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The Effects of Different Land Uses on the Temperature Distribution of a Humid Tropical Urban Centre

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Abstract: Urban areas consist of different land uses which result in various natural and man-made surfaces. These surfaces modify the materials, structure and the energy-balance of the urban environment and the composition of the urban atmosphere.This article analyses the differences in temperature and relative humidity of various land uses in the humid tropical urban climate of Kuala Lumpur. Data were measured at different source points within Kuala Lumpur area during the day (1100 and 1400 hr) and at night (2200 and 2300 hr). Temperature traverses were then drawn across different types of land uses. The results show that the temperature and relative humidity varied according to land uses. The minimum (28.1°C) and maximum (33.1°C) temperatures were recorded within the green and built-up areas respectively. The UHIIs for the daytime and nocturnal were calculated at 9.3°C and 9.7°C, respectively. The calculated average UHII for the study area was 9.5°C. In conclusion, the interplay between vegetation coverage and urban impervious surfaces in the context of different land uses led to the variation in surface temperatures and relative humidity in humid tropical urban areas. It is suggested that more green areas, gardens, water bodies or open spaces are provided for Kuala Lumpur to enhance thermal comfort for the dwellers.

Key words: Urban heat island · Temperature traverse · Nocturnal temperature · Relative humidity

INTRODUCTION

Urban areas are characterised by several land uses and these modify climate in urban areas. Climatologists believed that urbanization has played a significant role in changing the urban climate from 'natural' to 'man-made'. Human settlements modify the materials, structure and energy-balance of the urban environment and the composition of the atmosphere in ways that differ from the suburban and the rural 'natural' environment although these areas also suffer from some effects of human economic activities. This gives rise to a distinct local climate in of many cities in the world, a condition known nowadays as urban microclimate.

The distinct temperature variations in urban areas had attracted several studies around the world [1-10]. They showed that urban temperatures varied significantly in accordance with various land uses and formed an urban heat island (UHI) phenomenon. This paper is a further contribution to the literature in that it is focused on the case of a humid tropical urban area. The paper's specific objectives are two-folds: (1) to identify the similarities or deviations in the spatial and temporal distributions of urban heat island by using temperature traverses and (2) to analyse the difference between the night and daytime urban heat island intensity.

MATERIAL AND METHODS

The Study Area: The study was carried out within the City of Kuala Lumpur (lat. 3° 8' 00" N; Long. 101° 42' 00" E), formerly the capital of Malaysia. The geography of Kuala Lumpur is characterized by a huge valley known as the Klang Valley, on the west side of the Titiwangsa Range. The area stretches from a belt of hilly ground in the north (Batu Caves at 298 m and Bukit Rawang at 388 m) to lowland areas in the south with the Titiwangsa Range in the east and the undulating ground of Damansara and Bukit Kenny in the west.

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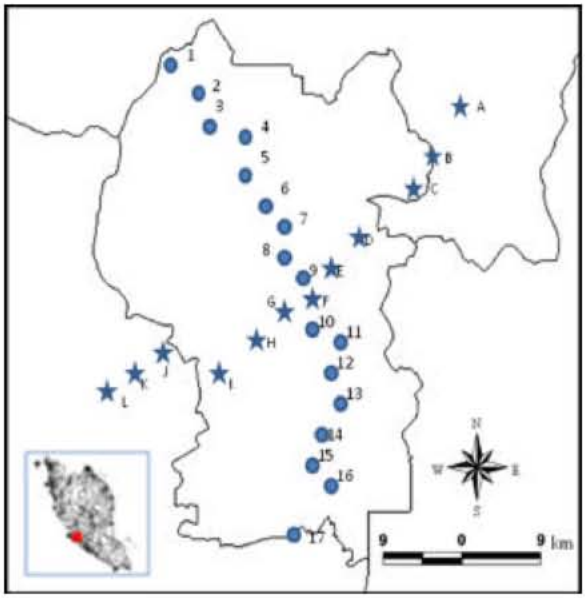

Fig. 1: Selected stations for the study in Kuala Lumpur

The climate of Kuala Lumpur is categorized as a tropical rainforest climate which is warm and sunny, along with abundant rainfall, especially during the northeast monsoon from October to March. Temperatures tend to remain constant with maximum values of between 31° and 33°C, while the minimum between 22° and 23.5°C. Kuala Lumpur typically receives 2,427 mm of rainfall annually with June and July being relatively dry. Even so rainfall typically exceeds 125 mm per month.

Data Collection: Seventeen point sources of the temperature measurements were selected within the Kuala Lumpur city (Figure 1).

The points were located at various land uses ranging from open space to built-up or man-made surfaces. However, for the particular purpose of this study only selected point sources at several types of land uses were used to form two temperature traverse routes, the east-west (A to L) and north-south traverses (1 to 17).Temperature, relative humidity and wind speed at selected point sources were obtained by using mini hygro thermo-anemometer Extech's Model 45158. The instrument had the temperature, relative humidity and wind speed accuracy of ± 1°C, ± 5% and ± 0.2 m/s, respectively, while the respective resolution for the temperature, relative humidity and wind speed were 0.1°C, 1% and 0.1 m/s. Fourteen days of observations were carried out in July 2008 by several field assistants. Temperature measurements were taken at two different times of the day i.e., in the afternoon around 1100 and 1400 hr and between 2200 and 2300 hr at night. This number of observation provided sufficient information of temperature distribution under different weather conditions, except for rain. Data were then averaged to represent mean daily temperature and relative humidity for the month of July 2008. Temperature and relative humidity data were then plotted graphically to form temperature-relative humidity traverses.

RESULTS AND DISCUSSION

Three generalized groups of land use types were identified in both east-west and north-south traverses, namely, built-up surfaces comprising business and commercial areas; public spaces comprising streets, parking lots, pavements, building etc; and open surfaces comprising vegetated, green or bare areas and water surfaces.

The highest recorded temperature of 33.1°C was observed within the core business and commercial areas of Kuala Lumpur for the east-west traverse i.e. around Central market, Petaling Street and Kota Raya (411590 and 348180). On the other hand, the lowest temperature of 28.4°C for the same traverse was recorded within the greenery area and near water body (419400 and 353680) (Figure 2).

The fluctuation of temperature trend was more pronounced for north-south temperature traverse. High temperatures were also recorded within the busiest areas such as the commercial centres, business areas and mixed built-up areas. The highest temperature of 33.1°C was recorded around Pasarama Kota, Pusat Seni DBKL and Jalan Tun H.S. Lee (41120 and 34720) while the lowest temperature of 27.9°C was recorded around the green area of Universiti Putra Malaysia (UPM) and the water body in Kepong (Figure 3).

The average highest and lowest temperatures for both traverses were calculated at 33.1°C and 28.1°C, respectively.

The data produced contrasting readings. On the one hand, the high ambient air temperatures were normally associated with low relative humidity. On the other hand, when high relative humidity prevailed the temperatures were at the low values (Figures 2 and 3). Further analysis was carried out by using linear regression to test the relationship between ambient air temperature and relative humidity. It was found that the value of $Y = 154.4 - 2.83X$ ($R^2 = 0.54$) and $Y = 138.4 - 2.21X$ ($R^2 = 0.47$) for the north-south traverse and the east-west traverse, respectively. This implies that there was a significant

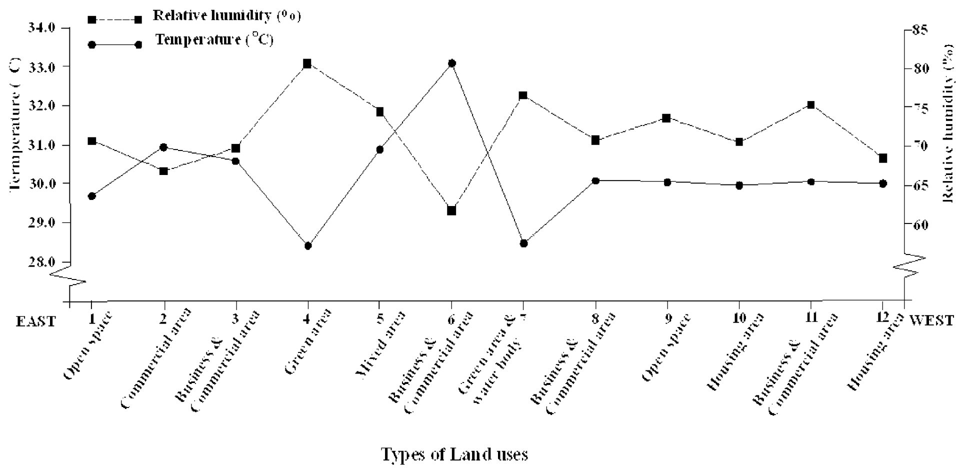

Fig. 2: East-west day time temperature traverse in the study area

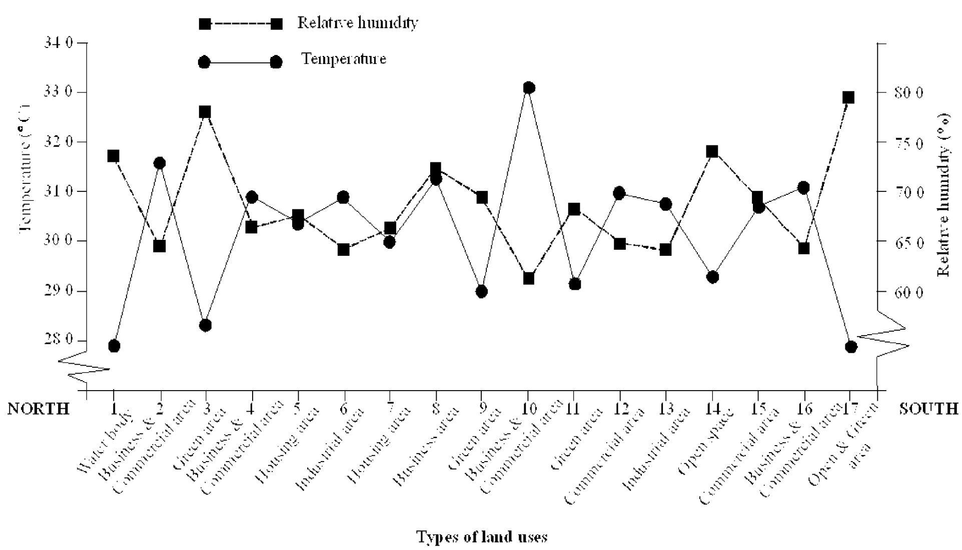

Fig. 3: North-south day time temperature traverse in the study area

negative correlation between the two variables. Similar findings were observed in cities of other countries such as Dhaka, Bangladesh [11], Beijing, China [12], Singapore [13] and in the medium sized administrative town of southwest Nigeria [14].

The Urban Heat Island Intensity (UHII) defined as the difference between the highest and lowest air temperatures recorded at the same traverse was calculated at 9.3°C and 9.5°C for the north-south traverse during the daytime and the nocturnal, respectively. This gave an UHII mean value of 9.4°C for the north-south traverse. Similarly, the UHII value for the east-west traverse was 9.2°C and 9.9°C for the daytime and the nocturnal, respectively, with the average being 9.6°C. Hence, the average UHII for daytime and nocturnal was about 9.3°C and 9.7°C respectively. The average UHII for the study area was observed at about 9.5°C. The nocturnal UHII was slightly higher than the daytime UHII for both traverses in line with findings observed in other studies [2, 8, 9, 15, 16].

During the day, the built-up surfaces in urban areas absorbed intense solar radiation, making them warmed faster than open spaces, water bodies and green areas. The high daytime heating also had the effect of generating convective wind within the urban boundary layer. Due to the atmospheric mixing that resulted, the ambient air temperature perturbation within the UHI was generally minimal or nonexistent during the day, even though the temperature could become extremely high.

By contrast, during the night, solar heating was almost zero and atmospheric convection decreased, hence the urban boundary layer began to stabilise.

Frequently, an inversion layer was formed during the night time. This had the urban air tripped near the surface and tended to keep the surface air warmed by the still-warm urban surfaces. The result was a nocturnal UHII generally higher than the daytime UHII.

The UHII profile was derived by subtracting the recorded temperature at each point source from the lowest recorded temperature (used as reference point or rural air temperature). The differences in physical properties and man-made factors or design variables had produced different values of UHII along both of the temperature traverses. Thus, the UHII profile ranged between 0°C and 5.2°C and between 0°C and 4.7°C for traverse A (north-south traverse) and traverse B (east-west traverse), respectively. The combination of both monthly profiles of the UHII had resulted in a monthly UHII average of about 4.9°C.

It was a decade ago since the then Prime Minister Mahathir claimed that the environment of Kuala Lumpur was too hot in the daytime hours. Today the excess heat load as manifested by the presence of UHI could be considered alarming if no appropriate mitigation measures are taken. The persistence of the UHI phenomenon in Kuala Lumpur will produce some negative impacts on both the city's physical and human environments. Previous studies have already gathered growing evidence of the UHI deteriorating the city's living environment [8] through increased energy consumption, elevated ground-level ozone and pollution [17] and rising mortality rates [18].

UHIs can also create secondary effects on local meteorology such as altering the local wind patterns, the development of clouds and fogs, the humidity level and the rates of precipitation [19]. With the extra heat provided by the UHI, especially during the day, there can be a greater upward motion which in turn can induce additional shower and thunderstorm activities. Besides, UHIs can create a local low pressure areas during the day where relatively moist air from 'cool' locales in the urban areas converge for cloud formation. In Kuala Lumpur, the presence of UHI does not only increase the intensity and frequency of convectional storms but also the annual rainfall amounts in urban areas.

In the interest of managing the comfort level of urban areas, it is important to propose some guidelines as to how to mitigate the UHI. The Urban heat island can be counteracted by using white or reflective materials when building houses, pavements, roads and car parks, to increase the overall albedo of the urban surfaces. Besides, trees could be planted to shade hot surfaces such as car parks, tarmac and pavements; or low-level bushes planted along the covered drains. A large number of trees and urban parks can reduce the local ambient air temperature significantly [20, 21]. In urban areas, roads, walkways and highways take up quite a significant percentage of the urban land. Therefore, creative ways must be found to green shade these land uses in order to reduce the surfaces' solar absorbance during the day and latent heat release during the night.

In Kuala Lumpur, large masses of concrete are present in new flyovers and light rail transports. These are capable of capturing and storing large quantities of solar heat during the day and release it during the night as latent heat to warm up the urban environment. It would also be imperative that these surfaces be covered with plants, such as the overhanging creepers which can shield or reduce heat absorption.

It is advisable to create more water bodies or increase the amount of well-watered vegetation. These options can be combined with the implementation of green roofs. The roofs and the presence of more water fountains at strategic locations such as business areas and small green parks and near tall concrete buildings and shopping areas.

In similar vein, urban car parks without shade trees should be reduced. Should they be maintained, they must be planted with a minimum of 50% shade requirement. Housing and construction developers should be advised to reintroduce tree planting programmes. Incentives like 'landscape competitions' and subsidies should be part of the a long term green urban planning.

Overseas studies proved that power consumption in urban areas increases with the increase of UHI [22, 23]. Normally, as heat builds up in an urban environment, urban dwellers will resort to more air conditioners, which in turn build up more heat. Moreover, the nocturnal UHII is much severe than that of the daytime. This means that temperatures are already too warm to sleep without air conditioners. Something therefore needs to be done to counteract this persistent trend of the UHI in order to minimise its impact on urban liveability.

CONCLUSION

The temperature traverse study had clearly indicated the presence of UHI in Kuala Lumpur City based on the three groups of land use types observed i.e., built-up surfaces comprising business and commercial areas; public spaces comprising streets, parking lots, pavements, building etc; and open surfaces comprising vegetated, green or bare areas and water surfaces. From both temperature traverses, it was confirmed that the recorded temperatures at the commercial and business areas were higher than those recorded at residential and green areas and at water body sites (31.2°C > 30.4°C > 28.9°C). The average daily UHII was 9.5°C with the maximum daily UHII of 9.6°C and 9.4°C recorded respectively at the east-west traverse and the north-south traverse. However, the average monthly UHII was around 4.9°C. Both temperature traverses displayed high UHII during nighttime as compared to the daytime. The nocturnal average UHII of 9.7°C was slightly higher than the daytime average UHII of 9.3°C. The study also confirmed the effect of water vapour on ambient air temperatures whereby high relative humidity was associated with low ambient air temperatures and *vice-versa*.

All this means that if not mitigated properly and adequately, the Kuala Lumpur's UHII could worsen in the near future and aggravate not only air pollution but also the green house gases in the city. The overall consequence is deteriorating living conditions for the urban dwellers with rising electricity demand for air conditioning of buildings producing more extreme local weather conditions. It is a matter of urgency, therefore, that the Cityhall takes the mitigation matter seriously.

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