In-situ Measurements and GIS-Based Analysis of the Microclimate at the Universiti Teknologi Malaysia, Kuala Lumpur

Siti Wan Syahidah[1], Sheikh Ahmad Zaki[2] and Khamarrul Azahari Razak[3]

[1] Malaysia-Japan International Institute of Technology, UTM Kuala Lumpur, *sitiwansyahidah@gmail.com*

[2] Malaysia-Japan International Institute of Technology, UTM Kuala Lumpur, *sheikh.kl@utm.my*

[3] UTM RAZAK School of Engineering and Advanced Technology, UTM Kuala Lumpur, *khamarrul.kl@utm.my*

Developing tropical countries are expecting a large number of population in the near future, thus, environmental degradation issues due to excessive economic development and urban climate change are becoming a major threat to modern society. In order to improve urban design and sustainable architecture, in accordance with this specific tropical climate, a quantitative grasp of the microclimate in a developed city is highly desirable. Moreover, only a few studies have been carried out on the aforementioned issues in a low-latitude tropical urban region. Therefore, this study aims to provide a better insight into the use of in-situ microclimatic measurements and Geographical Information Systems (GIS), particularly in analysing the effect of greenery coverage and morphological aspects, i.e. height to width ratio of built-up features, for understanding the microclimate pattern at the university campus. The study area is situated at the Universiti Teknologi Malaysia, Kuala Lumpur, (UTM KL), which is a local-scale city campus environment, located near the Kuala Lumpur city centre. The urban microclimate was observed for the duration of one year. The climatic data were mapped and spatially analysed in relation to different land cover types in the GIS environment. Moreover, the effect of green areas and building morphology are critically evaluated with regards to the changes made to the local climatic variables in the campus. As a result, this study reveals that the effects of greenery coverage and the morphological characteristics on the campus providing a good indicator of the microclimate pattern in a developed city campus. In conclusion, with the support of in-situ measurements and GIS analysis, the campus temperature properties were quantitatively evaluated, and this directly contributed to a better understanding of climate change in the city of Kuala Lumpur.

Keywords: urban microclimate; geographical information systems; in-situ measurement

Introduction

In the urban area, microclimate patterns are often characterized by the urban forms and land-use-land-cover (LULC) types. The surface land cover changes according to the purpose of the land uses, e.g. from large green-space to high-rise residential areas, which this scenario can be easily found in a tropical emerging country, such as Malaysia. The tropical, hot and humid weather conditions have caused the climate conditions at a local scale as mostly constant pattern of air temperature, relative humidity, and solar radiation (Buyadi et al., 2013). However, the differences in urban surface have altered this constant pattern of the local scale microclimatic conditions.

Consequently, several parameters, particularly air temperature, have been investigated in order to correlate the microclimate with the surface land covers, such as greenery percentage, built-up ratio, and building height to width ratio (Ahmed et al., 2014). The parameters were used to quantify the effect of surface land covers on the in-situ microclimate measurements. For instance, green areas have been subjected to lower air temperatures. In Singapore, a large green area in the city has had a cooling effect on the surrounding area, which revealed the correlation between large green areas and a decrease in air temperature (Wong & Yu, 2005). Furthermore, the built-up ratio within a study area, including its height-to-width ratio, have been proved to cause the variations in air temperature measurements (Jamei et al., 2015). The canyon effect, defined by the height-to-width ratio, has shown that a shallow canyon, with a lower height-to-width ratio value, has a higher temperature due to its exposure to solar radiation (Bakarman & Chang, 2015). Deep urban canyons provide cooling effects during the day, and thus provide a comfortable environment for pedestrians (Andreou & Axarli, 2012). In order to manage and analyse the microclimatic data and their related parameters, GIS applications have been used in order to clearly visualise and analyse the air temperature variations (Matouq et al., 2013).

This study presents in-situ measurements of the microclimate in the Universiti Teknologi Malaysia, Kuala Lumpur (UTM KL) and the analysis of these measurements using modern GIS tools. The greenery percentage and building morphology parameters, such as height-to-width ratio, were critically evaluated as to their correlation with air temperature variations within the campus. Moreover, the temperature variations around campus were spatially analysed using GIS, and the relationships between the microclimate and different surface land covers were visualised. This study developed an improved method, based on a geospatial approach, for analysing microclimatic information and surface land covers.

Methodology

Study Area

The UTM KL campus lies at a latitude and longitude of 3° 10’ N and 101° 43’ E, respectively. A branch campus of UTM covers an area of 192468.49 m^2. The campus is located approximately four kilometres away from the prominent highest twin towers of Kuala Lumpur City Centre (KLCC), as shown in Figure 1. This area faces additional challenges and pressures brought on by the rapid development, due to the limited space of land available and an increasing number of students and academic staff. As the campus is expanding in order to accommodate for the high number of research activities and educational learning opportunities, high-rise buildings were built within the campus. The development of high-rise buildings has changed the land surface cover in the campus, e.g. changes in greenery areas and built-up features, such as parking lots and tennis courts. As a consequence of this campus development, the awareness provided by microclimatic analysis is vital to the preservation of sustainable campus living. Microclimate conditions, which vary according to the urban surface characteristics in the campus, adversely affect sustainable campus development. Thus, this study highlights the microclimatic analysis in the city campus, emphasizing the greenery area percentage, building morphology, and other built-up feature percentages, using GIS.

Figure 1:
Case study area within the UTM KL campus (Source: Google Earth Image, 2015)

Field Measurements

A series of measurements were carried out in order to collect data on the microclimatic conditions in the UTM KL. First, three fixed weather stations, labelled as WS1, WS2, and WS3, were installed at three different locations in the campus (Figure 2). We systematically collected data on the climatic variables, e.g. air temperature, relative humidity, and solar radiation. WS1 was installed on the rooftop of the Malaysia-Japan International Institute of Technology (MJIIT) building with 53 meters height from ground, while WS2 and WS3 were installed 2.5 meters above ground level in front of Razak Tower and near the UTM KL field, respectively. The data collections were set at 10-minute intervals for all weather stations. Air temperature, relative humidity, and solar radiation data were recorded for one year in order to observe the microclimate pattern throughout the year.

In-situ measurements of the near-surface air temperatures were carried out at the UTM KL. HOBO data loggers, covered with solar radiation shields were installed at a height of 3 meters above ground level in order to collect the air temperature data of the surrounding area. The instruments were set at 10 minutes data sampling intervals and installed for seven days, starting from the 8th to 14th April 2015, at eight different locations around the campus. The locations of air temperature measurements were labelled A through H, as shown in Figure 2.

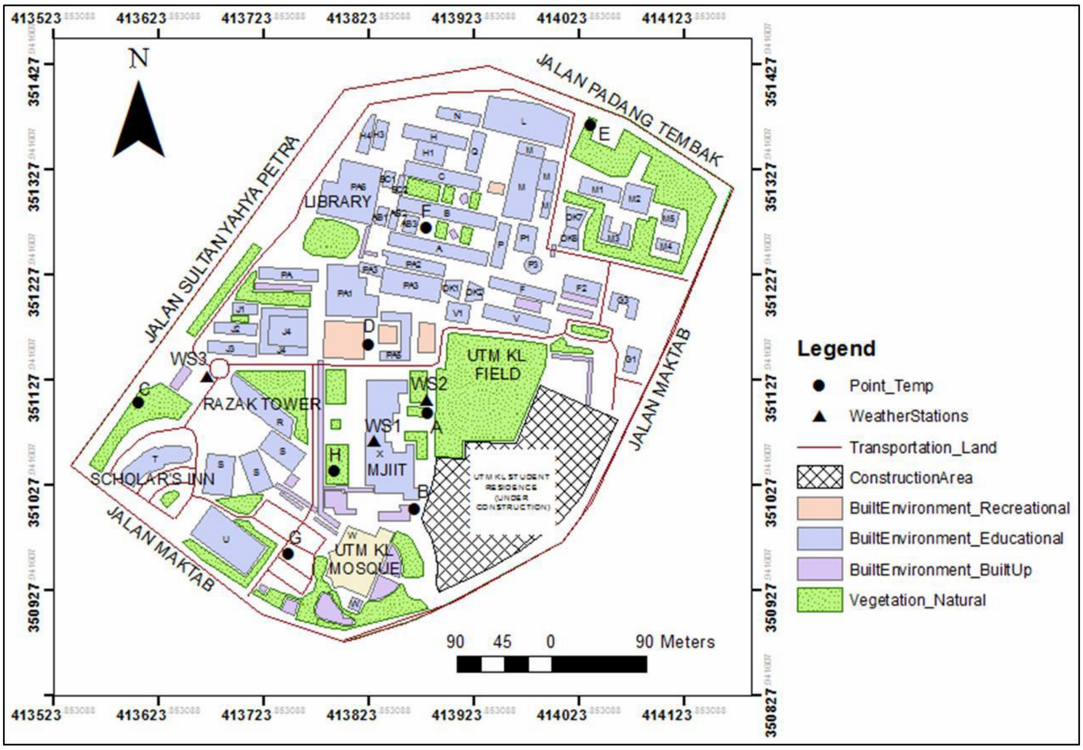


Figure 2: Locations of installed weather stations and air temperature sensors, characterised by different land cover types (see Table 1 for details)

Table 1: Description of the landmark locations of the installed HOBO data loggers used for in-situ air temperature measurements in the UTM KL campus

Points	Landmark Locations
A	UTM KL Field
B	Construction Area
C	UTM KL Main Gate
D	Tennis Court
E	Noise and Vibration Lab
F	Zone Between Block A and Block B
G	Parking Lot
H	Zone Between Razak Tower and Malaysia-Japan International Institute of Technology (MJIIT)

The selection of the locations to install the HOBO data loggers is made based on the surrounding surface land covers existing in the area. It takes into account the greenery percentage, building height, and built-up features, which affect the climatic variables. The descriptions of these locations are given in Table 1.

Development of the GIS Microclimate Database

A geodatabase of microclimate variables is developed using GIS allowing data management and in a spatial and quantitative manner. The GIS microclimate database workflow is shown in Figure 3. First, the base map provided by the Department of Survey and Mapping Malaysia (DSMM), was used to geo-reference the existing university campus base map prepared by the UTM KL Built Property Office using a projected coordinate system of Geocentric Datum of Malaysia 2000 (GDM2000) Malayan Rectified Skew Orthomorphic (MRSO). The feature class and feature dataset of surface land cover types within the campus were created in order to classify the land cover classes and to digitise the vector properties within the area, respectively. Next, the essential information from the microclimate data, i.e. air temperature, and buildings, i.e. building height, were imported and managed in the attribute table based on the feature class created.

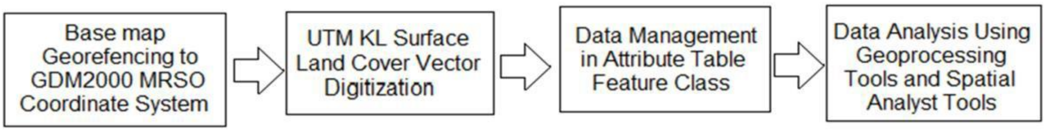


Figure 3: General workflow of the GIS microclimate database development

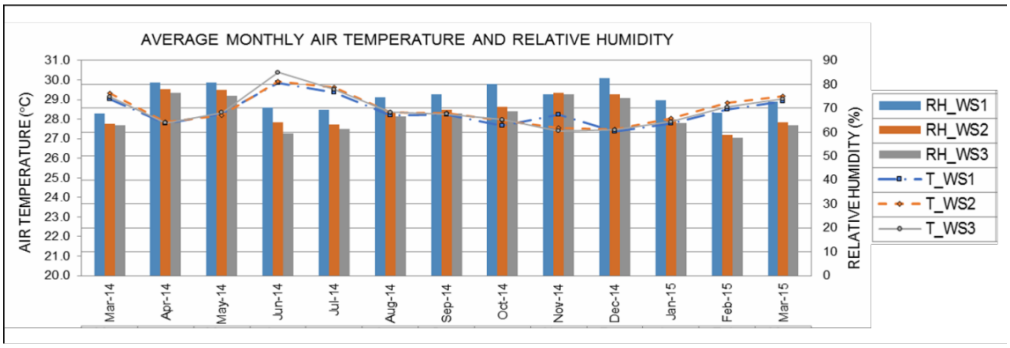
Geoprocessing and spatial analyst tools were used to analyse the microclimatic variables data. With respect to spatial land cover of campus, the areas of greenery, buildings, and built-up features were generated by geometry calculations. The areas within fifty metres from the air temperature measurement points were analysed by calculating the greenery percentage, buildings percentage, and built-up features percentage. Additionally, the building morphology parameters of the height-to-width ratio were calculated. In order to critically analyse the relationship between the surface land cover and air temperature variations, spatial analysis tools were used to interpolate the average air temperature within the campus.

Results and Discussion

The UTM KL Microclimate Data Measurements Over One Year

Air temperature, relative humidity, and solar radiation measurement data were collected starting from March 2014 to March 2015, by three weather stations. The air temperatures from the three weather stations were shown a very small differences because the weather stations were installed relatively close to one another (Figures 4 (a) and (b)). However, the maximum difference was reported as 0.8 ˚C, observed in November 2014, with WS1 recording the highest measurement compared to WS2 and WS3 dataset.

(a



(b

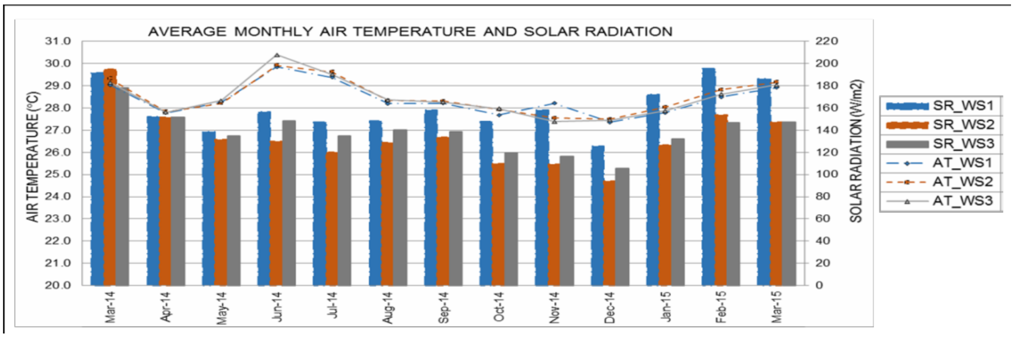


Figure 4: Plot of one-year (a) air temperature and relative humidity data (b) air temperature and solar radiation data recorded by WS1, WS2, and WS3 within the campus environment (see location of sensors in Figure 2)

The relative humidity data in November 2014, for the three weather stations were observed to be similar, with a 1 % to 3 % difference. However, WS1 received higher solar radiation in comparison to WS2 and WS3, due to its location on the MJIIT rooftop. Throughout the year, the highest temperature was observed in June 2014, with temperatures of 29.9 ˚C recorded at both WS1 and WS2, and 30.4 ˚C at WS3. In June 2014, WS1, WS2, and WS3 showed low relative humidity but varied in values of solar radiation. The lowest temperature recorded during the year was in December 2014, which showed a high value of relative humidity but low value of solar radiation. The climatic pattern of air temperature, relative humidity, and solar radiation throughout the year was nearly constant, with small variations. It is in an agreement with the tropical climatic pattern observed by Wong and Jusuf (2010). However, the air temperature measurements vary according to the surrounding surface land cover that further discussed by greenery percentage, buildings percentage, built-up features percentage and height-to-width ratio.

In-Situ Measurements of Air Temperature with the Greenery Percentage, Buildings Percentage, Built-Up Features Percentage, and Height-to-Width Ratio around the UTM KL Campus

The air temperature measurements on 8th to 14th April 2015 for the 8 locations were reported a constant daily pattern. We addressed the air temperature measurement dated on 11th April 2015. As shown in Figure 5, the in-situ air temperature during the day indicated that points H (between Razak Tower and the MJIIT building) and F (between blocks A and B) had a lower air temperature, while points B (near the construction area) and A (near the UTM KL field) were observed to have higher air temperatures in comparison to the other points. During the night, lower air temperatures were observed at points H, C (UTM KL main gate), and E (Noise and Vibration Lab), and higher air temperature values at points B and G (near the parking lot). Thus, the air temperature at point D (near the tennis court) consistently lay between the higher (A, B, and G) and lower (C, E, F, and H) air temperature values.

The maximum, minimum, and average air temperatures recorded at the 8 locations are shown in Table 2. A high greenery percentage (51.6 %, at point A) resulted in a high air temperature, as point A is located in the open space area and near to the construction site, causing the air temperature to rise. Moreover, air temperature at point G also high because of open space parking lot, covered with asphalt, as the surface land cover. Points C and E indicated lower air temperatures, as these areas have reported high greenery percentages of 23.9 % and 21.6 %, respectively. Contrarily points F and H were located inside building canyons with height-to-width ratios of 0.52 and 0.95, respectively.

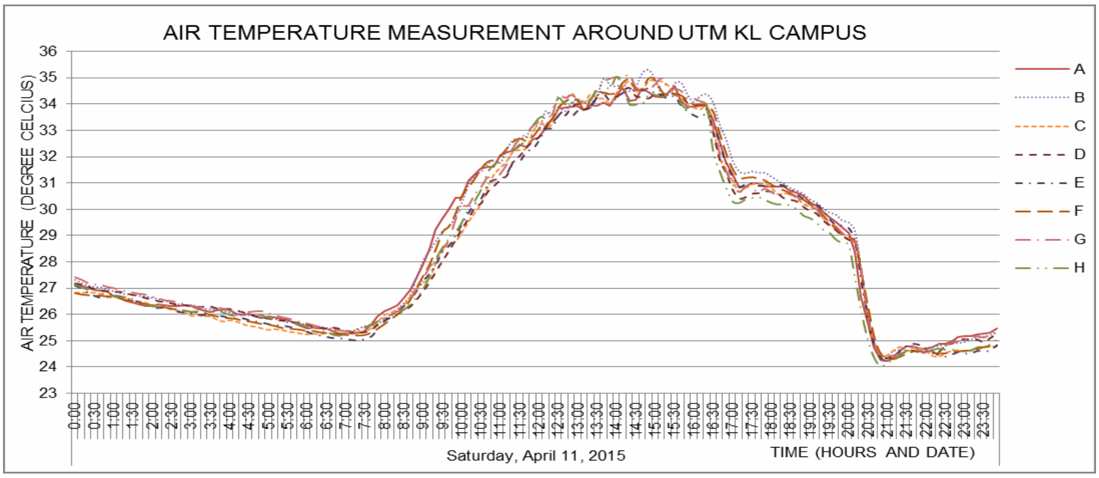


Figure 5: Measurement of near-surface average air temperature in eight different locations in the UTM KL campus

As a comparison, areas with low height-to-width ratios were observed to have higher average air temperatures. The interpolations of the average air temperature were visualised in a spatial mapping form (Figure 6). The map presents all the essential information on land surface covers, air temperature interpolations, and height-to-width ratios required to critically evaluate the relationship between the parameters involved.

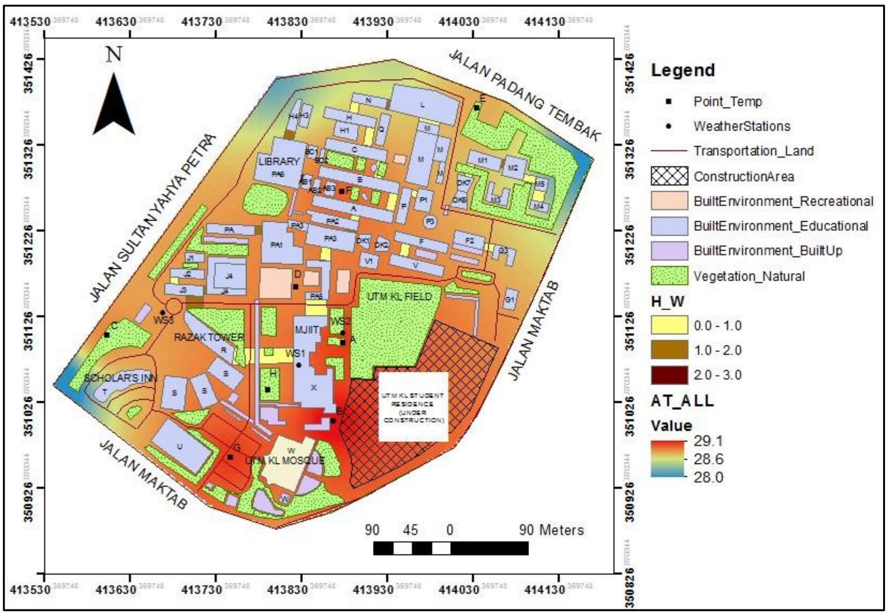
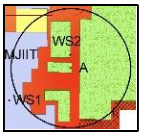
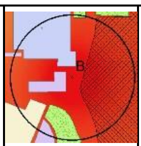
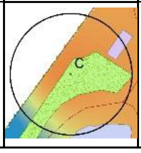
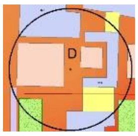
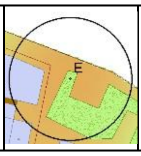
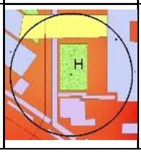


Figure 6: Air temperature interpolation, overlaid with different surface land covers and height-to-width ratios around the UTM KL Campus

Table 2: Greenery percentage, buildings percentage, built-up features percentage, height-to-width ratio, and near-surface air temperature within 50 meters from the 8 measurement locations around the UTM KL campus.

NO	LOCATIONS	GREENERY (%)	BUILDING (%)	BUILT UP (%)	HEIGHT - WIDTH RATIO	MAX AIR TEMP	MIN AIR TEMP	AVG AIR TEMP
1		51.6	14.6	CONSTRUCTION 1.0	-	34.7	24.2	28.8
2		6.1	23.2	CONSTRUCTION 32.7	-	35.3	24.2	28.9
3		23.9	2.8	-	-	34.9	24.4	28.6
4		3.1	25.9	TENNIS COURT 21.8	-	34.6	24.3	28.6
5		21.6	10.4	-	-	34.6	24.2	28.5
6		12.1	31.5	-	0.52	35.0	24.3	28.7
7		16.3	13.9	PARKING LOT 43.0	-	35.1	24.3	28.8
8		13.1	17.4	-	0.95	35.0	24.0	28.5

Conclusions

This research investigates the microclimatic patterns using in-situ measurements, particularly of the near-surface air temperature in a developed campus environment. We discussed the percentage of surface land cover taken up by greenery, buildings, and built-up features and the building height-to-width ratios. In this study, higher air temperature was observed in areas near to the construction site, although the area is reported with a high greenery percentage. Furthermore, an area of open space, with asphalt as the surface land cover, resulted in a higher air temperature. The areas with lower air temperatures were observed within building canyons and where there was a high greenery percentage, but in a low buildings percentage. A lower height-to-width ratio showed a higher air temperature. With the advancement of GIS analysis, it is possible to objectively analyse the microclimate and surface land covers. As a result of this study, it can be used by the urban planners to integrate microclimatic analyses into the development planning and urban design for future development in the campus or vicinity areas. Further study on the effect of shadows by trees in the area is recommended in relation to the air temperature variation.

Acknowledgement

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