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VEGETATION DENSITY AND THEIR IMPACT ON URBAN OPEN SPACES MICROCLIMATE: A CASE STUDY OF KLCC PARK, KUALA LUMPUR, MALAYSIA

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ABSTRACT

Urban open spaces are one of the characteristics of urban environment that is of enormous importance in the daily life of people living in urban areas. However, urban open spaces in tropical climate are highly exposed to solar radiation. These conditions will lead to increased global warming and urban heat island. Therefore, vegetation (trees) in urban areas is of special value as they can reduce the air temperature by direct shading of surface as well as by moderating solar heat gain through evapotranspiration of the trees. This study compares the effectiveness and influences of vegetation density (High, Medium and Low Density) on microclimate modification in improving ambient and human thermal comfort in urban open spaces. The study employed three (3) methods: (i) plant species selection procedure, (ii) a field measurement procedure and (iii) computer-based microclimate analysis (Temperature, Surface temperature and Relative humidity). The result from this study indicates that high vegetation, medium vegetation and low vegetation density of Peltophorum pterocarpum (Yellow Flame) species on 100 meter² have a different significance to direct microclimate on urban open spaces. The study found that the high vegetation density of the under turf and pavement of 100 meter² has more significance and influence on the microclimate modification in urban open spaces than the medium and low vegetation density due to the tree canopy. High vegetation density of Peltophorum pterocarpum (Yellow Flame) species of 100 meter² capability contributes to the reduction of the air temperature of up to 3.1 °C by promoting more evapotranspiration and effectively improving the ambience and outdoor thermal comfort in tropical urban open spaces.

Keywords: urban open space; vegetation; density; microclimate; modification

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1. INTRODUCTION

Rapid development and urbanization, in general are the main factors that strongly influenced the lives of the world community and its development. Research in the 20th century has revealed that there are approximately 3 million inhabitants in the city. Further research forecasted that in the 25th century another 2 million would migrate to the city (Bonan, 1997). The dramatic patterns of migration are usually observed in the developed countries that contributed to the increment of the net as well as the percentage of the population in the city. The city environmental space is very important to the daily life of the community. Open public spaces that confer healthy environmental characteristics are able to affect the lifestyle of the community in the city by enhancing its quality and calmness. It also gives huge impact on the community daily life by providing a very clean environment as well as sufficient recreational space complete with all the facilities and infrastructure. Unfortunately, the increase in the populations in towns or cities has resulted in the reduction of the greenery and open spaces for the sake of urbanization. The phenomenon further leads to Concrete Island effect which are formed due to the combination of the differences of the energy utilization factor, population density and rural area climate. Global warming is one of the consequential effects of urbanization and rapid development and this has ignited concern among the community. Different approaches and strategies are needed in order to reduce the urban heat island effect and global warming.

1.1 Problem Statement

The reduction of the effect of urban heat island can reduce the national energy consumption in the air conditioning system by 20% as well as improving the air quality (Shaharuddin Ahmad, 2006). Issues arising from global warming have shown the significant importance of vegetation and greenery, especially its influence on the physical aspects of city environment which involved the thermal comfort level, air quality and its effect on noise pollution. Moreover, the urban heat island is an after effect of high radiation absorbance on the surface of the city with minimal greenery coverage. In the urban area, vegetation possesses a very high value due to its contributory effect on mental health and its capability in reducing extreme heat radiation rate as extreme heat might severely affect the community's daily activities. As compared to other structural components in a building surrounding an area, vegetation is very important in reducing infrared radiation and air temperature, absorbing noise and reducing the radiation capacity as well as thermal conduction. Plants existing in the urban open spaces have the ability in creating a cool and clean air and this phenomenon is known as Park Cool Island. The urban heat island can be neutralized by the presence of plants and greenery, in reducing the air temperature and improving its environment through the shading effects of the tree, reducing the solar heat radiation through the evaporation process and converting solar heat radiation to latent heat (Akio Onishi, 2010).

1.2 Objective

The aim of the study is to measure the effect of the vegetation density of *Peltophorum Pterocarpum* for every 100 m² on public open spaces microclimate. A few objectives have been established in order to accomplish the research aims which are, to determine the density size of vegetation that is capable in assisting the restoration of the KLCC Park microclimate, to evaluate and compare the surface temperature, ambience temperature and relative humidity

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among the high, medium and low density vegetation under the turf surface and pavement surface as well as to evaluate and compare the influence of the plant density on the temperature differences and relative humidity in the KLCC Park microclimate.

1.3 Literature Review

1.3.1 Effects and benefits of Peltophorum Pterocarpum (Yellow Flame)

Specifically, the benefit of Yellow Flame lies in their ability to restore the community aesthetical value towards the green area extension and bring the community closer to nature. Furthermore, it can strongly alter local climate by providing shadings, evapotranspiration and wind velocity while storing and modifying the heat in between the urban spaces. Yellow Flame can specifically reduce radiation up to 90%. Evapotranspiration is defined as a process of radiation absorption through the canopy of trees which cools its surrounding environment and the air movement allows total cool air to be released (Bonan, 1997).

1.3.2 Urban Open Space Heat Reduction (Cooling)

The efficacy of the cooling effect in a building is best provided by the leaves of shady trees especially if the trees are placed near the windows and rooftops of the buildings. Shading provided by Yellow Flame surrounding the building is very useful in controlling the radiation rate received, thus reduce the ambience's temperature. The execution of the planting process and the park design of the park will affect the temperature of the urban open spaces. The air temperature around the park and under the trees is usually cooler as compared to the open areas that have less number of trees. This is due to the Yellow Flame canopies that are able to directly absorb radiation and lower the heat rate below the plant surface. According to McPherson (2011), the vegetation is essential as it balances the heat that the environment receives. Meanwhile, Taha, Akbar and Rosenfeld (1991), further stated that large scale planting has the ability to lower the surrounding temperature by 2 °C to 8 °C. Previous study evidently proves planting trees is a very useful method in reducing temperature at urban open space areas. Besides that, characteristics of a park are very important as it also has a definite influence on the cooling effect of the urban open space areas. Shashua Bar (2000) further added that the shading of trees is an essential element that is closely associated with the cooling effect of the open space ambience. In order to alter the urban open space ambience's temperature, coverage and shading of the trees play a very important role.

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2. RESEARCH METHOD

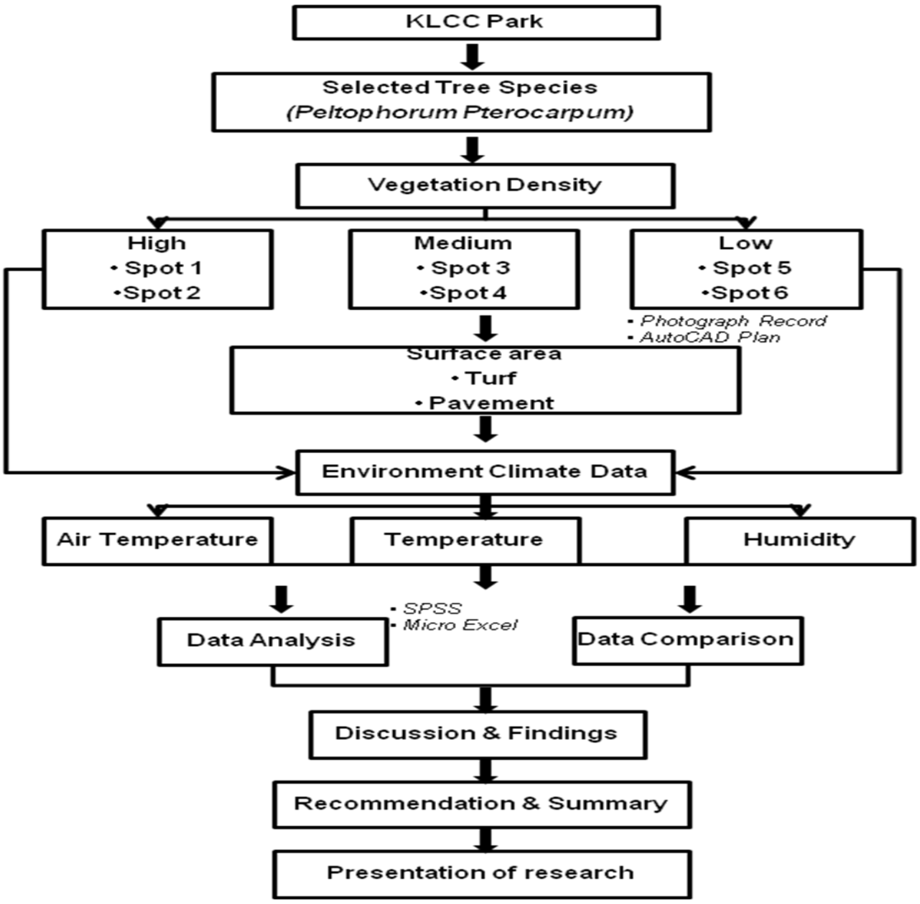

Figure 1: Research Methodology Framework

2.1 Site Selection (Study Location)

KLCC Park is one of the most popular urban public parks in Kuala Lumpur. The park has been planned in an effort to add greenery to the surrounding area. The KLCC Park itself is a 50-acre open space designed by the late Brazilian Landscape artist, Roberto Burle Marx (Figure 2). The park also provides for an integrated development with an appropriate balance between commercial and public land use between international image and national heritage and between engineered masonry and natural greenery. This study was conducted in order to determine which vegetation density category in an urban open space that will exert its effects and influence the micro scale climate and produce cool air for the local environment. *Peltophorum pterocarpum*, a type of tree species and local data climate were used as parameters for this research.

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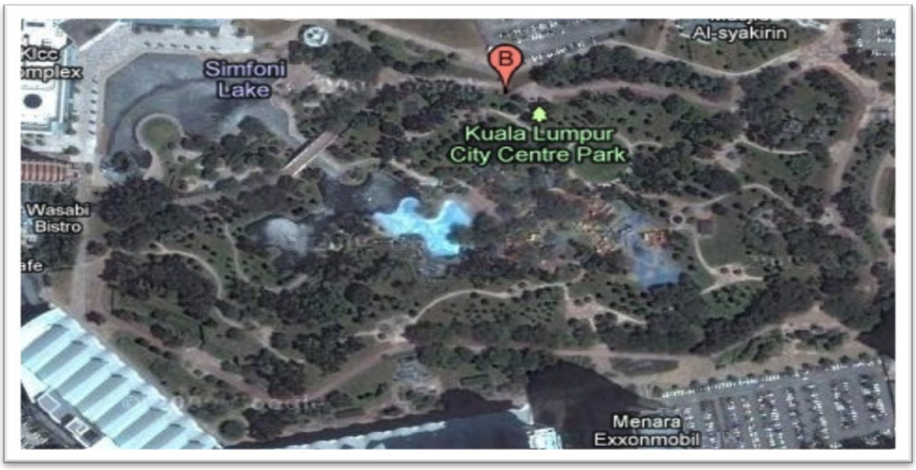

Figure 2: The Location of KLCC Park (Source:http://www.google.com.my/images)

2.2 Selected Tree Species

In order to observe the effect of plant species in microclimate at the research location, the tree species was selected based on the physiological characteristics and environmental condition. *Peltophorum pterocarpum* was selected based on the similar heights, tree size, constant greenery and had received similar weather and climate treatment. The *Peltophorum pterocarpum* was selected based on its positioning and placement at every 100 m². Besides that, the shape of the shade was uniform and the area that was shaded is covered by 30-40% of the pavement surface and 60-70% of grass surface. Yellow Flame or scientifically called *Peltophorum pterocarpum* is a plant species that has been selected in determining the microclimate condition and this species represents the trees from the umbrella like canopy tree species (Figure 3).

Yellow Flame was also chosen due to its (a) wide and medium size branches (b) dense spreading crown (used in shelterbelts because it is wind firm) (c) fast growing tree (has the ability to fix nitrogen) and (d) elegant ornamental tree. Besides that, Yellow Flame's wide and horizontal leaf structure which provides shading to its environment has made this plant to be commonly planted as landscape decoration that provides shading and is mostly planted in tropical gardens, public parks and in open public fields (Corner, 1997).

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Figure 3: Specimen Selected for Field Measurement; Yellow Flame (*Peltophorum pterocarpum*) (Source: Researcher)

2.2.1 Tree (Peltophorum pterocarpum) Location

There are three types of vegetation density involved in this research area which are the high, medium and low density (Figure 4).

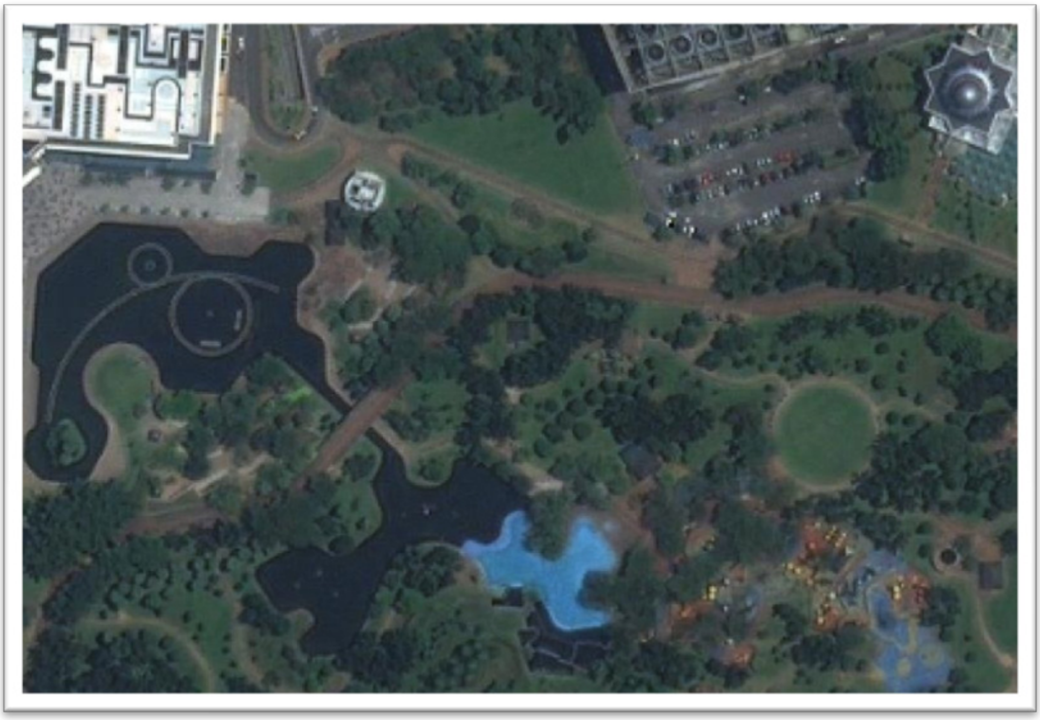

Figure 4: The Vegetation Density are Categorized Into Six (6) Spot (Source: Malaysian Remote Sensing)

The types of vegetation density are specifically categorized into six chosen area spots at every 100 m^2 areas. They are high vegetation density area (Spot 1 and Spot 2) which has eight trees within 100 m^2 area and canopy size of more than 4.5 meters, medium vegetation density area

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(Spot 3 and Spot 4) which has four trees within 100 m^2 area and canopy size of between 3-4 meters and lastly, low vegetation density area (Spot 5 and Spot 6) which has two trees within 100 m^2 area and canopy size of between 1-2 meters.

2.3 Environmental Climate Data

This study focuses on three out of five variables that affect the microclimate of the open space environment which are the air temperature, surface temperature and relative humidity. The remaining two variables which are the daylight luminance rate that is hot air ventilation (thermal) that has been absorbed by the tree canopies and air velocity were not measured as they give a minimal effect towards the ambient temperature of the surrounding (Kristin, 2009).

2.4 Measurement Time and Date

All the data were collected from 9 am in the morning to 5.30 pm in the evening at every 30-minute interval for every research spot. The research areas are monitored separately and systematically for 18 days in December 2010, January and February 2011.

2.4.1 Data Measurement Procedure under Tree Canopy (Turf and Pavement)

Measurements for climate under the tree canopy were executed by recording the reading of the surface temperature using the OAKLON TemTestr. The device was placed on the pavement and turf surface under the tree canopy. After obtaining the surface temperature readings, measurement for relative humidity and air temperature under the pavement and turf canopy were simultaneously recorded using Extech 3 in 1 Thermo-Hygometer-Anemometer. The device was positioned 1 meter under the canopy and 1 meter from the research surface area (Figure 5).

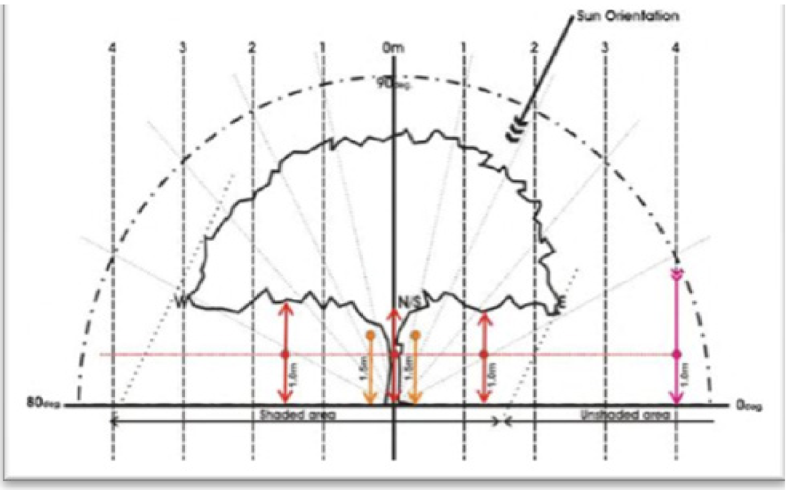

Figure 5: Sectional Diagram Showing Procedures in Measuring Air Temperature, Surface Temperature and Humidity at Turf and Pavement Surface Area

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3. RESULTS AND FINDINGS

The data and results were tabulated according to the vegetation density of the *Peltophorum pterocarpum* species at KLCC Park. Table 1 shows the relationship of the air temperature, surface temperature and humidity of the six spots and the vegetation density by using ANOVA.

Table 1: The Relationship of Air Temperature, Surface Temperature and Humidity for High, Medium and Low Vegetation

Vegetation Density	***Spot***	***Air Temperature***	***Sig.***	***Surface Temperature***	***Sig***	***Humidity***	***Sig.***
High	1 (Turf)	30.3°C	P<0.05 (0.032)	28.0°C	P<0.05 (0.029)	68.0%	P<0.05 (0.009)
	2 (Pavement)	31.5°C		29.4°C		62.7%	
Medium	3 (Turf)	30.6°C	P>0.05 (0.111)	28.2°C	P<0.05 (0.026)	66.4%	P>0.05 (0.259)
	4 (Pavement)	32.0°C		30.1°C		62.2%	
Low	5 (Turf)	31.5°C	P>0.05 (0.491)	28.5°C	P<0.05 (0.002)	63.2%	P>0.05 (0.910)
	6 (Pavement)	33.0°C		30.3°C		62.9%	

3.1 Effects of Yellow Flame Density on Air Temperature and Surface Temperature

The analysis of the relationship between air temperature and surface temperature for pavement canopy (Spot 2, Spot 4 and Spot 6) reveals that air temperature of the pavement canopy surface does affect the surface temperature of the pavement canopy. The data recorded at the pavement canopy and low plant density (Spot 6) of the KLCC Park shows the highest total average of the air temperature (33.0 ^{o}C) and surface temperature (30.3 ^{o}C). The data obtained are believed to be affected by the lack in tree shading effect (canopy) and low relative humidity level of the pavement surface at the research location. The result shows significant difference in the relationship of the pavement canopy surface at the research location, at Spot 2, Spot 4 and Spot 6 based on the two variables which are the air temperature and surface temperature i.e. ($t\ (53) = 19.873; p< 0.05$). The result evidently proves that Spot 6 does affect the research site and location in increasing the surrounding temperature.

Table 2: Calculated Mean at Pavement Area for Air and Surface Temperature for Spot (2), Spot (4) and Spot (6)

Location	**Air temperature_pavement surface**	**Surface temperature_pavement surface**
Spot (2)_High	31.5°C	29.4°C
Spot (4)_Medium	32.0°C	30.1°C
Spot (6)_Low	33.0°C	30.3°C

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3.2 Yellow Flame Density in Reducing the Air and Surface Temperature

The analysis on the relationship between air temperature and surface temperature for turf canopy (Spot 1, Spot 3 and Spot 5) reveals that air temperature of the turf canopy does affect the surface temperature of the turf canopy area. The data recorded at the turf canopy and high plant density (Spot 1) of the KLCC Park show the lowest total average of air temperature (30.0 ^{o}C) and surface temperature (28.0 ^{o}C). The data obtained are believed to be affected by the high amount of tree shading effect (canopy) and high relative humidity on the turf surface of the 100m2. The results show significant difference on the relationship between turf canopy of the research location at Spot 1, Spot 3 and Spot 5 based on the two variables which are the air temperature and surface temperature i.e. (t (53) = 12.465; $p < 0.05$). The result evidently proves that Spot 1 does affect the research site and location in reducing the ambient temperature.

Table 3: Calculated Mean at Turf Area for Air and Surface Temperature for Spot (1), Spot (3) and Spot (5)

Site Location	Air Temperature_Turf Area	Surface Temperature_Pavement Area
Spot (1)_High	30.3°C	28.0°C
Spot (3)_Medium	30.6°C	28.2°C
Spot (5)_Low	31.5°C	28.5°C

3.3 Yellow Flame Density Effects on Humidity Level

Based on the analysis done on the spots affecting the relative humidity at the research location, Spot 1 which has a high vegetation density shows the reading of 68%, Spot 3 with medium vegetation density shows the reading of 66.4% and Spot 5 with low vegetation density with the reading of 63.2%. Further analysis reveals that there are no significant difference in the relationship of Spot 1, Spot 3 and Spot 5 of turf canopy of the KLCC Park on the humidity level variable i.e. (F (2, 51) =(1.387); $p > 0.05$). The result shows a factor which highly affects the humidity level of the research location is at Spot 1, the area with turf canopy.

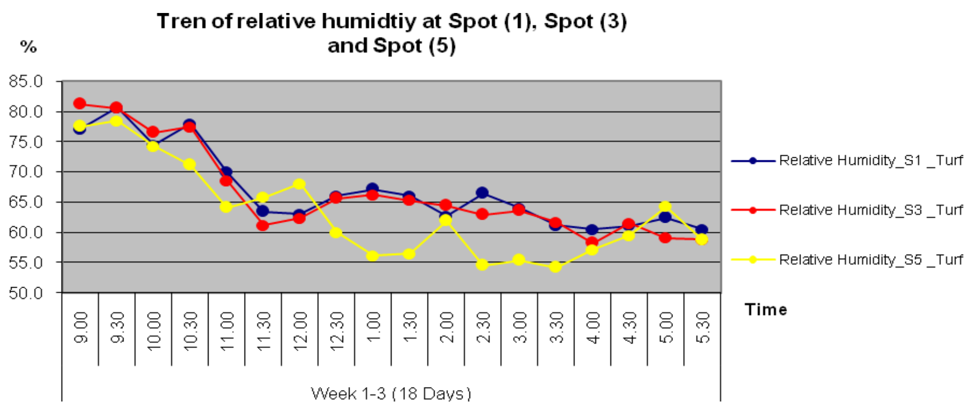

Figure 6: The Relationship of Relative Humidity at Spot (1), Spot (3) and Spot (5)

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3.4 Yellow Flame Density That Reduces the Humidity Level

Meanwhile, based on the analysis done on spots affecting the reduction of relative humidity level at the KLCC Park, Spot 2 which has a high vegetation density shows the reading of 62.7%, Spot 4, with the medium vegetation density with the reading of 62.2% and Spot 6, with the low vegetation density with the reading of 62.9%. Further analysis reveals that there are no significant difference in relationship of Spot 2, Spot 4 and Spot 6 of the pavement canopy of the research location on the relative humidity variable i.e. ($F (2, 51) = (0.816)$; $p > 0.05$). The result shows that the factors affecting the reduction of the humidity level of the KLCC Park is at Spot 6, the area with pavement canopy.

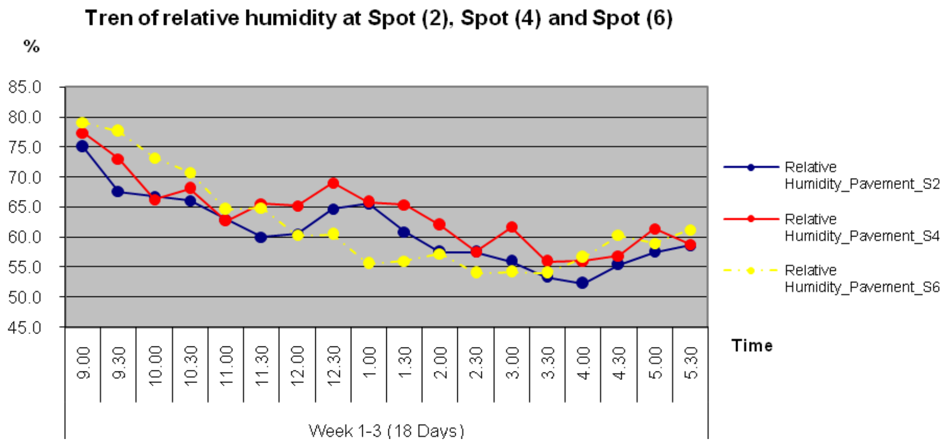

Figure 7: The Relationship of Relative Humidity at Spot (2), Spot (4) and Spot (6)

4. DISCUSSION

4.1 Plant Characteristic

Our results show that high vegetation of *Peltophorum pterocarpum* (Yellow Flame) plant species provides lower air temperature and surface temperature underneath the canopy of the turf and pavement areas than medium and low vegetation with 3.1 °C average air temperature. According to Brown (1995), the physical or structural aspects of a plant such as shape, height, density and branch structure as well as leaf structure and width are considered as the main component in creating the shading effect and conserving the urban open space microclimate. Modification on the research location microclimate was made possible and better around the high plant density area as the *Peltophorum pterocarpum* (Yellow Flame) plant species' physical aspects provide wider canopy coverage as compared to the areas with low vegetation density. The data obtained from the Table 1, show that lower reading for the air temperature (31.5 °C) and surface temperature (28.5 °C) at the low vegetation density area as compared to the high vegetation density areas where the reading for the air temperature and surface temperature is at 30.3 °C and 28 °C, respectively. Akhbari (2001) share the same view by mentioning that the abundant and wider canopy coverage will result in a more dense branch structure which gives rise to a dense limb and leaves that develope a huge shading effect, which will help the reduction of the ambient temperature as compared to the areas with lower canopy and vegetation density. Meanwhile, a total of 8 trees within the high vegetation density area also plays a significant role in modfying the urban open space area. Oke (1989)

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also agrees by stating that the amount of trees does have an effect on urban space microclimate. The air and surface temperatures can be reduced by 30 to 60% by the presence of a single tree in a particular area and the condition of the area can be further alterated by the tree structure such as the shapes, heights and leaves.

4.2 Surface Coverage

The surface coverage of the research location which are pavement and turf surfaces also plays an important fuction in affecting the urban open space microclimate. Acoording to Taha et al. (1991), the temperature around the turf surface is 4 °F (1 to 2 °C) cooler as compared to the pavement surface area. The relationship analysis that have been executed between turf canopy and pavement canopy concludes that there is a significant difference. This further indicates that the turf surface and pavement surfaces do have some effects on the research location micorclimate and this is further supported by the evidence obtained from the research data analysis. The data analysis shows for all areas, which have high, medium and low vegetation density, the surface average temperature for the turf surface is 28.3 °C which is lower as compared to pavement surface average temperature which is at 30.0 °C. The above phenomena is further supported by Wong (2007), where they mentioned that air and surface temperatures at the turf surface are cooler as compared to the pavement surface of an area. As compared to the pavement surface area of the research location, the turf surface has the contributory effect in improving the surrounding of the research location by reducing the air temperature as well as elevating the research location relative humidity level. Tzu-Ping Lin (2010), mentioned that the turf surface provides less barricades for air flow and produces the cool air temperature through the convection process. Besides that, high evaporation rate also influences the turf surface area as compared to the pavement surface area. Around the turf area, latent heat is fully utilized as compared to the pavement surface area where latent heat is usually stored, which as a result caused the increase of the surrounding temperature. The surface temperature and realtive humidity level on the grassy surface of the research location was reduced by a total average of 1.7 °C and 17% respectively as compared to the pavement surface area.

5. CONCLUSION AND RECOMMENDATIONS

Peltophorum pterocarpum (Yellow Flame) plant species' density for 100 m^2 does affect the KLCC Park microclimate by reducing the air and surface temperature of the urban open spaces. This previously mentioned factor shows the importance of plant species characteristics and it should be taken into consideration and listed in the selection criteria for the plantation of trees on the study site. The density of the plant canopy and the width of the branch, as well as the leaf arrangements are very efficient in conserving the environment microclimate. The micro-environment of high vegetation of Yellow Flame was statistically significant different from micro-environment of medium and low vegetation examined. The Yellow Flame plant species with higher values of relative humidity affords greater reduction of air and surface temperature as compared to the other species at the study site. The Yellow Flame species has a more densed foliage coverage than the multiple layer arrangements of its branches and twigs. Furthermore, the clustering of Yellow Flame improves larger reduction in the air temperature and produces cool island effects at the KLCC Park. Thus, planting Yellow Flame can be suggested to conserve the urban open space microclimate based on the results and information extracted from the data analysis. In order to restore the urban open space

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microclimate, the planting and selection of plant species should be taken into serious consideration. The efficiency of a plant species in reducing the temperature and elevating the humidity level is highly dependent on the morphology characterisitics of the chosen plant. Besides that, in creating a cool and shaded environment, the amount of trees and canopy density should also be taken into consideration. The combination between the surface coverage and plant density should be done in the KLCC Park. In paved areas, more trees and wider canopies are needed as compared to the turf areas. In Malaysia, the Yellow Flame species should be densedly planted as they are deemed suitable for the urban open spaces. This tree is able to fulfill the planting need towards the aesthetical value, shading functioning, ecology and bioclimate. Finally, is also noted that cool island effect can be created at the study site space where a large amount of Yellow Flame are planted. A total of 8 Yellow Flame trees planted for every 100 m^2 in an urban open space is sufficient in achieving the thermal comfort as well as creating a soothing condition for the users and community by reducing the ambient temperature by 3.1 °C. It is apparent that the Yellow Flame, can greatly influnce the thermal microclimate in urban spaces. This affects the area within the park as well as the surrounding areas. The Yellow Flame demonstrates that it can significantly improve the urban microclimate, as well as reducing the air temperature and mitigating the heat island effect thus giving more benefits to urban centres. Overall, the physical characteristics of Yellow Flame canopies, especially its leaf coverage and branches, are the main factors that contribute and influence the creation of cooling environment, modification of air and surface temperature which are created by this tree shade. This research is important in determining planting suitablility of a certain plant species and its density and size in tropical climate of an urban open space. Besides, the knowledge can contribute to energy saving in buildings and humans in tropical areas and the research analysis done in this research can be combined with the findings in other researches that share the same microclimate environment condition.

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