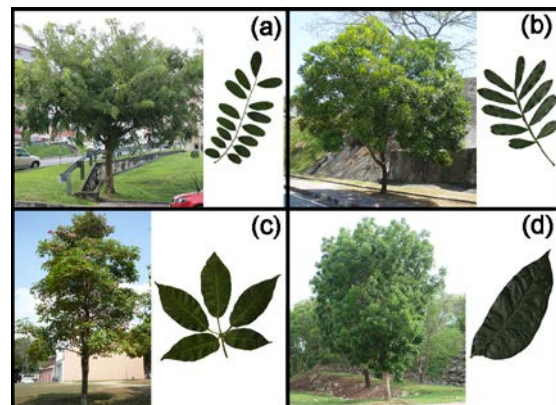


Fig.1 Tree species (a) *D. oliveri*, (b) *F. decipiens*, (c) *T. rosea* and (d) *S. macrophylla*



Fig.2 Locations of the four species investigated



Fig.3 Groups of selected tree species (a) *S. macrophylla*, (b) *F. decipiens*, (c) *T. rosea* and (d) *D. oliveri*

2.2 Measurement Procedure of Solar Radiation, Solar Transmission, Air Temperature, Relative Humidity and Surface Temperature

The measurements under the tree canopy were taken first. Solar radiation and solar transmission were done using the solar power meter (TES-1333). Air temperature and relative humidity measurements were taken using the (Extech's 45160) 3-in-1 Pocket Hygro-Thermometer-Anemometer. Infrared thermometer (IRtek IR60) was used in measuring ground surface temperature in each tree sample and measurement were taken at 1m height. Solar power meter (TES-1333) and (Extech's 45160) 3-in-1 Pocket Hygro-Thermometer-Anemometer attached to a tripod stand 1m above the ground. All measurements were carried out under the tree canopies and the data were recorded manually. All instruments were placed equidistant from the tree trunk and canopy drip line along each of the four main compass points (north, south, east and west).

The measurements in the open were taken after each set of measurements under the canopy had been completed. The measurements were done using the same set of instruments, approximately 2 m away from the canopy drip line and taken at one point for each tree.

2.3 Measurement Procedure of Leaf Area Index

The measurement of LAI using indirect method which is canopy analysis systems based hemispherical image analysis. It involves a lot of steps from photography to LAI calculation. Hemispherical photographs of a single tree were capture using a digital camera high resolution, Canon EOS 60D Kit with fish eye lens with a field of view of 180° was used. The camera was mounted on a sturdy tripod at 1.0 m height to characterize the canopy without the interfering presence of understory vegetation. The camera was

leveled to face exactly the vertical using a bubble level. The top of the camera (position of the flash socket) was orientated to magnetic north using a compass. Photographs were taken without direct sunlight entering the lens in the early morning, late afternoon or on overcast days [21][22]. Therefore, all measurements were done early morning before 9.00 am and it's taken over a one day, namely the 18th of May 2015. This study is using free software for computing LAI from hemispherical photograph, namely WINPHOT by Hans ter Steege [20][23]. The hemispherical photograph was then imported to Paint program to convert from format (.jpeg) to 256 Color Bitmap (*.bmp,*.dib). Finally, the image was then opened in WINPHOT to compute and analyze for getting LAI value.

2.4 Measurement Procedure of Shaded Area

To measure amount of shaded area by using computer simulation, main thing need create 3 dimensional of the tree form. Firstly, digital photographs of a single tree were capture using a digital camera. It was taken at 10 m away from the centre of the tree and held at the eye level of the photographer. Snap point were done in two option either from north, northwest and northeast or south, southeast and southwest according to the site conditions. The image was transferred to a computer and by using AutoCAD 2011 software to generate the skeleton of the tree. This skeletal drawing was then imported to SketchUp software to convert from format AutoCAD files (.dwg) to 3DS file (.3ds). The skeletal drawing was then transferred to ECOTECT 2011 to generate a 3D modelling of the tree and also conduct Shadow Analysis for each tree. Simulated shaded area for all trees was running on the 4th of May 2015 at 10.00 am, 12.00 pm and 14.00 pm (Fig. 4). Thus, this was the best time to compare all measurements.

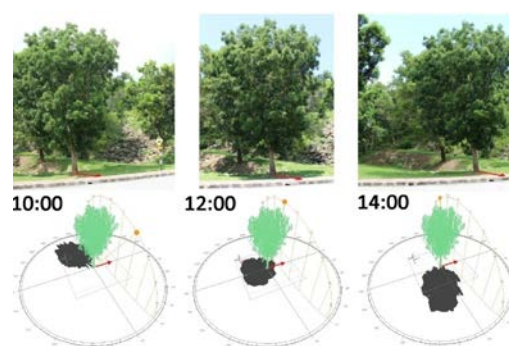


Fig.4 Shaded area between actual shaded area and computed analysis on the 4th May 2015 at 10:00, 12:00 and 14:00

3. RESULTS

The four species had quite different physical characteristic, one-way ANOVA showings significant differences between the species in tree height ($F_{(3,16)}=39.142$, $P=0.000$), crown height ($F_{(3,16)}=35.580$, $P=0.000$), crown diameter ($F_{(3,16)}=6.363$, $P=0.005$) and crown area ($F_{(3,16)}=5.203$, $P=0.011$). Post hoc analysis shows that of all species, *D. oliveri* had the shortest but widest canopy. Mean air temperature reduction was 3.697% (StD=0.850). One-way ANOVA showed that there were no significant differences between the species in air temperature reduction ($F_{(3,16)}=1.931$, $P=0.165$). The mean surface temperature reductions were 16.507% (StD=1.340). One-way ANOVA showed that there were not significant differences between the species ($F_{(3,16)}=1.032$, $P=0.405$). The mean solar radiation filtrations were 81.892% (StD=1.848). One-way ANOVA showed that there were not significant differences between the species ($F_{(3,16)}=1.544$, $P=0.242$). The mean leaf area indexes were 2.096 m^2/m^2 (StD=0.508). One-way ANOVA analysis showed that there were significant difference between species ($F_{(3,16)}=13.481$, $P=0.000$). Post-hoc analysis showed that the *S. macrophylla* had significantly higher leaf area index than *T. rosea*, *F. decipiens* and *D. oliveri*. The mean transmissivity were 12.206% (StD=1.317). One-way ANOVA showed that there were not significant differences between the species ($F_{(3,16)}=1.762$, $P=0.195$). The mean shade areas were 104.80 m^2 (StD=29.579). One-way ANOVA showings significant differences between the species in shade area ($F_{(3,16)}=5.254$, $P=0.010$). Post-hoc analysis showed that the *S. macrophylla* shade area significantly more than other species.

3.1 Relationship between solar radiation filtration and (transmissivity, leaf area index, shade area, air temperature and surface temperature)

3.1.1 *Dalbergia oliveri*

The results show that transmissivity ($t=-19.585$, $P=0.000$, $R^2=0.992$, $SEE=0.123$), shade area ($t=5.080$, $P=0.015$, $R^2=0.896$, $SEE=0.449$) and air temperature reduction ($t=5.652$, $P=0.011$, $R^2=0.914$, $SEE=0.408$) are significant factors for solar radiation filtration but no significant for LAI ($t=1.946$, $P=0.147$, $R^2=0.558$, $SEE=0.925$) (Fig. 5) and surface temperature reduction ($t=1.911$, $P=0.152$, $R^2=0.549$, $SEE=0.935$). The increase solar radiation filtration percentage corresponds to the decrease transmissivity percentage value of *D.*

oliveri canopy. In addition, the increase solar radiation filtration percentage corresponds to the increase value of shade area, LAI, air temperature reduction and surface temperature reduction of *D. oliveri* canopy.

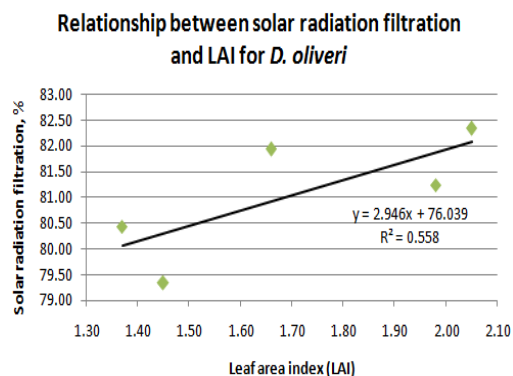


Fig.5 Regression of solar radiation filtration and leaf area index (LAI) of *D. oliveri*

3.1.2 *Filicium decipiens*

The results show that transmissivity ($t=-14.755$, $P=0.001$, $R^2=0.986$, $SEE=0.227$), LAI ($t=3.434$, $P=0.041$, $R^2=0.797$, $SEE=0.878$), air temperature reduction ($t=34.913$, $P=0.000$, $R^2=0.998$, $SEE=0.097$) and surface temperature reduction ($t=3.454$, $P=0.041$, $R^2=0.799$, $SEE=0.874$) are significant factors for solar radiation filtration but no significant for shade area ($t=2.144$, $P=0.121$, $R^2=0.605$, $SEE=1.225$). The increase solar radiation filtration percentage corresponds to the decrease transmissivity percentage value of *F. decipiens* canopy. In addition, the increase solar radiation filtration percentage corresponds to the increase value of LAI, shade area, air temperature reduction and surface temperature reduction of *F. decipiens* canopy.

3.1.3 *Tabebuia rosea*

The results show that transmissivity ($t=-13.039$, $P=0.001$, $R^2=0.983$, $SEE=0.385$), LAI ($t=15.869$, $P=0.001$, $R^2=0.988$, $SEE=0.317$), shade area ($t=5.136$, $P=0.014$, $R^2=0.898$, $SEE=0.935$), air temperature reduction ($t=7.679$, $P=0.005$, $R^2=0.952$, $SEE=0.644$) and surface temperature reduction ($t=7.993$, $P=0.004$, $R^2=0.940$, $SEE=0.619$) are significant factors for solar radiation filtration. The increase solar radiation filtration percentage corresponds to the decrease transmissivity percentage value of *T. rosea* canopy. In addition, the increase solar radiation filtration percentage corresponds to the increase value of LAI, shade area, air temperature reduction and surface temperature reduction of *T. rosea* canopy.

3.1.4 *Swietenia macrophylla*

The results show that transmissivity ($t=-10.313$, $P=0.002$, $R^2=0.973$, $SEE=0.261$), LAI ($t=10.521$, $P=0.002$, $R^2=0.974$, $SEE=0.256$) (Fig. 6), shade area ($t=7.269$, $P=0.005$, $R^2=0.946$, $SEE=0.946$) and air temperature reduction ($t=6.036$, $P=0.009$, $R^2=0.924$, $SEE=0.434$) are significant factors for solar radiation filtration but no significant for surface temperature reduction ($t=2.463$, $P=0.091$, $R^2=0.669$, $SEE=0.905$). The increase solar radiation filtration percentage corresponds to the decrease transmissivity percentage value of *S. macrophylla* canopy. In addition, the increase solar radiation filtration percentage corresponds to the increase value of LAI, shade area, air temperature reduction and surface temperature reduction of *S. macrophylla* canopy.

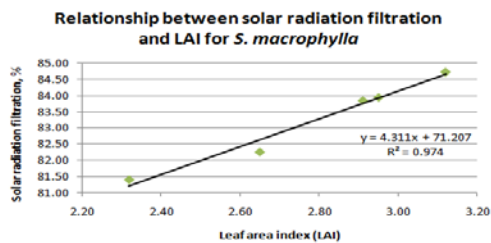


Fig.6 Regression of solar radiation filtration and leaf area index (LAI) of *S. macrophylla*

3.2 Evaluate the cooling potential of scenario modifications

The evaluation of the current as well as the proposed scenarios by adding trees for microclimate modification was achieved with the use of ENVI-met model. ENVI-met was used to simulate the interaction of surface-air-plants in three dimensional models. The simulation included two main development strategies that were proposed to improve outdoor thermal environments through their implementation. The findings were discussed based on three conditions and were coded as: (A) current condition, (B) applied by adding double the amount of trees with high LAI value at current ground surface condition, and (C) applied by adding double the amount of trees with low LAI value at current ground surface condition. Simulations were performed at Tekun hostel of Universiti Sains Malaysia in the sunny day. The maximum building height in the study area was 30 m (10 stories). A main model domain area was built within 99 x 88 x 33 grids with input dimensions of dx, dy and dz = 2m x 2m x 3m. Basic data settings in this simulation for air temperature is 29.85 °C, wind speed is 1.5m/s at 10 m height, relative humidity is 78% and roughness length in 10 m is 0.1.

Meanwhile in Fig. 7 shows the current conditions were compare with two modification strategies. This comparison is discussed regarding air temperature variation and to identify hot and cool spot on the campus area. In the current condition, the air temperature at pedestrian level, ranged between 27.43°C to 29.87°C (average 28.65°C) during the peak of the day (15:00). The conditions (A) were compared with condition (B), a maximum temperature difference of 0.05°C occurred. The air temperature reduction occurred between these scenarios with an average difference of up to 0.15°C. The conditions (A) were compared with condition (C), a maximum temperature difference of 0.02°C occurred. The air temperature reduction occurred between these scenarios with an average difference of up to 0.05°C.

This comparison is discussed regarding relative humidity variation at the campus area (Fig. 8). In condition (A), the relative humidity at pedestrian level, ranged from 48.83% to 58.35% (average 53.59%) during the peak of the day (15:00). The conditions (A) were compared with condition (B), a maximum relative humidity difference of 1.64% occurred. The relative humidity increase occurred between these scenarios with an average difference of up to 0.88%. The conditions (A) were compared with condition (C), a maximum relative humidity difference of 0.60% occurred. The relative humidity increase occurred between these scenarios with an average difference of up to 0.35%. In condition (B) were made to achieve optimum cooling effect beneath the canopy level.

In this experimental study, despite various buildings, ground pavement and tree planting generally provided cooling benefits at the pedestrian level and people who use outdoor space around the campus especially during summer days. Therefore, these green features are recommended in combination with outdoor landscape designs. These modifications will benefit the outdoor thermal environment.

(A) current condition, (B) and (C) modified conditions

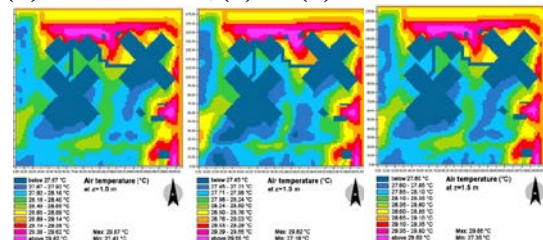


Fig.7 Air temperature at three different conditions: (A) current condition, (B) and (C) modified conditions compared at 15:00 in pedestrian level (1.5m)

(A) current condition, (B) and (C) modified conditions

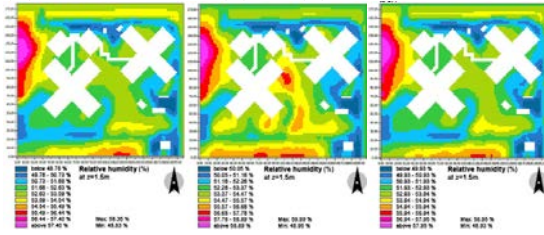


Fig.8 Relative humidity at three different conditions : (A) current condition, (B) and (C) modified conditions compared at 15:00 in pedestrian level (1.5m)

4. DISCUSSION

4.1 Tree physical characteristic and shade area

The sampled tree species showed significant differences in their canopy size and shape, and these differences also show in significant differences between the shade areas produced by the tree canopies. This because the taller trees, such as *S. macrophylla* had narrower canopies, while the shorter trees such as *D. oliveri* had wider canopies. Statically relationship through the correlation between the amount of shaded areas and radiation filtration is not significant ($r=0.289$, $P=0.217$). The results indicated that there is significant difference in the mean amount of shaded area of *D. oliveri* (103.732m²), *F. decipiens* (83.340m²), *T. rosea* (94.452m²) and *S. macrophylla* (137.680m²). Based on ECOTECT analysis results and observation, the roundhead canopy of *S. macrophylla* and the spreading canopy of *D. oliveri* provide a broader shaded area than that of *T. rosea* and *F. decipiens*. Shade coverage is important especially in tropical environments during the middle of the day when the sun position overhead for longer duration and it is hottest. Shade characteristics for each tree depend on the form of the canopy and branching of the species, the amount of leaf cover, growing location and the angle of the sun.

4.2 Air temperature and surface temperature

The outcome shows that the mean air temperature reduction of *D. oliveri* (3.070%), *F. decipiens* (3.574%), *T. rosea* (3.930%) and *S. macrophylla* (4.214%) (Fig. 9). Meanwhile, results for the mean surface temperature reduction of *D. oliveri* (16.126%), *F. decipiens* (15.858%), *T. rosea* (16.964%) and *S. macrophylla* (17.082%) (Fig. 10). Meaning that, *S. macrophylla* and *T. rosea* are more reduction in air temperature and surface temperature than *F. decipiens* and *D.*

oliveri. Air temperature reduction ($r=0.778$, $P=0.000$) and surface temperature reduction ($r=0.690$, $P=0.001$) are show positive relationship and significant factors for LAI. Meaning that, *S. macrophylla* and *T. rosea* has thicker branching, twigs and leaves that can create a higher LAI value provide greater surface cooling. Shade trees can contribute to significant reductions in surface temperatures and this will have effect of reducing heat storage in the paved surface. This condition will increase latent heat, promote more evapotranspiration and reduce surrounding air temperature, this should help improved the urban heat island effect.

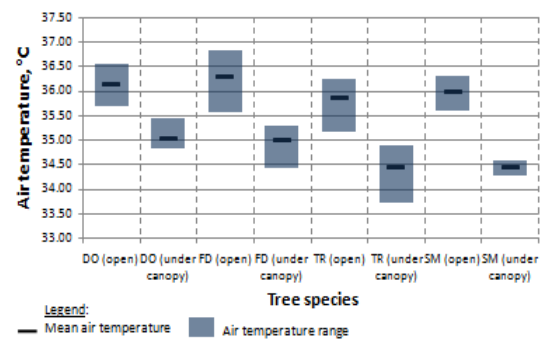


Fig.9 Mean air temperature and temperature range, within 10:00 to 14:00 for the tree species

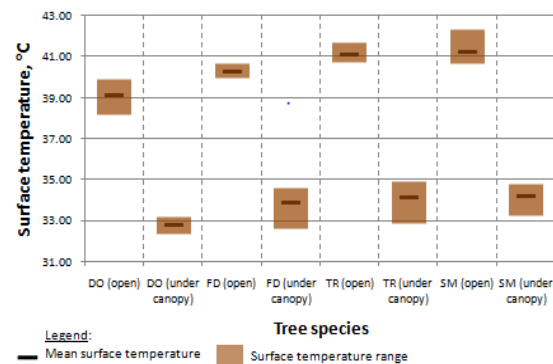


Fig.10 Mean surface temperature and temperature range, within 10:00 to 14:00 for the tree species

4.3 Solar radiation

All trees have the ability to filter solar radiation. The results indicated that the mean solar radiation filtration of *D. oliveri* (81.052%), *F. decipiens* (81.266%), *T. rosea* (82.016%) and *S. macrophylla* (83.234%). Thus, *S. macrophylla* and *T. rosea* are more effective in solar radiation than *F. decipiens* and *D. oliveri*. Meaning that, *S. macrophylla* and *T. rosea* has thicker branching, twigs and leaves that can create a higher LAI value, less canopy transmissivity and made the best contribution in

blocking radiation from reaching the ground surface. On the other hand, *D. oliveri* have spreading and an open crown with droopy and feathery compound leaves, this condition will allow more radiant heat passed through the canopy. That means, *D. oliveri* provide some shade from solar radiation, but the effect is not sufficient due to higher radiation transmission and reflection when compared to *S. macrophylla*.

4.4 Transmissivity

The results indicated that the mean transmissivity of *D. oliveri* (12.920%), *F. decipiens* (12.482%), *T. rosea* (12.242%) and *S. macrophylla* (11.182%). There was a significant negative correlation between solar radiation filtration and transmissivity ($t=-22.500$, $P=0.000$, $R^2=0.966$). The increase solar radiation filtration value corresponds to the decrease transmissivity value. A lower value of transmissivity is considered a suitable condition. This means that the transmissivity of the *S. macrophylla* and *T. rosea* canopy is better than *F. decipiens* and *D. oliveri*. This indicated that the *S. macrophylla* and *T. rosea* canopy provides greater density of branching and twigs than *F. decipiens* and *D. oliveri*. A higher reduction of light intensity and glare due to obstruction from branching will create better shade and could increase human comfort.

4.5 Leaf area index (LAI)

The outcome shows that the mean LAI of *D. oliveri* ($1.702\text{m}^2/\text{m}^2$), *F. decipiens* ($1.842\text{m}^2/\text{m}^2$), *T. rosea* ($2.052\text{m}^2/\text{m}^2$) and *S. macrophylla* ($2.790\text{m}^2/\text{m}^2$). This means that the foliage cover and surface area of *S. macrophylla* and *T. rosea* is denser and higher than *F. decipiens* and *D. oliveri*. Correlation results show positive relationships are strong and significant between solar radiation filtration and LAI for *S. macrophylla* and *T. rosea*. Therefore, it can filter solar radiation and light more effectively than the latter. Based on images of leaf sizes (Fig. 1) and branching (Fig. 11), it is evident the most of the *S. macrophylla* canopy has dense rounded crown with leaves are usually paripinnate (12–45cm long) and are made up of 3–6 pairs of lanceolate or ovate leaflets are asymmetrical (5–12cm long x 2–5cm wide). This provide more multiple layers of leaf throughout the branching and twigs will promote more reflection and absorption of incoming solar radiation and helps in reducing transmission of radiant heat under the canopies. Shaded trees with a higher LAI should contribute more of reducing the urban heat island. In addition, for *F. decipiens* canopy has a

dense spreading crown with leaves (13–17cm long) and small oval leaflets (1.8–3.0 long x 1.2–1.8cm wide) that are alternately arranged, and it provides a less multiple layer and low density of leaf cover. So for the tree with better radiation filtrations are significantly relate with branching habits and leaf distributions characteristics.



Fig.11 Image record from under *S. macrophylla* (right) and *D. oliveri* (left) trees showing leaf and branching characteristics

5. CONCLUSION

This paper set out to illustrate the shading effectiveness of two types of tree canopy shape in hot humid regions. All trees, namely *D. oliveri*, *F. decipiens*, *T. rosea* and *S. macrophylla* have ability to vary solar radiation due to their physical characteristic. Physical characteristics related to higher LAI values contribute to tapping more incoming solar radiation. Study have shown that some physical characteristics likes foliage cover, branching habit and types, size and arrangement of leaves play important roles in improving efficiency in radiation reflection and absorption. Study find that species with a higher LAI, higher solar radiation filtration, less transmissivity, such as *S. macrophylla* and *T. rosea*, do reduce air temperature and surface temperature and increase relative humidity more because they cast a denser shade. These effect is thought to increase when this species is planted in clusters and its will help in producing cool island effects in city areas. Meanwhile for species provides less LAI value, less solar radiation filtration and higher transmissivity, such as *D. oliveri*, due to the less dense branch habit and small size of leaves. However, physical characteristic of *D. oliveri* with spreading structure of the canopy create more shade, especially during overhead sun. Thus, the study suggest that *D. oliveri* is suitable for planting in parking area or open space because this tree require a wider shade but can tolerant moderately reduced radiant heat. ENVI-met simulations showed that applying tree planting in a road, parking lot, sidewalk and open space could lead to air temperature decrease and relative humidity increase, respectively. The condition with adding

trees with high LAI value can contributed of the air temperature reduction and relative humidity increase with an average difference of up to 0.15°C and 0.88%, respectively. Finally, this knowledge can be implementing by professionals in urban planning and design to offer better outdoor thermal comfort and contribute to energy budgets of buildings and humans in tropical urban climate environments.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

- [1] Y. J. Huang, H. Akbari, and H. Taha, "The wind-shielding and shading effects of trees on residential heating and cooling requirements," in *Proceedings of the ASHRAE Winter Conference*, 1990, pp. 1403–1411.
- [2] R. A. Nasir, S. S. Ahmad, A. Zain-Ahmed, and N. Ibrahim, "Adapting human comfort in an urban area: The role of tree shades towards urban regeneration," *Procedia - Soc. Behav. Sci.*, vol. 170, pp. 369–380, 2015.
- [3] T. R. Oke, *Boundary Layer Climates_2nd ed.*, Taylor & F. Routledge, London, 1987.
- [4] H. Akbari, D. M. Kurn, S. E. Bretz, and J. W. Hanford, "Peak power and cooling energy savings of shade trees," *Energy Build.*, vol. 25, no. 2, pp. 139–148, 1997.
- [5] S. Klaus I, S. James R, and M. E Gregory, "Effetcs of tree cover on parking lot microclimate and vehicle emissions," *J. Arboric.*, vol. 25, no. 3, pp. 129–142, 1999.
- [6] S. Streiling and A. Matzarakis, "Influence of single and small clusters of trees on the bioclimate of a city: a case study," *J. Arboric.*, vol. 29, no. 6, pp. 309–316, 2003.
- [7] B. Kotzen, "An investigation of shade under six different tree species of the Negev desert towards their potential use for enhancing micro-climatic conditions in landscape architectural development," *J. Arid Environ.*, vol. 55, no. 2, pp. 231–274, Oct. 2003.
- [8] X. Picot, "Thermal comfort in urban spaces: Impact of vegetation growth. Case study: Piazza della Scienza, Milan, Italy," *Energy Build.*, vol. 36, no. 4, pp. 329–334, 2004.
- [9] H. Akbari, M. Pomerantz, and H. Taha, "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas," *Sol. Energy*, vol. 70, no. 3, pp. 295–310, Jan. 2001.
- [10] R. Pandit and D. N. Laband, "Energy savings from tree shade," *Ecol. Econ.*, vol. 69, no. 6, pp. 1324–1329, 2010.
- [11] S. Leuzinger, R. Vogt, and C. Körner, "Tree surface temperature in an urban environment," *Agric. For. Meteorol.*, vol. 150, no. 1, pp. 56–62, 2010.
- [12] D. Armson, P. Stringer, and a. R. Ennos, "The effect of tree shade and grass on surface and globe temperatures in an urban area," *Urban For. Urban Green.*, vol. 11, no. 3, pp. 245–255, 2012.
- [13] H. Akbari, S. Davis, S. Dorsano, J. Huang, and S. Winnett, "Cooling our communities. A guidebook on tree planting and light-colored surfacing," Washington, D.C., 1992.
- [14] M. F. Shahidan, M. K. M. Shariff, P. Jones, E. Salleh, and A. M. Abdullah, "A comparison of Mesua ferrea L. and Hura crepitans L. for shade creation and radiation modification in improving thermal comfort," *Landsc. Urban Plan.*, vol. 97, no. 3, pp. 168–181, Sep. 2010.
- [15] a Matzarakis, H. Mayer, and M. G. Iziomon, "Applications of a universal thermal index: physiological equivalent temperature.," *Int. J. Biometeorol.*, vol. 43, no. 2, pp. 76–84, 1999.
- [16] G. Scudo, "Thermal comfort in greenspaces," in *Proceeding COST C 11 "Green structures and urban planning"*, 2002.
- [17] B. S. Lin and Y. J. Lin, "Cooling effect of shade trees with different characteristics in a subtropical urban park," *HortScience*, vol. 45, no. 1, pp. 83–86, 2010.
- [18] L. Vieira de Abreu and L. Chebel Labaki, "Trees and heat fluxes: how much do they contribute to the energy balance at urban spaces?," in *27th International Conference on Passive and Low Energy Architecture*, 2011, vol. 1, pp. 245–250.
- [19] D. Armson, M. A. Rahman, and A. R. Ennos, "A comparison of the shading effectiveness of five different street tree species in Manchester, UK," *Arboric. Urban For.*, vol. 39, no. 4, pp. 157–164, 2013.
- [20] N. J. J. Bréda, "Ground-based measurements of leaf area index: a review of methods, instruments and current controversies.," *J. Exp. Bot.*, vol. 54, no. 392, pp. 2403–17, Nov. 2003.
- [21] G. Frazer, J. Trofynow, and K. Lertzman, "A method for estimating canopy openness, effective leaf area index, and photosynthetically active photon flux density using hemispherical photography and computerized image analysis techniques.," 1997.

- [22] J. Glatthorn and P. Beckschäfer, "Standardizing the Protocol for Hemispherical Photographs: Accuracy Assessment of Binarization Algorithms," *PLoS One*, vol. 9, no. 11, pp. 1–19, 2014.
- [23] H. ter Steege, "Winphot 5.0: A Programme to Analyze Vegetation Indices, Light and Light Quality From Hemispherical Photographs," 1997.

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