Effect of Greens on the Land Surface Temperature and Outdoor Thermal Comfort in Tropical Areas: A Case Study at a Malaysian University Campus

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ABSTRACT

Global warming, climate change and urban heat island are contributed by a high rate of carbon emission. Less green areas cause more carbon emissions than increased global warming as well as urban heat island intensity. However, there is a limited number of studies on the impact of greens on the outdoor temperature and thermal comfort in a tropical country's university campus with the involvement of students' perceptions. Thus, a study was carried out to measure the variation of land surface temperature and thermal comfort at varying distances from green areas. Besides that, the effect of the type of surface and tree shading on the temperature, as well as the thermal comfort of the study area were examined. Thermo Anemometer was used to record the land surface temperature. Meanwhile, a questionnaire in a form of a survey was conducted to identify the thermal comfort among the university students based on their perceptions. The results showed a positive impact of greens on the reduction of surface temperature and better thermal comfort among the students (the respondents). The findings will provide a guide to planners and related professions on campus planning for better thermal comfort of the students and other users.

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Introduction

Malaysia faces a high rate of urbanisation after 60 years of national independence. In 2000, 61.8 percent of Malaysia's population lived in urban areas [1]. Based on the projection, 78.5 percent of Malaysia's population will be living in cities and towns by 2020 [2]. Due to the rapid growth of this urban population and economic development, there is increased pressure on the need for urban expansion. It requires the clearing of more green fields (undeveloped land) for urban development. As a result, it will be a rise in density for urban commercials, residential areas and also, university campuses. The high rise buildings are built to replace low rise buildings, and green areas are developed [3]. Meanwhile, the higher education sector is intended to serve the public needs for tertiary educational service [4]. Nevertheless, the needs should be met by the provision of buildings, outdoor spaces and facilities which are safe and healthy for the users.

The development process changes the land cover and reduce natural vegetation/greens, as well as producing heat and causes a temperature rise of an area [5], [6]. This is because the physical urban developments, especially on buildings, transportations, infrastructure, and other concentre structures have an impact on the reduction of green areas [3]. A statistical study at the tropical regions of Myanmar [5] showed an increase of a built-up area by 11.7 percent and a decline of a vegetation area by 19.7 percent from 1989 to 2017. At the same time, a land surface temperature had risen by 4 degrees Celcius during these 28 years [5]. Generally, the climatic deterioration of overcrowded and urbanised zones is due mainly to the scarcity of green space, in which a concrete surface replaces the green cover [7].

Globally, the temperatures of the last three decades were likely the warmest of the last millennium, about 0.2 degrees celcius warmer than during warm periods in the 11^{th} and 12^{th} centuries [8]. From 1900 to 2002, the surface temperature rose linearly by 0.069 degrees celcius per decade [9]. The top 10 hottest years have been on record since 1998 [10]. In fact, 2016 was the hottest year ever recorded [10]. Recent climate change has caused extreme heatwaves that would likely occur two to four times [11]. Based on a prediction, over the next 40 years, the heatwave events would likely occur 100 times than the record in the late 20^{th} century [11].

In Malaysia, the Malaysian Meteorological Department [12] projects that range of temperature increase among the nine Atmospheres – Ocean General Circulation Models (AOGCMs) for East Malaysia and Peninsular Malaysia are 1.0 to 3.5 degrees celcius and 1.1 to 3.6 degrees Celcius, respectively. Earth surface temperature record has indicated that the climate of

the earth is warming day by day [12]. Based on a projection by the Malaysian Meteorological Department (refer to Figure 1) [12], Malaysia will experience an increase in temperature trend in time series started from the year 2000 till 2098. This trend analysis is considered based on a scientific study and, the observations that were done. It shows that Peninsular Malaysia, Sabah and Sarawak will experience a hotter temperature decade by decade.

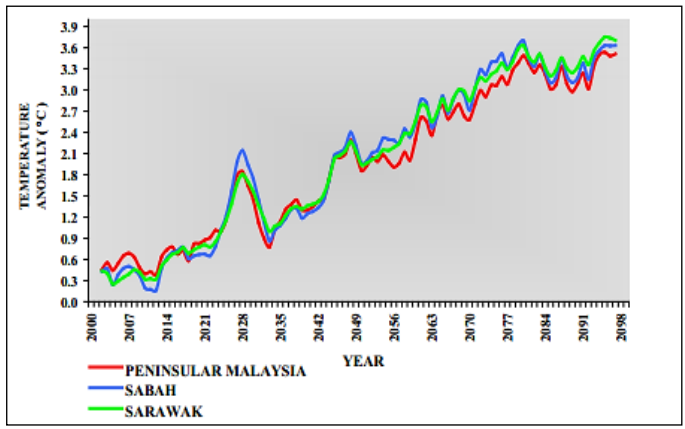

Figure 1: The projected temperature for Peninsular Malaysia, Sabah and Sarawak [12].

Higher temperature conditions occur in urban areas (Urban Health Island, UHI intensity). Green spaces can reduce the temperature of an area. Green spaces are extra cool due to the active evaporation process [13]. The green spaces discharge moisture into the atmosphere and help to reduce heat, as well as make an area a more comfortable place to live and work. Places that are near green spaces are found to be 2 to 3 degrees Celcius lower than the areas that are far from the green spaces [14]. A study in Bangi New Town [15] displayed that there was a lower temperature reading (UHI intensity) at a green area as compared to a build-up area during daytime. Besides that, greens improve air quality and environmental health [16], [17]. In other words, fewer greens and a higher temperature are not good for human's health. The health impacts of warming pertaining to the impact of tropical diseases will be increased in the poorest and hottest countries. On the other hand, extreme weather events will be harmful to human's health everywhere [11]. Besides the good impact of greens on temperature and human health, greens or parks are also able to increase the quality of life as well as the active lifestyle among people [18, 19]. A recent study [20], concluded that temperature in or close to

hot spots in cities could be regulated by increasing the height of adjacent vegetation, besides the size of green coverage.

Apart from the issue of temperature increase, thermal comfort should be taken into consideration in the research. Thermal comfort can be defined as the situation of the mind in expressing satisfaction with the thermal environment [21]. It clearly states that thermal comfort is an acceptance of humans in facing an environment temperature of the area, and thermal comfort is a cozy area. Nonetheless, this comfort differs according to individuals, as well as timing. Nikolopoulou [22] argues that the majority of work in outdoor thermal comfort focuses mostly on scientific parameters but lacks an understanding of subjective human parameters in the study of thermal comfort. Thus, this study covers respondents' perceptions of thermal comfort.

Relatively, a few studies [23] on thermal comfort for outdoor environments had been done as compared to indoor environments. Furthermore, there were limited studies on the impact of green on the outdoor temperature and thermal comfort of students at a university campus. One of the most related research [24] was carried out at National Formosa University (NFU) campus in Huwei Township, which is the centre of Taiwan. The related research aimed to determine the shading effect on long-term outdoor thermal comfort through a field experimental study. Hwang et al.'s study [24] found that the barely-shaded locations were uncomfortable in summer and highly-shaded locations were uncomfortable in winter, and the median shading levels contributed to the longest thermal comfort period in an entire year. Hwang et al.'s study [24] was carried out in a hot-humid four-seasons region which was different as compared to this present study that was conducted in a tropical country.

Thus, this is necessary to carry out a study in a tropical country, namely, Malaysia. For this purpose, Universiti Teknologi Mara (UiTM) Shah Alam campus had been selected as the study area. This study aimed to examine the variation of land surface temperature at different distances from two green areas, and the thermal comfort among students in relation to the existence of greens.

Case Study and Methodology

Universiti Teknologi Mara (UiTM) Shah Alam campus is located in Selangor state, Malaysia. The areas of study were Seroja College and the Academy of Language Studies of the UiTM Shah Alam Campus (see Table 1, Figure 2 and Figure 3). Seroja College consists of three (3) hostel blocks which are Seroja 1, Seroja 2 and Seroja 3. The total number of residents is 1,320 (based on the university's record). This residential college is located near to Faculty of Hotel and Tourism Management, as well as the Sultan Abdul Aziz Building.

Conversely, the Academy of Language Studies has 256 lecturers (based on the university's record).

Studies on thermal comfort in the built environment had been carried out since the past decades using different approaches, such as field surveys, experimental setups, computational tools, and a combination of these methods [25]. For this study, a field survey was conducted. First sampling points for both areas (A and D) were located inside the green spaces (see Table 1, Figure 2 and Figure 3). The second sampling points (B and E) were positioned approximately 50 metres outward from the first points. The third points (C and F) were 50 metres farther away from the second point. Hence, the sampling points were located with three different distances from green spaces which aimed to measure the variation of temperatures in the green spaces, areas located at a moderate distance from the green spaces, and also, areas located far from the green spaces.

Table 1: Temperature sampling points

Academy of Language Studies			Seroja College		
Point A In the green area (under a shaded tree)	Point B Moderate distance from the green space (parking area with concrete surface)	Point C Far from the green space (entrance to parking with concrete surface)	Point D In the green area (open field)	Point E Moderate distance from the open field (pedestrian space with concrete surface)	Point F Far from the open field (parking area with concrete surface)

Note: the distance between points A and B, B and C, D and E, as well as E and F was approximately 50 metres.

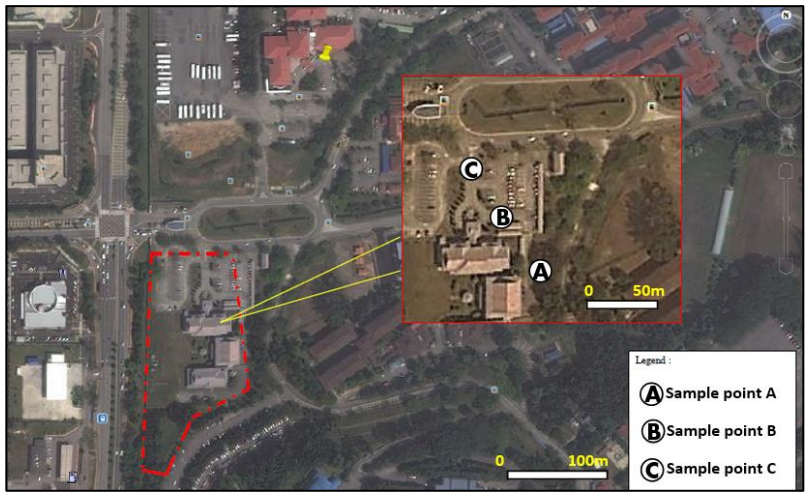

Figure 2: Sampling points at the Academy of Language Studies, UiTM.

Figure 3: Sampling points at Seroja College, UiTM.

For all the six (6) points of sampling, the temperatures were recorded for three (3) periods of times: in the morning (8 am to 9 am), at noon (12 pm to 1 pm), and in the evening (6 pm to 7 pm) for three (3) days. The average reading of every period was recorded. The study used Thermo Anemometer in recording the temperature (see Figure 4). Samplings were taken place far from

any elements that could affect the reading, such as a motor vehicle, air-conditioning or a student.

Figure 4: Thermo Anemometer used to record temperature.

Besides the temperature recording works, a questionnaire in a form of a survey had been carried out with a total of 40 students chosen as respondents. Studies on outdoor thermal comfort had highlighted the need to develop interdisciplinary frameworks that integrated physical, physiological, psychological, and social parameters to assist urban planners and designers in design decisions [26]. Thus, the students' perceptions of thermal comfort were necessary to be incorporated into this study. From the total of 40 respondents, 20 respondents were selected randomly at the Academy of Language Studies. Meanwhile, another 20 respondents were selected randomly at Seroja College. Among the respondents, 40 percent were males (16 respondents) and 60 percent were females (24 respondents). Table 2 illustrates the general background of the respondents. The questionnaire contains items about the perceptions of the students on the effectiveness of the green spaces in reducing temperature and the impact on thermal comfort at the study areas.

Table 2: Background of the respondents

Variables		Percentage (%)
Gender	Male	40
	Female	60
Age group	18-23 years old*	95
	24 years old and above	5
Academic program	Graphical design & media digital	45.0
	Accountancy	17.5
	Town & regional planning	10.0
	Quantity surveying	5.0
	Others	22.5

Note: *most of the diploma and degree students are in this group

Results and Discussion

Temperature

In general, the study indicated that temperature was increased when the sampling points were located farther away from the green areas (see Table 3). The temperatures of the concrete spaces (points B, C, E, and F) were higher as compared to green spaces (point A and D). Moreover, point D was higher in temperature than the temperature at point A. Point A was on the shaded green area, while point D was on the open field. It showed that the green shaded area (Point A) was found around 2 degrees Celcius lower than the concrete surfaced spaces which were far from the green spaces (Point C and F). The finding of the study is in line with DTLR's finding [14].

This shows the ability of green areas, especially the green leaves in increasing the moisture in the air, reducing the heat and making the surrounding area feel more comfortable. In general, up to 10 to 30 percent of sun energy reached the space below a tree. The rest of solar energy was absorbed by the leaves and used for photosynthesis, while some of the solar energy was reflected into the atmosphere.

Table 3: Average temperature for the six (6) sampling points

	Academy of Language Studies			Seroja College		
	Point A	Point B	Point C	Point D	Point E	Point F
Average temperature	29.5 ˚C	30.5 ˚C	31.6 ˚C	30.4 ˚C	30.6 ˚C	31.3 ˚C

By examining the recorded temperature data for every individual sampling day (see Tables 4 to 6), the result showed the same pattern as the average figures (see Table 3). The result illustrated that the points in green areas (A and D) were cooler as compared to the points (with the concrete surface) located farther away from the green areas (B, C, E, and F). The lack of greens or leaves in points "B, C, E, and F" was a possible explanation for its higher temperature as compared to points "A and D". Furthermore, the cooling effect of a shaded green area (trees) at the Academy of Language Studies clearly showed its ability to reduce the temperature as compared to the open field area in Seroja College. Therefore, greens can influence temperature [7].

The study (see Tables 4 to 6) also displayed the effect of sunlight to increase the temperature of the study areas. Data showed a higher temperature in the noon (12 to 1 pm) as compared to morning (8 to 9 am) and evening (6 to 7 pm). Besides that, the data showed that the evening time was higher in temperature as compared to the early morning time. It is due to the ability of man-made materials (concentre surface) to store energy (heat) in the daytime and slowly release it in the evening or nighttime [27].

Table 4: Average temperatures for the six (6) sampling points on Day 1

	Academy of Language Studies (˚C)				Seroja College (˚C)			
	Point			Average	Point			Average
	A	B	C		D	E	F	
8 - 9 am	28.6	29.0	31.2	29.6	29.4	29.6	29.8	29.6
12 - 1 pm	30.1	31.1	31.4	30.9	30.4	31.0	32.1	31.2
6 - 7 pm	28.6	29.0	32.3	29.9	30.6	31.3	32.6	31.5
Average	29.1	29.7	31.6	30.1	30.1	30.6	31.5	30.7

Table 5: Average temperatures for the six (6) sampling points on Day 2

	Academy of Language Studies (˚C)				Seroja College (˚C)			
	Point			Average	Point			Average
	A	B	C		D	E	F	
8 - 9 am	28.4	29.2	30.3	29.3	29.3	30.6	31.5	30.5
12 - 1 pm	30.6	33.4	33.9	32.6	32.4	31.5	32.0	31.9
6 - 7 pm	31.4	33.5	32.9	32.6	32.5	31.8	31.9	32.0
Average	30.1	32.0	32.4	31.5	31.4	31.3	31.8	31.4

Table 6: Average temperatures for the six (6) sampling points on Day 3

	Academy of Language Studies (˚C)				Seroja College (˚C)			
	Point			Average	Point			Average
	A	B	C		D	E	F	
8 - 9 am	28.6	28.9	29.3	28.9	29.3	29.5	29.9	29.6
12 - 1 pm	30.3	31.0	33.3	31.5	30.2	30.6	31.3	30.7
6 - 7 pm	29.4	29.6	29.8	29.6	29.9	30.1	30.4	30.1
Average	29.4	29.8	30.8	30.0	29.8	30.1	30.5	31.1

Thermal comfort of students

Findings from the questionnaire survey showed that most of the respondents felt more comfortable in the shaded green area as compared to the open field (see Table 7). However, the open field was still more comfortable than the areas outside or far from the green areas. When they moved farther away from the green areas, they felt less comfortable. This was supported by the results of the recorded temperature in the study areas. The increase of around 2 degrees Celcius when it was compared to the shaded green area (Point A) and area far from the green area (Point C or F) caused most of the respondents to feel comfortable at Point A, but not comfortable at Point C or F. This was because the green spaces were extra cooler due to active evaporation process that occurred which created less diurnal temperature variation [13]. Hence, in the tropical area, the reduction of the temperature (around 2 degrees Celcius) could increase the thermal comfort among the respondents. The temperature was observed to be the highest contributor to thermal conditions [28].

Table 7: Perceptions of respondents on the thermal comfort in the form of percentage

Thermal comfort	Percentage of respondents			
	Shaded green area	Open field	Near to green area	Far from green area
Not comfortable	0.0%	0.0%	0.0%	32.5%
Less comfortable	0.0%	5.0%	7.5%	27.5%
Moderate	27.5%	42.5%	45.0%	17.5%
Comfortable	42.5%	50.0%	40.0%	12.5%
Very comfortable	30.0%	2.5%	7.5%	10.0%
Total (40 respondents)	100%	100%	100%	100%
Average temperature*	29.5 ˚C	30.4 ˚C	30.5 ˚C - 30.6 ˚C	31.3 ˚C - 31.6 ˚C

Note: *Average temperature data from Table 1

In the questionnaire survey, the respondents (students) were also asked about their feeling of comfort (thermal) when they carried out activities in the green area. Most of the respondents (60%) agreed that they were comfortable (see Table 8). Apart from that, there were 27.5% of respondents strongly agreed that they were comfortable, while only 12.5% felt moderate while conducting activities on the green area. No respondent did not feel comfortable when carrying out activities in the green area (see Table 8).

Table 8: Perceptions of respondents on their feeling of comfort when carrying out activities on the green area

Thermal comfort	Percentage of respondents
Not comfortable	0.0%
Less comfortable	0.0%
Moderate	12.5%
Comfortable	60.0%
Very comfortable	27.5%
Total (40 respondents)	100%

Table 9 shows that 82.5% of respondents agreed or strongly agreed on the effect of lacking green spaces on the issue of temperature rising. There were only 10% of respondents who disagreed or strongly disagreed on it. This displayed that the respondents (university students) did feel the impact of the green areas in reducing temperature and improving the thermal comfort of the campus.

Table 9: Perceptions of respondents on the effect of lacking green area on the temperature rising

Perception	Percentage of respondents
Strongly disagreed	2.5%
Disagreed	7.5%
Moderate	7.5%
Agreed	40.0%
Strongly agreed	42.5%
Total (40 respondents)	100%

Conclusion

To conclude, this study showed a definite effect of greens (trees and grass) in reducing the outdoor temperature and increase thermal comfort at the study area as located in a tropical country. Moreover, it was observed that trees with

a larger surface of leaves (more shading) were more effective in decreasing the temperature and improving thermal comfort as compared to open fields. However, the study at a four-seasons region in Taiwan conducted by Hwang et al. [24] showed different results. The results indicated that too much shading was not good in winter. Thus, the present study in a tropical area found that more shading was better for thermal comfort among people in the tropical area.

Based on the results of this study, it is recommended that planners and administrators in tropical countries, especially Malaysia should allocate part of the area for open space or any form of green area for all human settlements, including university campuses. This will reduce the temperature of the area, as well as improve the thermal comfort of people. An urban area should not just depend on the hindered land (rural areas) in preserving green areas or forests for the urban. The cooling effect of greens will be more effective when the greens are located closer (within our habitat or campus) as compared to the greens that are located far from the habitat or campus.

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