Quantifying the Air Temperature Reduction with Greenery in UiTM Shah Alam: A Microscale Study

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Abstract. Growth in cities population has caused urban sprawl which is the key factor in the issues of high temperatures as well as UHI in many countries. This issue has affected the urban microclimate as well as the indoor and outdoor conditions of human thermal comfort. This issue is also aggravated by the replacement of natural greenery area with building and other man-made features. For that reason, greening the cities, as part of bioclimatic concept of build environment, could be the way to decrease the outdoor temperature and making the surrounding more comfortable. To understand this issue further, ENVI-met software was used to simulate all activities either natural or man-made to attain accurate prediction and evaluation of microclimate changes in certain area. For this study, the simulations were run in three scenarios of pavement, asphalt pavement without plants (scenario 1), concrete pavement without plants (scenario 2), and asphalt pavement with plants (scenario 3). Plants were design in area surrounding the building and in courtyard consisting of pine trees and hedges of 2 metre height. The result shows that greenery plants can influence air temperature and airflow in the surrounding thus improving thermal comfort in the area. Existing plants can decrease temperature from 0.5°C to 2.3°C and air velocity become slower at 0.05 m/s to 0.15 m/s. Overall, although the changes are at small scale, it is shown that plants are able to improve microclimates surrounding better towards thermal comfort standards.

1. Introduction
The concept of urban microclimate usually includes the elements of its local wind, humidity, solar radiation, and temperature, influenced by urban parameters such as the building infrastructures, vegetation, and its surface materials. Growth in cities population has caused urban sprawl which is the key factor in the issues of high temperatures of the frequent heat waves in many countries, over the last decades. This issue has affected the urban microclimate as well as the outdoor conditions of human comfort. With the complexity of the urban environment and more urban problems arising, the need for adaptation and change has increasingly becomes important. It is agreed by many that the connection between the ecosystem and cities should exist as a sustainable way of development. On the other side, the limited open spaces, the lack of green spaces, the high building density, the
compactness of the urban blocks, the poor air quality and the traffic congestion can lead to the urban environmental degradation [1]. For that reason, greening the cities, as part of bioclimatic concept of build environment, could be the way to decrease the outdoor temperature during hot days. A result of the abovementioned microclimate improvement technique of more greenery growth would be the improvement of the outdoor thermal comfort conditions. Moreover, the existence of greenery can contribute to cooling of the urban environment through the evapotranspiration process. Many studies have shown that the shade of tree foliage can control the solar radiation as the incident radiation is absorbed through photosynthesis process [2]. In Asia, almost 60% case study are in China and 9% in South Korea [3] has analysed microclimate conditions of urban areas. Therefore, this paper is trying to simulate the greenery impacts and air flow influence on the micro scale surrounding temperature thus either improving thermal comfort of the area or otherwise.

2. Background research
Part of the global warming issue, urban growth, or urbanisation has caused a series of environmental hazards such as Urban Heat Island (UHI). The UHI is a phenomenon where a significant difference in temperature can be observed within a city or between a city and its surrounding rural areas. Areas of maximum temperature can expectedly be found within the densest part of the urban area [4]. Significantly, temperature in urban area should be warmer than suburban areas cause by replacement of natural surface to man-made surface. Shah Alam is one of city in Malaysia also have hot and humid tropical climate. Previous study had been done in Shah Alam, by combining Geographical Information System (GIS) and Remote Sensing by generated temperature distribution map through mono-window algorithm. Based on previous result, cooling effects depends on green space profile and distance from the park [5].

The main factor causing UHI could be the heat emissions and pollution from the energy consumption that happen within the city itself. The reduced speed of wind caused by the structure of the built environment, the intensive land use and the high density in urban areas combined with buildings with high thermal masses and the heat retaining properties also has been detected as part of the contributing factor [6]. Some study also verifies that the lack of greenery and the presence of low-albedo materials on buildings external facades and road surfaces [7] has become another contributing factor in this UHI issue.

Studies has shown that the strategies to mitigate urban heat islands can be divided into two categories that is by either increasing the urban albedo (reflectivity to solar radiation) or increasing the evapotranspiration [8] In order to achieve an increase in urban albedo, high albedo roofing and paving technologies need to be implemented. As for increasing the evapotranspiration, a combination of decreasing the fraction surface materials and planting vegetation in urban areas have been proposed. Although the lack of green space and higher building density is common for urban scenario, planting trees for its shade, vegetated walls, and rooftop gardens has shown some positive effect in lowering the surface air temperatures as well as beautifying the landscape. Measured and simulated energy reductions caused by vegetation around individual buildings generally range from 5 to 15 per cent for heating and 5 to 50 per cent for cooling [9].

Basically, the main reason of greening the cities is to decrease the outdoor temperature and making the surrounding more comfortable. The presence of greenery not only contributed to the cooling of the surrounding but also act as natural filters and noise absorbers, improve microclimates and the quality of natural resources including soil, water, vegetation, and wildlife [10].

Thermal comfort is a mind expression of satisfaction with the thermal environment the body is experiencing. Too cold or too warm can cause discomfort towards the body. Most of the common indicator for the human body is temperature. However, relaying only to air temperature as an indicator for identifying thermal comfort is not an accurate way. According to ASHRAE Standard 55-100, environmental parameters are air temperature, mean radiant temperature, wind speed, and relative humidity [11]. Today, rapid urbanization in Malaysia has affected indoor and outdoor thermal comfort. Most of the air temperature in the urbanized area relatively higher compared
to the rural area. Department of Standards Malaysia, 2007 had published a guideline for standard indoor temperature should be in the range 23°C to 26°C [12]. Due to this standard, the UHI phenomenon can cause discomfort to the urban occupant.

Another alternative solution is to attain physiological comfort at high temperatures is the movement of air. Significantly, heat can transfer in the air movement through convection and evaporation process [8]. A previous study has shown that the wind speed at the average 0.5 m/s to 1.2 m/s able to reduce thermal discomfort while according to Chartered Institution of Building Services Engineers (CIBSE), recommend for the comfort of most people in a tropical climate is between the range 0.1 m/s to 0.25 m/s [13]. This study aims to predict greenery impacts and air flow influence on the microclimate establishing either thermal comfort is improved or otherwise.

3. Study area and data collection.
The study area is a model with 98m x 98m space area with building dimension of 80m x 80m x 10m. To mimic the real microclimate weather data at UiTM Shah Alam, an actual observation was conducted by using weather station model Rain Wise MK III at latitude 3° 35'59.69”N and longitude 101°30'18.22”E (WGS 84). Observations were carried for two days 5th and 6th March 2020, starting at 0900 hours until 1630 hours. Relevant meteorological parameters have been considered in the data collection such as temperature, wind chill, dew point, heat index, humidity, wind direction, wind speed, and solar of the two days.

All the scenarios were tested based on the same building materials which is heavy concrete wall while the scenarios used for plants were 3D pine and two meters hedges surrounding the building included as well at the courtyard of the study area. Based on those microclimate parameters and to the structure of the urban morphology, three pavement scenarios were simulated through ENVI-met software. The scenarios were 1) asphalt pavement without plants, 2) concrete pavement without plant, and 3) asphalt pavement with plants. All scenarios were simulated using ENVI-met software for 3 hours from 1130 hours until 1430 hours for both days.

4. Methodology

Figure 1 illustrates the overall methodology used in this study. Modelling was constructed based on the input parameter at the stage of ENVI-Met database. A simple layout for building was designed without including any detail of the building itself. Before starting the simulation process, there is a need to create a file for configuration purposes, such as for time and date, temperature range, wind speed and wind direction. The details of the input data are shown in Table 1.

| Simulation input data          |
|-------------------------------|
| Simulation Date               | 6 March 2020                |
| Start and Duration of Simulation | 11:30, 3h                 |
| Temperature range             | 22 to 33 Degree Celsius    |
| Wind speed value (Average)    | 2.7 m/s                    |
| Wind direction                | 272 Degree                 |
The simulation has been carried out at low level to suit with specification of a personal computer (PC) with the intel i5 processor and 8GB RAM. The range of temperature for the observation was set up manually between 22 degrees Celsius to 33 degrees Celsius. It takes almost a day to complete the simulation process for each scenario. The output for the simulation was used for analysing and visualizing the simulation in 2D. Figure 2 illustrates two (2) modelled scenario which is with the presence of plant and the one without plant.

The result was visualized in 2D by using Leonardo tools which is useful in assisting the analysing process. The changes in the atmosphere in term of temperature and wind direction was recorded between 1130 hours and 1430 hours. The observation focused mainly on the outer building surrounding, as well as the courtyard area. (The study area surrounding the outer building is categorised into 4 different areas namely North, South, East and West following the north scale orientation. The air movement information is also included in the analysis to study the influence of air movement to the temperature of the study area. The data can be exported not only limited to diagram format but also in tabulated data which then can be presented in statistics in the form of graph. The map can be exported into three types of format including bitmap, metafile, and enhanced metafile. The data were presented in the range of 10 temperature classes, with each class represents the value of potential air temperature as shown in Figure 3. For the wind direction and speed data, the result was presented in the form of arrow size. Based on Figure 3, result had been classified into 10 classes to differentiate more details for the changes. Darker blue colour is below than 31.30°C while ascending order to higher temperature above 33.70°C with colour light red.

![Figure 2. Modelling the scenario](image)

![Figure 3. Potential air temperature legend](image)
5. Result and analysis

5.1. Potential air temperature

The simulation starts at 1130 hours and ends up at 1430 hours, so the result is shown in an hourly simulation.

1230 hours

For scenario 1, it is shown that the highest temperature obtained was 34.69°C at the south and southwest part of the building while the lowest temperature recorded was 31.89°C at the east and northeast part of the building. At the courtyard area, the temperature in average was recorded to be below 32.80°C. North part of courtyard was higher compared to southern part of the courtyard which also occurred the lowest temperature of 31.60°C to 31.90°C. For outer building surrounding temperature, some part remained below 32.80°C and some others part above 32.80°C. From figure 3 the highest temperature obviously shown at western and southern part of building with temperature mostly above than 33.70°C.

1330 hours

Scenario 2 which is concrete pavement without plant shows the highest temperature recorded was 32.29°C while the lowest temperature was 30.98°C. The temperature range in the courtyard area of asphalt pavement with the absence of plant is lower compared to the concrete pavement without a plant with which is only 1.31°C compared with 2.80°C range difference in scenario 1. At the outer building surrounding, the temperature recorded was between 31.30°C to 32.50°C and the highest
temperature occurred in the southern part of the building and different temperature were recorded at eastern and northern of the building with temperature of 31.30°C to 31.90°C.

Scenario 3 shown almost every part of the courtyard area temperature was below 31.30°C and only some part in the middle area is higher. Temperature higher than others recorded at the southern and the eastern part of the outer building area. The lowest temperature recorded was 27.54°C and this time of the day shows the lowest maximum temperature obtained compared to other timing scenarios.

The scenarios illustrate the simulation that occurred at 1330 hours with the highest temperature recorded at 36.73°C and the lowest temperature recorded 32.95°C for the asphalts without plant scenario. Almost all the building outer surrounding was above than 33.70°C, with only minor part at the east and north east of the building temperature between recorded between 32.80°C to 33.70°C. At the courtyard of the building, lower temperature range between 32.80°C to 33.70°C is recorded with exception the northeast corner of building above 33.70°C. While for scenario 2, the highest temperature recorded was 34.21°C while the lowest was 32.15°C. Temperature above 33.10°C occurred at the southern and western part surrounding the building and other areas shows temperature below 32.80°C. At the courtyard area, the temperature was between 31.90°C to 32.80°C. Scenario 3 same as the others which shows a mix of high and low temperature in the courtyard and surrounding the building. Temperature recorded at the southern and western side of the building surrounding have a range between 32.20°C to 35.07°C, while the north and eastern side shows temperature range between 31.3°C to 31.9°C. The highest temperatures surrounding the southern part as well as the courtyard was above 33.40°C.

1430 hours

![Figure 6. Results for simulation at 1430 hours](image)

1430 hours is the last duration of observation and all the scenarios recorded the highest temperature of 37.65°C while the minimum temperature was 31.6 °C. In scenario 1, temperature above 33.70°C are recorded in the open area of the building as well as the courtyard. Lower temperature between 33.40°C to 33.70°C was spotted at the eastern part of the building and at the southwest corner of the courtyard. Scenario 2 also shows high temperature recorded in almost the whole building surrounding and in the courtyard. Maximum temperature recorded was 35.32°C at the southern and western part of the building while minimum temperature recorded was 32.75°C in the eastern part of the building. For the courtyard, high temperature above 33.70°C was recorded at the north-east corner while other parts, temperature mostly ranging between 32.80°C to 33.40°C, just minor part between 32.50°C to 32.80°C.

For scenario 3, it is observed that the temperature recorded was much better compared to the other two scenarios as it recorded the lowest maximum temperature that occurred of 30.65°C. The building open surrounding especially at the southern and western part seems to record high temperature above 33.0°C but on the eastern side temperature was recorded below 31.90°C. At the courtyard, the
temperature was around 31.90°C with some spot reaching 33.70°C. Compared to the other scenarios, this scenario with plants seem to create various class of temperature within the courtyard. Overall, all the scenarios show temperature increases in every hour and maximum temperature exceeding that of the maximum temperature which measured on site. The only scenario without plant which is of concrete pavement without plant at 1230 hours shows reading below 32.80°C. For pavement with plants, it seems to have various temperature range for each observed hour including the area at the courtyard.

5.2 Wind simulation analysis

Based on Figure 7, scenario 1, outside of building air comes from the west mostly at 0.25 m/s stopped by the wall of the building then, change its direction towards the east and west making the speed slower than before. At southern part of the building the air is moving diagonally at rate 0.15 m/s and changed direction towards east till the end corner of building. Some of the air particles is shown moving to spaceat the east of building at velocity 0.10m/s. The air at the east keeps moving till at the corner of building. In the northern part of the building, some air changed direction after hitting the wall and moving to that space at rate 0.15m/s. The air moving straight forward without any changes of direction. At courtyard, the air seems to be coming from the southwest with the lowest velocity at rate 0.05 m/s and the velocity increased when moving towards the centre of courtyard. Air was scattered all over the area in the courtyard until it hit the wall. Although with the change of direction, air movement and velocity did not manage to change the air temperature.

In scenario 2, which is the concrete pavement without plant, air is also coming from the west at velocity 0.25 m/s and changed direction causing some velocity decreased after hitting the wall. Southern part is also experiencing the same situation, but the air is coming in a diagonal direction and changed direction only to the east. The temperature remains the same which is above 33.70°C. Some of the air particles from south entered the eastern part of the building at the rate of 0.10m/s moving forward till at the corner, some components changed direction towards east. Along with air moving there occurred a decrease of temperature but only momentarily, the temperature increased back between 32.80°C to 33.10°C. At the northern part of the outer space of the building, some particles coming directly from the west caused by the change of direction after hitting the building. In this area, there was no change of wind direction, but a change of temperature was recorded in the range of 32.80°C to 33.10°C. Air at the courtyard also seemed to changed temperature from rate 32.80°C to higher. Trends of the air moving looks the same as the previous scenario which is air coming from southwest scattered to all areas in courtyard.

Result for scenario 3 illustrates the condition for asphalt pavement with plants. Generally, it seems a variation of temperature and different trends of air movement occurred compared to scenario without any plant. There are fewer kinds of air velocity in the range of 0.25 m/s and mostly below it. At the west of building air coming was above 33.70°C with velocity 0.20m/s. Before hitting the wall its temperature decreased reaching between 32.20°C to 32.50°C then changed direction towards north and south. There is also a change of temperature although not as low as the western area and only occurred at a certain place. Air velocity at that area between 0.15 m/s, does not change much until at the corner, increased to 0.20 m/s and 0.25 m/s. Temperature recorded in the middle of
building air was below 31.30ºC, then gradually increased again reaching plateau 32.20ºC. Air at the east area also the same situation likes others change direction to the east after passing the corner. North area of the building has the same trends of air moving like other scenarios but at different velocity and temperature. Air velocity moving below than 0.10 m/s and happened rise and fall rate of temperature between 32.80ºC to 31.30ºC. The air seems not too directly straight in movement, some diagonal can see if observe closely for the free particles which do not have any interaction with the wall.

For courtyard, the air temperature recorded above than 33.70ºC and the lowest between 31.90ºC to 32.20ºC. Air temperature in this area keeps changing when through a certain area and sources of air coming from the corner southwest then scattered to almost area. Most air particles directly moving towards the northeast although had hit the wall the direction seem to still interact towards the corner.

6. Conclusion
Based on the result and analysis all the scenarios have shown different result for simulation with plants and without plants. Started from 1130 hours until 1430 along the duration have shown gradually increasing temperature for every part outside of building in all the scenario. Asphalt pavement without plant was the fastest scenario with rapid increased in temperature since at the first an hour and the maximum temperature exceeded 32.20ºC which was the maximum temperature at site. There is no sign of temperature decreased for all scenarios. Mostly, peak maximum temperature for all the scenario occurred at 1430 hours. For scenario one, pavement without any features, temperature pattern was uniform to most of the area.

In scenario 3, it is proven that plants could reduce the maximum surface temperature between 0.5ºC and 2.3 ºC depends on the capability of matured plants to reduce the temperature. This scenario clearly shows that by using this passive cooling method, the outdoor thermal comfort could be improved with reduction of the air temperature. However, from the result obtained, with existing plants in scenario 3, occupants inside the building will not meet an ideal thermal comfort because the indoor temperature will be relatively higher than outdoor temperature and based on published guideline by Department of Standards Malaysia, 2007, recommends indoor temperature should in range 23ºC to 26ºC [9]. This result also shows that 2m hedges and pine trees can only give minimal effect for controlling temperature in the surrounding.

Most of the scenarios have the same pattern for air direction the only changes are in temperature and velocity. All the scenario shows sources of air movement coming from the same direction that is from west to east. From the observation, different type of pavement does not make airflow changes because, as shown in scenario 3 which is with the presence of plants surrounding the building and at the courtyard. With existing 2m hedges and several pine trees, it can make the air velocity decreased at a very small magnitude. For conclusion on the overall study, the movement of air had occurred causing changes in velocity, direction, and temperature. Although all the scenarios are
shown in temperature and not in range of thermal comfort but existing moving air at rate 0.05 m/s to 0.25 m/s does help with the temperature. The faster the air motion produced, the greater the rate of heat flow by both convection and evaporation [10]. Based on ASHRAE (Std-55,2004) an ideal air velocity is between 0.2 m/s to 1.50 m/s. This clearly shows the air movement could help to achieve thermal comfort.

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