AcE-Bs2014Seoul
Asian Conference on Environment-Behaviour Studies
Chung-Ang University, Seoul, S. Korea, 25-27 August 2014
“Environmental Settings in the Era of Urban Regeneration”

Adapting Human Comfort in an Urban Area:
The role of tree shades towards urban regeneration

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Abstract

Trees are an essential part of every community in an urban area. The trees’ canopies and crowns provide comfortable conditions for outdoor activities and recreation. This paper presents the simulations of tree shades, which is proven to enhance the microclimate of an urban park. The results showed that the tree shades sustained the microclimate of the park; lower the air temperature control the thermal comfort and maintained the wind flow. The implications of the outcomes show significant modifications in the human comfort sensation concerning the restoration of urban setting with tree shades.

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Peer-review under responsibility of Centre for Environment-Behaviour Studies (AcE-Bs), Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Malaysia.

Keywords: Trees; canopies; thermal comfort; urban park

1. Introduction

Trees are an essential part of every community in an urban area. Trees contribute to their environment by supplying the needed oxygen, absorbing CO\textsubscript{2}, improving air quality, enhancing the microclimate, conserving water, preserving soil and filtering air pollution as well as increasing the quality of life by hosting natural elements and wildlife habitats into urban settings. In an urban setting, trees are planted

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Peer-review under responsibility of Centre for Environment-Behaviour Studies (AcE-Bs), Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, Malaysia.
doi:10.1016/j.sbspro.2015.01.047
along streets, riverbanks, in recreation areas and parks and sometimes conserved in urban forests and arboretums. In the hot and humid region, trees in urban parks provide urbanites with shaded areas during the late mornings and afternoons. The trees canopies and crown provide comfortable conditions for outdoor activities and recreation. In addition, using trees in cities to refract the sunlight and cast shades reduces the urban heat island effect caused by open spaces, hardscapes and complex surfaces of urban structures. The expansion of the urban areas draws the awareness of the adaptation of the urban climate condition. The issues of climate; Urban Heat Island (UHI) and global warming turn out to be the community issues. People become more interested with the topic of thermal comfort, microclimate, pollutions, and even the issue of El-Niño and La-Nina. The challenge of those topic give the idea for the designer to be more prepared and practice in their daily tasks in giving the society more comfortable than their current condition. This study aims to show the importance of the trees’ canopies and crowns and the role of tree shades towards urban regeneration by analysing the trees’ shading patterns through computer simulations. This paper presents the simulations of the algorithm for the trees shades, which is proven to enhance the microclimate of the area. The simulation series showed the comparison of four different scenarios to verify the changes related to canopies and crowns on plants structure and composition. The study employed iteration algorithm to experiment different conditions of scenarios. Further analysis of these results produced a modified adaptive human comfort model. The results showed that the tree shades sustained the microclimate of the area; lower the air temperature control the thermal comfort and maintained the wind flow. The implications of the outcomes show significant modifications in the human comfort sensation concerning the restoration of urban setting with tree shades, which, would be a positive aspect towards urban regeneration.

2. Literature Review

2.1. The implication of green area in urban form

The causes of Urban Heat Island (UHI) are heat stress and other effects triggered by the densely built environment when the natural landscapes are with buildings and roads. The microclimate condition has significant impacts on urban occupants, as the higher temperature in cities will result in increased energy use for indoor and cooling and higher water demand for landscape mitigation. The high humidity in tropical cities combined with high air temperature will create discomfort and undermine the function of outdoor places. As a result, the demand for a better microclimate condition is more pronounced today than decades ago. Shading from trees has proven to improve the condition of human energy heat balance while doing outdoor activities and improve the indoor conditions of building by reducing the solar radiation on the building facades. Previous studies (Akbari, Pomerantz, & Taha, 2001; Mohd Fairuz Shahidan, Jones, Gwilliam, & Salleh, 2012) have verified that the density of the tree crown would reduce the air temperature under the tree between 2 and 4 °C. When the UHI effect is correlated with the trees density, the result showed that a significant value of green area or vice versa (Chow & Brazel, 2012; Gago, Roldan, Pacheco-Torres, & Ordóñez, 2013). Besides energy consideration, high temperatures could increase health risks and atmospheric pollution, as it is known that the greenhouse effect contributes towards global warming, higher energy demand and emission. Hence, the urban green areas and infrastructure should be maintained in tropical hot and humid cities to guarantee the well-being of the urban communities (Mansor, Said, & Mohamad, 2010).

Therefore, the strategies of planting more vegetation in urban areas are used to alleviate the greenhouse effect since vegetation plays a significant role in regulating the urban climate. In a hot climate, vegetation planted around buildings can alter the energy balance as well as cooling energy requirements of buildings by sheltering windows, walls, and rooftop from strong solar radiation as well as
radiation reflected from the surroundings. Trees could help reduce the CO2 level, increase O2 and the quality of life (Borhan, Ahmed, & Hitam, 2013).

2.2. Outdoor thermal comfort for urban regeneration in hot and humid climate

Previous studies discovered the role of green area in mitigating the UHI effect in tropical cities (Emmanuel, 2005; Wong & Yu, 2005). In those studies, the air temperature across the city was reduced between 1 and 4°C by the green area. The results showed that urban green areas can improve the urban microclimate and mitigate the UHI effect by reducing the ambient temperature. In addition, earlier investigations on the adaptation of thermal comfort in Shah Alam showed that the shaded area played an important role to sustain the sensation of comfort among the public (Nasir, Ahmad, & Ahmed, 2012, 2013). The results confirmed the practice of adaptive thermal comfort when the respondents perceived the microclimatic condition to be satisfactory. They perceived better microclimatic conditions than what was measured. This may show how the respondents think about their microclimatic condition and adapt to it effortlessly. The perception and the sensation of thermal comfort are vital in urban form (Kariminia & Ahmad, 2013). Thus, further study on what settings should be provided in various types of urban form is important to sustain the urban regeneration. This study emphasises the condition of certain criteria of urban park setting could offer better microclimatic conditions than an urban park without any planning strategy.

3. Methodology

3.1. Field study

The site of this study was at the Shah Alam Lake Garden, Selangor, Malaysia (3°5’00”N, 101°32’00”E). The chosen location for matured trees and the soil surround the field study covered with grass. The centre of attraction of the study area is a playground with sitting and resting places for picnicking and leisure activities. The study area is approximately 2 acres. The exact study area is called Tasik Barat, Taman Tasik Shah Alam (Fig. 1). The main instrument used in the measurement is the weather station (RainWise). The equipment measured air temperature (Ta), relative humidity (RH), wind velocity (v), wind direction, rainfall and solar radiation (Ir). The microclimatic conditions were measured simultaneously using portable weather data instruments at 10-minute intervals. The sensors were installed at the centre of perimeter of the study area in Fig 1.

Fig. 1. The study area, Tasik Barat, Taman Tasik Shah Alam
3.2. Vegetation profile

The vegetation on the site was recorded using Global Position System (GPS) and grid plotted in the CAD system. The trees' configurations such as the Leaf Area Index (LAI) has been set according to a previous study (Mohd Fairuz Shahidan et al., 2012). The layout of the area was then outlined in the Envi-Met simulation programme. The main vegetation cover is Samanea saman, Peltophorum pterocarpum, Tabebuia pentaphylla and Pterocarpus indicus. The proposed vegetation profile that has been set up in the simulation program is shown in Table 1.

Table 1. Major vegetation profile

| ID | a_f | H | TT | LAD 1 | LAD 2 | LAD 3 | LAD 4 | LAD 5 | LAD 6 | LAD 7 | LAD 8 | LAD 9 | LAD 10 | Name                  |
|----|-----|---|----|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|-----------------------|
| xx | 0.2 | 0.63 | 0.5 | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | Grass 50cm aver. dense |
| gb | 0.2 | 0.5  | 0.5  | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | Grass 50cm aver. dense |
| AX | 0.2 | 0.1  | 0.5  | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | 0.3   | Grass 10cm aver. dense |
| Pp | 0.2 | 13   | 2    | 0     | 0     | 0     | 0.104 | 0.208 | 0.208 | 0.208 | 0.208 | 0.208 | 0.208 | Tree 13m ave. dense    |
| Tp | 0.2 | 12   | 2    | 0     | 0     | 0.183 | 0.183 | 0.366 | 0.366 | 0.366 | 0.366 | 0.366 | 0.183 | Tree 12m ave. dense    |
| PI | 0.2 | 20   | 2    | 0     | 0     | 0.075 | 0.075 | 0.1   | 1.15  | 1.15  | 0.92  | 0.38  | 0.38  | Tree 20m dense         |
| SS | 0.2 | 15   | 2    | 0     | 0     | 0     | 0     | 0.4   | 0.45  | 0.45  | 0.49  | 0.49  | 0.49  | Tree 15m               |

a_f: short-wave albedo of the plant leaf; H: height of the plants; TT: Total depth of the root zone; LAD: Leaf Area Density; RAD: Root Area Density in m²/m³ for the 10 data points is set to 0.1

The estimation of the vegetation profile is based on the combining an allometric method for tree leaf area with the MacArthur–Horn (MH) method (MacArthur & Horn, 1969; Sumida et al., 2009). This method using a portable laser rangefinder for the measurements and calculate the fragmented of LAD of each 10 sections. The details were then, included in the simulations to be modeled. The tree species; Peltophorum pterocarpum, Tabebuia pentaphylla, Pterocarpus indicus and Samanea saman is the major species being planted in the study area. The height and the vegetation profile has been determined by the average size of the whole vegetation. The arrangements of the ‘extra trees’ scenarios were randomly tabulated. This study evaluated the differences in cooling effect of only four species of trees and one species of ground cover. The theory has proven that vegetation density of trees and tree characteristics affect the efficiency of cooling effect.
3.3. *Envi-met* simulation

"*ENVI-met* is a three-dimensional non-hydrostatic model for the simulation of Surface-Plant–Air interactions in the urban environments" (Bruse & Team, n.d.). It is designed for micro-scale with a typical horizontal resolution of 0.5-10 m, and a typical time frame of 24–48 h with a time step of 10 s. This placement of vegetation was simulated as is Fig. 2(a) and an additional 80% in ‘extra trees’ Fig. 2(b) scenarios to observe the differences in the results.

This study decides 10 March 2012 as the selected day for the simulations. *Envi-met* programme is used to compare the thermal conditions with the three different scenarios (Fig. 2); Scenario 1— existing settings: This scenario is the base case, which simulates the current thermal conditions of Taman Tasik Shah Alam (Tasik Barat) and its surroundings. Scenario 2— extra trees: In this scenario, a broad change on vegetation cover is done surrounding of Taman Tasik Shah Alam. High-density trees and its surroundings are examined. Scenario 3— ground cover: In this scenario, all plants in the park are removed but the soil and ground cover (grass) are retained. The thermal conditions of the areas were investigated.

![Fig. 2. Three scenarios: (a) existing settings; (b) extra vegetation; (c) ground cover](image-url)
Thirteen hours of simulation time are employed since it could give the model 12 hours (0700-1900) to acquire the optimum data for the daytime. The data was modeled every hour. The configurations of the main data of the Envi-Met simulations are as shown in Table 2.

Table 2. Basic configurations in the Envi-Met simulations

| Main Data                        |          |
|----------------------------------|----------|
| Initial Temperature Atmosphere [K]| 298.85   |
| Relative Humidity in 2m [%]       | 88       |
| Wind Speed at 10 m [m/s]         | 4        |
| Wind Direction (0:N..90:E..180:S..270:W..) | 240 |
| Roughness Length in 10m          | 0.1      |
| Total simulation time (h)        | 13       |

4. Results and Findings

The simulated microclimate parameters were Air Temperature (Ta), Relative Humidity (RH), Wind Velocity (v) and Mean Radiant Temperature (Tmrt) as shown in Table 3. These data indicate the comparisons between three scenarios in an hour simulation interval. The highest temperature present between 1500 and 1600 hrs. The relative humidity is at the highest state before 1000 hrs. However, wind speed evaluation cannot be determined by hours, yet, the scenario differ the evaluation.

Table 3. Simulated microclimate parameters

| Time   | Air Temperature (°C) | Relative Humidity (%) | Wind Speed (m/s) | Tmrt (°C) |
|--------|----------------------|-----------------------|------------------|-----------|
| 7:00   | 23.9                 | 87.1                  | 2.0              | 16.0      |
| 8:00   | 24.2                 | 86.9                  | 1.9              | 16.3      |
| 9:00   | 25.0                 | 84.7                  | 1.8              | 49.2      |
| 10:00  | 26.1                 | 82.7                  | 1.8              | 45.0      |
| 11:00  | 27.5                 | 80.4                  | 1.9              | 44.6      |
| 12:00  | 28.6                 | 78.7                  | 1.9              | 53.9      |
| 13:00  | 29.3                 | 77.4                  | 2.0              | 47.4      |
| 14:00  | 29.9                 | 76.3                  | 2.0              | 49.1      |
| 15:00  | 30.1                 | 75.7                  | 2.0              | 56.3      |
| 16:00  | 30.1                 | 75.5                  | 2.0              | 52.0      |
| 17:00  | 29.8                 | 75.9                  | 2.0              | 46.7      |
| 18:00  | 29.3                 | 77.0                  | 2.0              | 38.2      |
| 19:00  | 28.5                 | 78.4                  | 2.0              | 21.0      |

Fig. 3 displays a scatterplot of the association of air temperature between the real condition (measurements using weather station) and simulated data in Envi-Met. The comparison of hourly data...
logged for 10 March 2012 of air temperature in measurements and simulations as shown in the scatterplot clearly indicates that there is a positive relationship between the measurements and simulations.

Fig. 3. The correlation analysis between measurements and simulated data

Fig. 4, Fig. 5, and Fig. 6. show the comparisons of air temperature (Kelvin), Relative Humidity (%) and wind velocity (m/s) between three scenarios; ‘existing setting’, ‘extra trees’ and ‘ground cover’. The ‘extra trees’ shows the reduced ambient temperature during daytime. The average of one-degree Celcius reductions in twelve hours proved that the denseness of mature trees would reduce the ambient temperature perfectly (Fig. 4). Moreover, the relative humidity (%) is higher in the ‘extra trees’ scenarios. The lowest temperature and higher relative humidity of the scenarios offer a better microclimate condition. Moreover, the ventilation of the ‘extra trees’ scenarios is the best due to the channel effect by the plants.
Fig. 4. The comparisons of air temperature (Kelvin) between three scenarios

Fig. 5. The comparisons of relative humidity (%) between three scenarios
The chart also explains shows that there is a correlation between ‘extra trees’ and ‘ground cover’. When the ‘extra trees’ scenario shows lowest degree of temperature and highest degree on humidity and winds speed, there is vice versa on the ‘ground cover’ scenario. This trend supports the theory that the denser vegetation and mature plants are established in the area, the microclimate condition improve into the comfort state of thermal comfort condition.
Furthermore, is important to analyse human energy balance from the simulations in order to study the thermal comfort parameters that the human body is exposed to. The Mean Radiant Temperature ($T_{\text{mr}}$) is defined as the ‘uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure’ (ANSI/ASHRAE Standard 55, 2004). The simulations data shows that the cooling effect are significantly governed by the extra trees scenarios (Fig. 7). Figure 7 also shows that between noon and 1400h, all three scenarios recorded the same results due to the shadow pattern effect (Lindberg, Holmer, & Thorsson, 2008).

5. Discussion

This study has showed the simulation and actual microclimate condition of Tasik Barat, Taman Tasik Shah Alam, Malaysia. The identification of the scenarios that promote better thermal comfort condition in the shaded green area of the city clearly explained in this study. In this study, an investigation on the cooling effect by the dense and mature plants in a small shaded urban green area has been conducted. The scenarios studied have various types of arrangement; the existing setting, the extra vegetation covered and the ground cover without mature and full canopy plants. The species of plants also give important role to the cooling effect. *Peltophorum pterocarpum*, *Tabebuia pentaphylla*, *Pterocarpus indicus* and *Samanea saman* are known for the common species that being planted in the public parks and along the streets. This major species that being planted in Taman Tasik Shah Alam is already in full crown and give full shaded area for the whole area. However, to see the differences, the ‘extra trees’ scenario was added with additional 80% of the vegetation cover from the ‘existing condition’. The dense and the mature tree show the significant finding in Mean Radiant Temperature, air temperature, humidity and wind flow. The complete differences in the parameters give the greatest contribution of the comfortable and adaptation level to the outdoor thermal comfort. The analysis of the data showed that the coolest scenario in Taman Tasik Shah Alam is with ‘extra trees’. This is due to the denseness of vegetative cover. The ‘ground cover’ scenario can be seen as the least area to offer a better microclimate condition. As the ‘ground cover’ area is covered with pavement and grass, it recorded a higher temperature at about 0.1 to 0.8 degree Celsius. An increment of 80% vegetation cover than the existing condition shows the significant results of cooling effect. However, the differences are not vast since the moisture level in the soil and the ground temperature impeded the increment of the air temperature. When the existing setting with the ‘extra trees’ is simulated, the results showed that the density of the mature trees played an important role to influence the human energy balance to be in a comfortable range. The higher wind velocities through, the taller plants and effects of the channel pattern of wind through the trees allowed better comfort in the area. The taller plants established higher velocities of air to pass through the site, thus increasing ventilation and reducing temperature.

6. Conclusion

Trees are most beneficial as a mitigation strategy for the optimization of the area. There lots of studies show how the trees is effective for cooling a building, give the shades and improve microclimate conditions. Moreover, trees might improve quality of life. Trees and vegetation significantly provide the aesthetic value, habitat for the wildlife species even in the urban areas and reduce the pollutions. This study confirmed that the urban form achieved satisfactory thermal comfort levels based on different physical configurations of the urban park settings. It was found that to gain optimum energy heat balance of the human body, urban form should provide the area with lower air temperature, higher humidity and good ventilation. The structure of the surface also played an important role in making the setting as a place with better microclimate. The shaded area planted with mature plants, set with full canopy and tree
crown undoubtedly would give the public an opportunity to optimize the outdoor park in the daytime. This study proves that the plants in the urban environment have functions for controlling the microclimate, decreasing air temperature, increasing humidity and modulate the wind ventilation. It is not possible if this study extent to the regional area, the evidences of trees contribute to the cooling effect for the larger area can be determined. This study also should be extent for the complex urban form to see the changes of difference type of material and energy use. This study also needs to be precise in the focus of the tree species. Tree species and the growth of the tree will give significant and important findings for the designers. The trees selection become important as the tree canopies provide different type of shading. Although the profits of green area is intangible, yet, the vegetation is considerably value for provide the community the place for social communal. The amount of dollar and cents can be calculated if the carbon of pollution can be reduced and calculated, so it can be tangible. Thus, the importance of the green area is sustainable. It gives the urban area soul moreover, it creates regeneration. The optimization of public urban setting would encourage urban regeneration on the social aspect. Furthermore, the outcome of this study offers a solution to the issue of heat stress. Also, it suggests the proposed way to mitigate the Urban Heat Island (UHI). The denser and mature trees for optimization of green area, and at the same time give the community a place for urban regeneration. The importance of trees should be emphasizes by the designer, community and the authorities for the sustainable community for the generations.

Acknowledgement

This research has been funded by the Ministry of Higher Education under the Exploratory Research Grant Scheme (ERGS) file no: 600-RMI/ERGS 5/3 (45/2013), the Fundamental Research Grant Scheme (FRGS) file no: 600-RMI/ST/FRGS 5/3/Fst (104/2012) and RMI/UiTM Excellence Fund. Universiti Teknologi MARA and Majlis Bandaraya Shah Alam also support this research.

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