Study of Thermal Comfort in Tree-shaded Areas in the Green Space of Yogyakarta, Indonesia

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Abstract: Heat problems in the tropical countries cause thermal discomfort affecting human activity. Tree-shaded areas can reduce the heat effect by amelioration of microclimate and enhances the human thermal comfort outdoors. The objective of this study is to investigate thermal comfort and activity in tree-shaded areas in the green space of the tropical Yogyakarta, Indonesia. The investigation of thermal comfort in tree-shaded areas was conducted by structured interview, microclimate measurement and activity observation. The shade coverage was analyzed by hemispherical images and Sky View Factors (SVF) with classification of soft and hard surfaces. It was described that the cooling effect of tree-shaded areas is significant on thermal comfort in the tropics. The thermal sensation of cool-slightly cool-neutral was a condition of high comfort in tree-shaded areas in the tropics. The shade coverage was indicated by SVF values as full shade (0.0-0.2), not-full shade (0.2-0.4), and no shade (0.4-0.5). Tree-shaded areas with no shade and hard surface (NS-H) were not recommended in tropics because of the lack of comfort. The long duration of spending time, the high intensity of activity, and the willingness of using shade areas can be the indications of comfort in tree-shaded areas.

Keywords: thermal comfort, tree-shaded areas, hemispherical images, green space, Yogyakarta, Indonesia

キーワード：温熱快適性，緑陰地，半球写真，緑地，ジョグジャカルタ，インドネシア

1. Introduction

In the tropics, regarded as a region where heat problems have been increasingly becoming an issue, thermal comfort has often been taken for granted to encourage human activity. Thermal comfort is approached by taking three steps of landscape design: (1) understand the mechanism by which landscape affects microclimate, (2) gain an understanding of microclimate conditions that can be considered thermally comfortable, and (3) connect these two ideas to create an understanding of how landscape design affects thermal comfort (Brown, 1995). Outdoor thermal comfort in an urban climate may be affected by a wide range of parameters, including air temperature, relative humidity, wind speed, solar radiation, air quality, human activity, clothing level, age, etc. (Stathoupoulos, 2004).

Thermal comfort is one of the factors influencing activities in urban parks. The amount and intensity of such activities is affected by the level of the discomfort experienced by the inhabitants when they are exposed to the climatic conditions in the urban park (Givoni, 2003). Tree-shaded areas in the tropical city create thermally comfortable condition for human activity, because air temperature in this area is 0.8-1.6°C lower than in exposed area (Irwan, 2004). The availability of shaded outdoor area may result in greater utilization of the open space by the public (Diomoudi, 2003).

The objective of this study is to investigate human thermal comfort condition in tree-shaded areas in green space of tropical Yogyakarta, Indonesia, and to understand the effect on human activity.

2. Materials and Methods

The method of this study was structured in three steps presented on Figure 1.

![Figure 1. Methods Frame](image)

(1) Considering the study area

A large green space located at 20 km East of the centre of Yogyakarta City, Central Java Province, Java Island, Indonesia was considered as study area (Figure 2). The Prambanan Park was chosen because of the wide variety of green configuration; such as the composition, types, planting pattern of trees and variety of tree-shaded areas. This was based on direct field observation on several parks in Yogyakarta.

Site observation was conducted in the Prambanan Park to arrange the investigation of study. The park is about 77 hectares and is visited by an average of 1500 people per day indicating high intensity of activity in the green space. The park has been famous with the name of The Prambanan Recreational and Archaeological Park contains a main temple of Prambanan in the centre of the park and other small temples.
(2) Investigating thermal comfort

Activity observation, structured interview and microclimate measurement were conducted simultaneously to investigate thermal comfort. This procedure was repeated every hour when the tree-shaded areas existed in the park at 09.00-16.00 (8 times per day) during 6 days on August 22nd-29th, 2004. It took place in tree-shaded areas within the park when days were sunny, in order to study the effect of tree-shaded areas on thermal comfort. Characteristics of tree-shaded areas were classified through visual observation of tree-shade coverage and tree canopy into three types: full shade (FS), not-full shade (NFS) and no shade (NS).

The study area was divided into three areas, because of the highest intensity of user activity and site functions in the park and: parking area (A), entrance area (B), and exit area (C). Each area was studied for two days. In order to study spatial variations of the investigation within the areas, each area of parking, entrance and exit was subdivided into three sections (A1-A3, B1-B3, C1-C3), each over a total of 9 sections (Figure 3). The parking area was a green space with ground surface of asphalt; the entrance area was covered by an equal proportion of pavement and grass surface; the exit area consisted of green space with small portion of asphalt. Then, this study location was divided into two types of ground surfaces: A1-A3, B1 were hard surfaces (asphalt, pavement with small green), and B2, B3, C1-C3 were soft surfaces (grass, green area with path walk).

At least 2 interviewees were asked every hour in each section. All of interviewees were Indonesian, 20-60 years old, they were randomly selected in the park. The structured interviews, which were performed in Indonesian language, identified personal identification of interviewees: age, sex, clothing, human performance (height, skin color, weight) and position (standing, sitting). Then, their purpose of being there, their use of time in the park, and their assessment of the microclimate of the place were investigated followed by questions aiming at attitude to stay in tree-shaded areas. They also reported their thermal sensation on 11 points and comfort level on 5 points (Table 2).

Microclimate measurements were included of air temperature, humidity, and wind speed. They were recorded near interviewee while interview was taking place. A digital thermo-hygro-anemometer was used for measurements in position at one meter height for air temperature and humidity, and two meter height for wind speed.

Visual observation of activity in the park shows the numbers of people were doing activities in the tree-shaded areas; such as eating, walking, talking, reading and working; and their positions, such as standing, sitting on chair and sitting on ground, were noted about 10 minutes, once per hour at each section within the designated areas of parking, entrance and exit in the park.

(3) Observing Physical Tree shade

Hemispherical images of shade performance observation were carried out on 35 spots inside the park. The images were taken by digital camera and fish eye lens at one meter height at 16.00-18.00 on August 31st, 2004. The image spots were selected as places where the thermal comfort investigation was conducted.

The three characteristics of shades in tree-shaded areas; FS, NFS, and NS were analyzed by Sky View Factor (SVF) of the hemispherical images calculated by Rayman 12 (by Matzarakis, 2000).
3. Results

(1) Activity and thermal sensation in the park

A total of 296 people were interviewed, of which 96 in the parking area, 99 in the entrance area and 101 in the exit area. The interviewees were in FS (34.12%), NFS (55.74%) and NS (10.14%), so that there happened to be more people in tree-shaded areas than no-shade areas. The majority (87.5%) of them was between 21 and 50 years old, and they were 62.2% men and 37.8% women.

![Figure 4. Activity in the park](image1)

Table 1. Percentage frequency (%), activity in the park

<table>
<thead>
<tr>
<th>Activity</th>
<th>Parking area</th>
<th>Entrance area</th>
<th>Exit area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreation</td>
<td>17.7</td>
<td>37.4</td>
<td>76.5</td>
</tr>
<tr>
<td>Study</td>
<td>2.1</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Working</td>
<td>71.9</td>
<td>31.3</td>
<td>20.6</td>
</tr>
<tr>
<td>Other</td>
<td>8.3</td>
<td>28.3</td>
<td>11.0</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Figure 4 shows activity in each area of parking, entrance and exit. In general, they came to the park for recreation (54.0%) and working (41.0%) purposes. Activities of working purpose were selling some souvenirs, selling food, renting umbrella, guiding, and photographs. People 82.4% people reported they were carrying out activity in tree-shaded areas.

The total attendance within the park was investigated by 144 observations. Based on data in Figure 5, it was found that number of the attendance decreased during 11.00-14.00, when the air temperature was in high range of 32-33°C. It also indicated high intensity of activity was being in the morning (10.00) and in the afternoon (15.00). Furthermore, people doing activities were classified on positions of standing/walking (56.2%) sitting on chair (28.9%) and sitting on ground (14.9%).

![Figure 5. Total attendance and air temperature](image2)

More than 50% people in tree-shaded areas reported their thermal sensation in points of neutral, slightly cool and cool on both of ground surfaces (Figure 6). Despite the total attendance decreased at noon, it was not indication discomfort condition in tree-shaded areas.

![Figure 6. Thermal sensation on hard surface (above) and soft surface (below)](image3)

(2) Human thermal comfort

Results of interview of correlation between comfort level and thermal sensation in tree-shaded areas are presented on Figure 7, 8, and Table 2. The majority (91.3%) of people were asked about their preference of comfort level were reported in three levels, i.e. comfort (21.3%), high comfort (33.6%), and very high comfort (16.3%). For thermal sensation, they voted 95.6% for the points of neutral (20.1%), slightly cool (27.7%) and cool (47.8%) for the acceptable comfort conditions.

![Figure 7. Comfort level](image4)

![Figure 8. Thermal sensation](image5)
Table 2. Percentage frequency (%), thermal sensation and comfort level

<table>
<thead>
<tr>
<th>Thermal sensation</th>
<th>Discomfort</th>
<th>Slightly discomfort</th>
<th>Comfort</th>
<th>Slightly comfort</th>
<th>High comfort</th>
<th>Very high comfort</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intolerable hot</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Very hot</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Hot</td>
<td>0.1</td>
<td>1.8</td>
<td>2.2</td>
<td>2.8</td>
<td>5.0</td>
<td>7.8</td>
<td>17.8</td>
</tr>
<tr>
<td>Warm</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Slightly warm</td>
<td>0.0</td>
<td>0.0</td>
<td>1.5</td>
<td>2.0</td>
<td>3.0</td>
<td>4.4</td>
<td>13.4</td>
</tr>
<tr>
<td>Neutral</td>
<td>0.2</td>
<td>1.7</td>
<td>3.3</td>
<td>5.0</td>
<td>12.9</td>
<td>20.1</td>
<td>45.5</td>
</tr>
<tr>
<td>Slightly cool</td>
<td>0.2</td>
<td>1.7</td>
<td>3.3</td>
<td>5.0</td>
<td>12.9</td>
<td>20.1</td>
<td>45.5</td>
</tr>
<tr>
<td>Cool</td>
<td>0.0</td>
<td>0.0</td>
<td>13.5</td>
<td>18.1</td>
<td>35.7</td>
<td>57.0</td>
<td>125.4</td>
</tr>
<tr>
<td>Cold</td>
<td>0.0</td>
<td>0.0</td>
<td>0.9</td>
<td>0.9</td>
<td>0.3</td>
<td>2.9</td>
<td>5.7</td>
</tr>
<tr>
<td>Very cold</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Intolerable cold</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>0.6</td>
<td>8.3</td>
<td>21.3</td>
<td>37.4</td>
<td>15.4</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Though, the neutral-slightly cool-cool point is a condition on the comfort-high comfort-very high comfort, Table 2 presents hot-warm-slightly warm point is a kind of comfort condition in this case. The comfort condition performed in a common tropical weather parameter at Yogyakarta, Indonesia with the maximum and minimum mean value of temperature 29-33°C, relative humidity 38.4%-62.20% and wind speed 0.51-2.32 m/s.

(3) Hemispherical images and Sky View Factor (SVF)

A fish eye lens was used to take hemispherical images at spots of tree-shaded areas investigation in the park (Figure 9). These images show a variety of shade coverage and tree canopy indicated by Sky View Factor (SVF) of these images.

No-shade areas (B1, C1) were tree-shaded area without shade in the spot area that people carrying out activity in the green space.

Not-full-shade areas (A1, C1) were tree-shaded area with many stream lights and not much overlay of tree canopy. Full-shade areas (A2, A3, B2, B3, C3) performed tree-shaded area with a dark shade and a little stream lights.

The value of SVF was found between 0.0 and 0.5. The three categories of tree-shade areas: FS, NPS, and NS, can be showed by SVF that were found between 0.0 - 0.5 (Table 3). It was grouped in three values, i.e. 0.0-0.2 (FS), 0.2-0.4 (NPS) and 0.4-0.5 (NS).

4. Discussion

(1) Effect of microclimates

Though in tropics, the weather is warm humid, people carrying out activity in tree-shaded areas reported their comfort judgement (Table 2). This phenomenon is likely to have a considerable impact over the judgement, hence by randomised selection interviewee the possibility of having over conscious responses are minimized.

Relation between air temperature and total attendance in tree-shaded areas (Figure 10) presents a low relationship (R² 0.14). The high temperature in tree-shaded area was balanced by the trees function of microclimate amelioration which affects thermal comfort in tree-shaded areas.

Figure 9. Hemispherical images of investigation
This correlated to thermal sensation in tree-shaded areas showed at points of neutral, slightly cool, and cool (Figure 6, and Table 2), that the cooling effect of tree-shaded area on human thermal comfort is high significant.

(3) Comfort, activity and use of time in the park
Duration of being in the park should take into account regarding comfort and activity. Figure 12, 13 and Table 5,6 shows variation of spending time in the park correlated to activity in the park (Figure 4, Table 1) and site functions of parking, entrance and exit areas.

The difference of activity types in parking, entrance, and exit areas affects the spent time and the planned-spending time in the park. However, both of these graphs and tables present people spend much time in the park. This assumes indication of comfort in tree-shaded areas in all sites of the park.

(2) Variety of shade coverage and ground surfaces
The combination of shade darkness and stream lights can be seen on hemispherical images (Figure 9), and the shade coverage classification is showed by SVP with the difference of ground surfaces (Table 3). Analyses of relation between shade coverage and comfort level regarding ground surface types were presented on Figure 11 and Table 4.

The lack of comfort was happened on hard surface with NS, because in this area no people reported the high comfort—very high comfort point and discomfort point was the highest value. On another side, tree-shaded areas with FS on hard surface showed high comfort. The point of high comfort was dominant in tree-shaded areas with NFS and FS. However, the effectiveness of NFS and FS on human thermal comfort is needed to be a further research, whether it is significantly support human activity.

![Graph: Correlation between total attendance and air temperature](image)

**Figure 10.** Correlation between total attendance and air temperature

![Graph: Percentage frequency (%) of comfort level on shade coverage and ground surface](image)

**Figure 11.** Shade coverage effect on human comfort

![Table: Percentage frequency (%) of comfort level based on shade coverage and ground surface](image)

**Table 4.** Percentage frequency (%) of comfort level based on shade coverage and ground surface

<table>
<thead>
<tr>
<th>Shade coverage</th>
<th>Ground surface</th>
<th>Discomfort</th>
<th>Slightly comfort</th>
<th>Comfort</th>
<th>High comfort</th>
<th>Very high comfort</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full shade</td>
<td>Hard</td>
<td>0.0</td>
<td>4.3</td>
<td>65.4</td>
<td>33.2</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Soft</td>
<td>0.0</td>
<td>7.7</td>
<td>42.9</td>
<td>46.2</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Near-full shade</td>
<td>Hard</td>
<td>1.0</td>
<td>10.7</td>
<td>41.4</td>
<td>12.6</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Soft</td>
<td>0.0</td>
<td>2.0</td>
<td>28.6</td>
<td>51.0</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td>No shade</td>
<td>Hard</td>
<td>14.3</td>
<td>57.1</td>
<td>28.6</td>
<td>0.0</td>
<td>0.0</td>
<td>100.0</td>
</tr>
<tr>
<td></td>
<td>Soft</td>
<td>0.0</td>
<td>5.6</td>
<td>33.2</td>
<td>53.6</td>
<td>0.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

![Table: Percentage frequency (%) of the spent time in the park](image)

**Table 5.** Percentage frequency (%) of the spent time in the park

<table>
<thead>
<tr>
<th></th>
<th>Parking area</th>
<th>Entrance area</th>
<th>Exit area</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 10 minutes</td>
<td>18.8</td>
<td>20.2</td>
<td>30.0</td>
</tr>
<tr>
<td>10-30 minutes</td>
<td>7.2</td>
<td>13.1</td>
<td>5.9</td>
</tr>
<tr>
<td>30-60 minutes</td>
<td>10.4</td>
<td>19.2</td>
<td>16.8</td>
</tr>
<tr>
<td>more than 60 minutes</td>
<td>63.5</td>
<td>47.5</td>
<td>74.3</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

![Table: Percentage frequency (%) of the planned-spending time in the park](image)

**Table 6.** Percentage frequency (%) of the planned-spending time in the park

<table>
<thead>
<tr>
<th></th>
<th>Parking area</th>
<th>Entrance area</th>
<th>Exit area</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 10 minutes</td>
<td>4.2</td>
<td>12.1</td>
<td>47.5</td>
</tr>
<tr>
<td>10-30 minutes</td>
<td>3.1</td>
<td>6.1</td>
<td>15.8</td>
</tr>
<tr>
<td>30-60 minutes</td>
<td>10.4</td>
<td>13.1</td>
<td>8.9</td>
</tr>
<tr>
<td>more than 60 minutes</td>
<td>82.3</td>
<td>68.7</td>
<td>27.7</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

5. Conclusion
The result and analysis of this study revealed the cooling effect of tree-shaded areas was significant on human thermal comfort at the survey area, in Yogyakarta, Indonesia. The thermal sensation of cool—slightly cool—neutral was a condition of high comfort in tree-shaded areas.

Thermal comfort condition can not be indicated by air temperature and total attendance in tree-shaded areas. Though, the low correlation between high temperature and the decrease of total attendance at noon, this was not an indication of discomfort in tree-shaded areas.
Six categories of tree-shaded areas were classified according to shade coverage and ground surfaces as FS-H (FS-Hard), FS-S (FS-Soft), NS-H, NFS-S, NS-H, and NS-S. The shade coverage was indicated by SVF values as FS (0.0-0.2), NFS (0.2-0.4), and NS (0.4-0.5).

The effect of tree-shaded areas on human activity was considered by the indication of the long duration of spending time, the high intensity of activity and the willingness of using shade areas. Tree-shaded areas with NS and hard surface (NS-H) were not recommended because of the lack of comfort, and the other five tree-shaded area categories showed high comfort regarding thermal sensation and comfort level.

Further, study of the effectiveness of the six categories of tree-shaded areas and green shade quality should be continued for the purposes of thermal comfort in the tropics, in general.

References
13) Parsons K.C. (2002) The effects of gender, acclimation state, the opportunity to adjust clothing and physical disability on requirement for thermal comfort, Energy and Building 34, 583-599.

摘要：熱帯での熱問題は、屋外活動に影響を与える不快原因と考えられ、緑陰微気象を改善することと快適性が高まると期待される。本研究では熱帯のインドネシア、ジャックジャルタを対象として熱帯地での快適性行動の関係をインキュベーション、微気象測定、活動観察を行って分析した。舗装面と非舗装面の日影と快適性評価の関連分析を半球写真と天空率（SVP）の値 [全日影 (0.0-0.2), 一部日影 (0.2-0.4), 無日影 (0.4-0.5)] を主要指標として分析を行った。その結果、全日影舗装面 (NS-H) は快適性が高く、緑陰冷却効果を評価した。