

THE EFFECTS OF BUILT-UP AND GREEN AREAS ON THE LAND SURFACE TEMPERATURE OF THE KUALA LUMPUR CITY

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ABSTRACT:

A common consequence of rapid and uncontrollable urbanization is Urban Heat Island (UHI). It occurs due to the negligence on climate behaviour which degrades the quality of urban climate condition. Recently, addressing urban climate in urban planning through mapping has received worldwide attention. Therefore, the need to identify the significant factors is a must. This study aims to analyse the relationships between Land Surface Temperature (LST) and two urban parameters namely built-up and green areas. Geographical Information System (GIS) and remote sensing techniques were used to prepare the necessary data layers required for this study. The built-up and the green areas were extracted from Landsat 8 satellite images either using the Normalized Difference Built-Up Index (NDBI), Normalized Difference Vegetation Index (NDVI) or Modified Normalized Difference Water Index (MNDWI) algorithms, while the mono-window algorithm was used to retrieve the Land Surface Temperature (LST). Correlation analysis and Multi-Linear Regression (MLR) model were applied to quantitatively analyse the effects of the urban parameters. From the study, it was found that the two urban parameters have significant effects on the LST of Kuala Lumpur City. The built-up areas have greater influence on the LST as compared to the green areas. The built-up areas tend to increase the LST while green areas especially the densely vegetated areas help to reduce the LST within an urban areas. Future studies should focus on improving existing urban climatic model by including other urban parameters.

1 INTRODUCTION

As a developing country, Malaysia experiences rapid urbanization which brings a lot of benefits to the citizens. Unfortunately, it's become uncontrollable and tends to alter the environment negatively (Elsayed, 2012). The most obvious impact of urbanization is the increase in ambient temperature that leads to the formation of heat islands which degrades the urban climate (Amanollahi, Tzanis, Ramli, & Abdullah, 2016; Shahrudin, Noorazuan, Takeuchi, & Noraziah, 2014). Due to this, considerations on urban climate in urban planning activities are recommended by many authors in various studies (e.g. Agato, 2013; Ariffin & Zahari, 2013; Hebbert, 2014; Raghavan, Mandla, & Franco, 2015; Rajagopalan, Lim, & Jamei, 2014).

The concept of urban climatic mapping is introduced by previous researchers as an approach to portray the urban climate information for urban planning purposes (Ibrahim, Samah, & Fauzi, 2014; Katzschner & Burghardt, 2015; Matsuo & Tanaka, 2014; Ren, Lau, Yiu, & Ng, 2013; Ren, Ng, & Katzschner, 2010; Srivanit, Hokao, & Iamtrakul, 2014; Wong, Jusuf, Katzschner, & Ng, 2015). This mapping concept is able to characterize the urban climatic condition in a simple way so that it can be easily interpreted by urban planners and policy makers.

Previous studies related to urban climatic mapping studies by Acero, Kupski, Arrizabalaga, & Katzschner, (2015) Burghard, Katzschner, Kupski, Chao, & Spit, (2010), Cavan, Lindley, & Smith (2015), Eum, Scherer, Fehrenbach, Koppel, & Woo (2013), He, Shen, Miao, Dou, & Zhang, (2015), Houet & Pigeon (2011), Mora (2010); Ren et al. (2012), Reuter (2011), Tanaka, Ogasawara, Koshi, & Yoshida (2009), Yoda (2009) concentrated in four season countries. However, only recently related studies have been carried out in tropical countries like Singapore, Thailand and Vietnam (Katzschner & Burghardt, 2015; Srivanit et al., 2014; Wong et al., 2015).

The understanding of urban climate behaviour is crucial in mitigating urban heat island. In mapping the urban climate, the critical urban parameters that affect the urban climate should be investigated and identified. Therefore, this study aims to investigate the relationships between the land surface temperature (LST) and two urban parameters; built-up areas and green areas. Based on previous studies, these two selected urban parameters found to significant to the urban climate condition of an urban area (Buyadi, Mohd, & Misni, 2014; Salleh, Latif, Mohd, & Chan, 2013). This study scrutinized the effects of the urban parameters using correlation analyses and multi-linear regression (MLR) modelling.

2 STUDY AREA AND DATASETS

In this study, Kuala Lumpur city is chosen as the study area. This city is selected due to rapid urbanization in the last few decades. The area covered by this study is shown in Figure 1. Located in the west coast of Peninsular Malaysia, Kuala Lumpur is the capital city of the country and is known as the densest city of the country. The city is surrounded by four towns of Selangor state; Batu Caves, Seri Kembangan, Ampang Jaya and Petaling Jaya.

Figures 2 and 3 show two selected test sites within the study area, which are Bukit Damansara and Kampung Baru. These sites were chosen to estimate the value of LST using the model proposed by the authors. These sites were chosen due to their variability of urban settings. Kampung Baru is a compact area with urban developments. Bukit Damansara on the other hand is a mixed area of residential and vegetation.

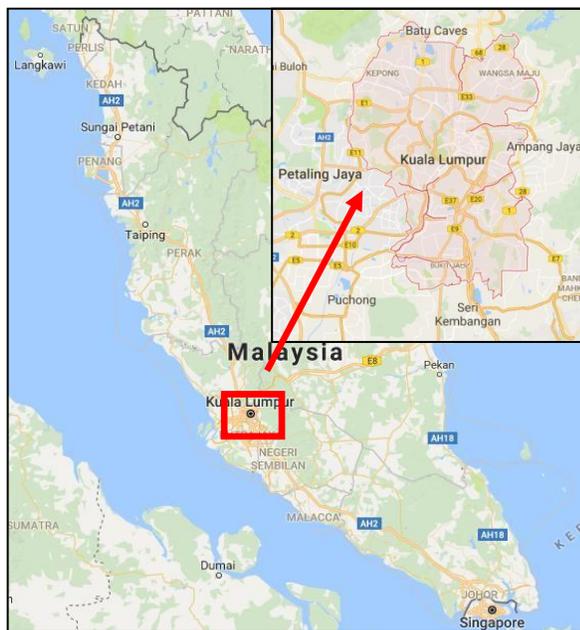


Figure 1. The study area (Adapted: Google Map, 2017)

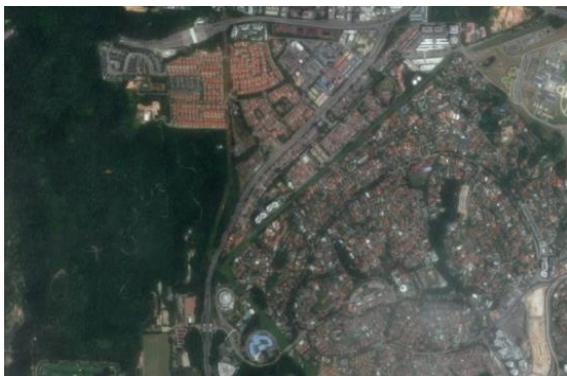


Figure 2. Test Site 1 : Bukit Damansara (Source: Google Map, 2017)



Figure 3. Test Site 2: Kampung Baru (Source: Google Map, 2017)

3 METHODOLOGY

The methodology of this research is organised into four (4) main stages: LST retrieval, extraction of built-up area, generation of NDVI layer and relationship assessments between LST and the selected urban parameters. A multi-spectral satellite Landsat 8 OLI/TIRS image was used in this study. The image used was captured in 29th of March 2016. This image was downloaded from the U.S Geological Survey website.

3.1 Land Surface Temperature (LST) Retrieval

In this study, the mono-window algorithm was used to retrieve the land surface temperature from the Landsat 8 OLI/TIRS data. At first, radiometric calibration was performed by converting the original pixel values into spectral radiance and brightness temperature. The vegetation proportion and land surface emissivity required in the mono-window algorithm were estimated using the NDVI derived from the same image. The LST layer was then retrieved using Equation 1.

$$T_s = \frac{BT}{(1 + \frac{\lambda}{\rho}) \times \ln \epsilon \lambda} \quad (1)$$

where, T_s - LST in degree Celsius ($^{\circ}C$)
 BT - at-sensor brightness temperature
 λ - wavelength of emitted radiance
 $\epsilon \lambda$ - the estimated land surface emissivity and

ρ is a constant derived from Equation 2.

$$\rho = h \times \frac{c}{\sigma} \quad (2)$$

where, h - Planck's constant (6.626×10^{-34} J/s)
 c - the velocity of light (2.998×10^8 m/s)
 σ - Boltzmann constant (1.38×10^{-23})

3.2 Extraction of Built-Up Area

In this study, the built-up areas were extracted using combined algorithms of NDBI, NDWI and NDVI. The combined algorithms improve the performance of NDBI (common method) in extracting the built-up areas. Bhatti and Tripati

(2014) also suggested that the result of built-up areas extraction can be improved using principal component analysis (PCA) images in the NDBI layer generation, whereas common methods were used to generate the NDWI and NDVI layers. Equations 3, 4 and 5 shows the algorithm used to prepare the NDBI, NDWI and NDVI respectively.

$$NDBI = \frac{(PCA\ Band\ 6,7+PCA\ Band\ 10,11)-Band\ 5}{(PCA\ Band\ 6,7+PCA\ Band\ 10,11)+Band\ 5} \quad (3)$$

$$NDWI = \frac{Band\ 3-Band\ 7}{Band\ 3+Band\ 7} \quad (4)$$

$$NDVI = \frac{Band\ 5-Band\ 4}{Band\ 5+Band\ 4} \quad (5)$$

Equation 6 shows the algorithm used to extract the built-up areas.

$$Built-up\ Area = NDBI - NDVI - NDWI \quad (6)$$

3.3 Generation of Normalized Difference Vegetation Layer (NDVI) Layer

The fragmentation of the green or vegetated portions of the study area was portrayed using NDVI layer. This study used the same Equation 5 (as used in previous sub-section) to generate the NDVI layer. It is proposed that the classification of the green areas should be made based on the corresponding emissivity values of the particular areas (Buyadi et al., 2014). The classification used in this study to separate the vegetated areas from the others is shown in Table 1.

Class	NDVI Range	Note
1	< 0.2	Non-vegetated
2	0.2 < NDVI < 0.5	Mixed (Bared soil, vegetation and hard surfaces)
3	> 0.5	Fully Vegetated

Table 1. NDVI Classification

3.4 Relationships between LST and Urban Parameters

The relationships between the LST and the two urban parameters were analysed through two statistical analyses. The correlations between them were tested using the Pearson correlation technique since the data prepared were normally distributed. Then, MLR analysis was carried out to characterize the effects between the LST and two urban parameters. These statistical tests and analyses were carried out using SPSS software.

4 RESULT AND ANALYSIS

The following sub-sections explained the results and analyses of the study.

4.1 Land Surface Temperature (LST), Built-up Area and Green Cover of Kuala Lumpur

Figure 4 shows the distribution of LST of Kuala Lumpur city in the year of 2016. Based on Figure 3, the lowest and highest LST were 27.6°C and 37.9°C respectively. The mean LST for the entire study area was calculated as 33.7°C. The lowest LST was found in highly vegetated areas in Bukit Tabur whereas the highest LST was found in the compact built-up area in Sri Petaling (near to Sg Besi). An initial hypothesis was made during this stage; the green cover contributes to the decrease in temperature, whereas the built-up area contributes to the increase in temperature.

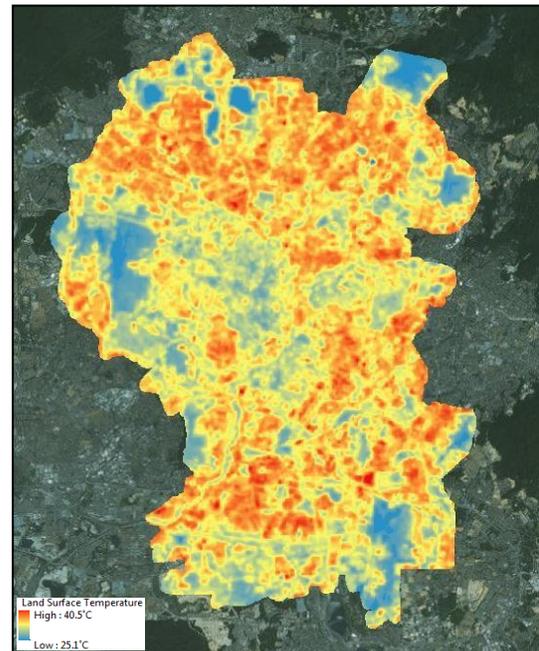


Figure 4. LST distribution in Kuala Lumpur

Figure 5 shows the distribution of built-up areas in Kuala Lumpur. As shown in Figure 4, the built-up area dominates more than half of Kuala Lumpur regions. In this study, it was found that 67.8% of Kuala Lumpur was covered by built-up areas. The central regions of Kuala Lumpur are packed with man-made features which made the temperature to be higher than the surrounding regions. Table 2 shows the difference between the mean LST in built-up and non-built-up areas.

Classificati	Mean
Built-up	34.7°C
Non-built-	31.5°C

Table 2. The mean LST of built-up and non-built-up areas

As shown in Figure 6, the distribution of fully vegetated areas of Kuala Lumpur was less than half of the entire study area. It was found that the densely-vegetated areas covered only 12.7% of Kuala Lumpur and are mostly located in the outskirts of the city. 83% of Kuala Lumpur is covered by mixed urban structures (vegetated, bare soil and hard surfaces). This study identified that areas covered with matured trees and other green vegetation tend to have lower temperature as shown in Table 3.

Classification	Mean LST
Non-vegetated areas	34.9°C
Mix of vegetation and built-up areas	34.1°C
Fully vegetated areas	31.3°C

Table 3. The mean LST within different land cover classification

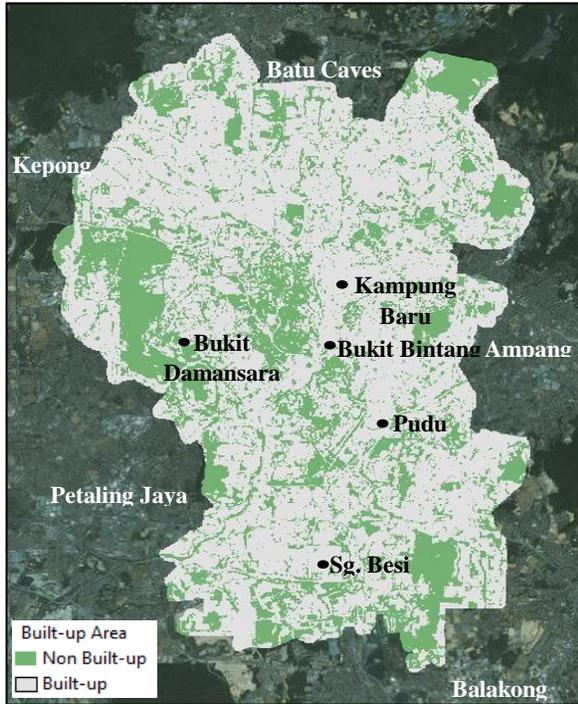


Figure 5. Distribution of the Built-up Areas in Kuala Lumpur.

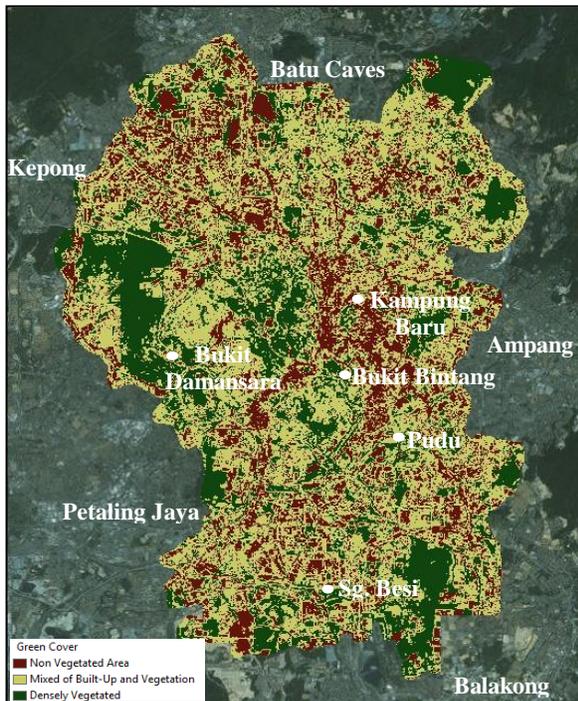


Figure 6. Distribution of green areas in Kuala Lumpur

4.2 The Correlation between LST and Built-Up Area and LST and Green Areas

Strong correlations between LST and both of urban parameters were found in the study area. A positive correlation was identified between LST and built-up areas with $R^2 = 0.791$. This shows that the higher the built-up areas, the higher the LST. For green area, a negative correlation was identified between the two variables, i.e. $R^2 = -0.760$. It can be concluded that, if the area is densely vegetated, the LST is found to be lower.

Figure 7 and Figure 8 shows the scatter plots of LST and the two urban parameters.

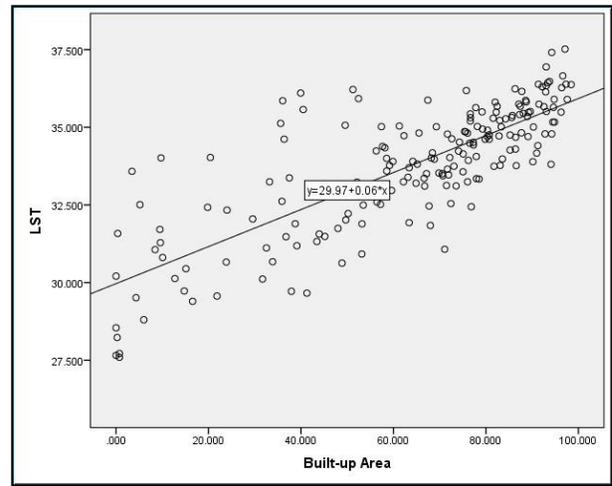


Figure 7. The relationship between LST and the density of built-up area

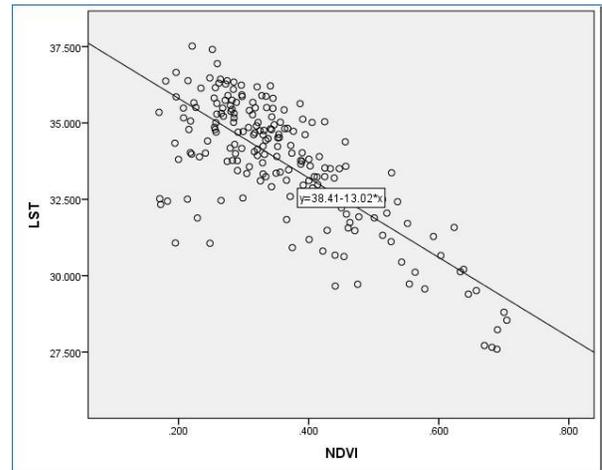


Figure 8. The relationship between LST and green area (NDVI)

4.3 The Effects of Built-Up Area and Green Cover on LST of Kuala Lumpur

Through the MLR analysis, it was found that built-up areas and green areas were significantly affected the LST of Kuala Lumpur city. The model produced through this analysis shown that these two urban parameters contributed almost 70% of the

LST variations with the $R^2 = 0.695$. Thus, the value of LST in Kuala Lumpur can be estimated using these two urban parameters with a reasonable accuracy. Equation 7 is the model produced in this study to estimate the LST value of Kuala Lumpur.

$$LST = 33.746 + 0.038X_1 - 6.735X_2$$

where,

- LST - land surface temperature (LST)
- X1 - built-up area (in percentage)
- X2 - green area (NDVI value)

Based on the model produced, an increase of 26% of built-up area will elevate the value of LST by 1°C whereas an increase of 15% in NDVI value will decrease 1°C of LST within an area of 500m × 500m coverage. A large urban development which involves a land conversion of more than 26% will rapidly increase the LST of that particular area. An increase of 1°C will change the thermal comfort as this value has a significant effect to human thermal comfort. Mature green cover needs to be planted and maintained within an area to balance the negative effect of built-up area. Even though the increment value seems to be lower in percentage, the increase of 15% (approximately 0.148 increments) in NDVI value is not easy.

4.4 Estimation of LST in the Selected Test Sites

The model produced in this study was used to estimate the value of LST within selected test sites in Kuala Lumpur. Different urban scenarios were set up for each of the selected test sites to estimate the value of LST. The results obtained are shown in Table 4.

The mean LST of Kampung Baru and Bukit Damansara were found to be 36.2°C and 33°C respectively. The mean LST of Kampung Baru was found to be higher than Bukit Damansara as the area is mostly covered by man-made features (built-up area). The mean LST of Bukit Damansara area was found to be almost 3°C have lower compared to Kampung Baru as the area is mainly covered by man-made features and a large portion of vegetated areas. This is consistent with the earlier research findings that states that the higher the density of the built-up areas, the higher the LST and the higher the NDVI value (greenness), the lower the LST.

Tables 4 and 5 show the simulated LST values for Kampung Baru based on the different built-up and green area percentage. Both parameters were manipulated by adding 25%, 50%, 75% and 100% increments of the built-up area and green area of the selected test sites. Based on both tables, the reduction of built-up areas is a great help to reduce the LST values.

However, it is a difficult endeavour to be conducted. Though, the increment of green areas within Kampung Baru is seen to be the most suitable measures to reduce the LST value.

Based on Table 4, the effect of the increment of built-up area in the effect of the increment of built-up area in Kampung Baru will result in severe effect (up to 3.1°C) of urban heating. It is advised that Kampung Baru should focus on mitigating the urban heating. Mature vegetation should be used in the

mitigation plan as it will decrease the LST up to 2.2°C.

Increase built-up area by	Estimated LST (°C)	Increase green area by	Estimated LST (°C)
25%	36.599	25%	35.265
50%	37.508	50%	34.842
75%	38.418	75%	34.418
100%	39.303	100%	33.994

Table 4: Estimated LST value if both parameters are increased by 25%, 50%, 75% and 100% of the current built-up area and green areas in Kampung Baru.

Table 5 shows that the increment of built-up areas can reduce the value of LST with 4.1°C. The reduction of green vegetation in Kampung Baru will increase the LST up to 1.2°C.

Decrease built-up area by	Estimated LST (°C)	Decrease green cover by	Estimated LST (°C)
25%	34.779	25%	36.113
50%	33.870	50%	36.537
75%	32.961	75%	36.960
100%	32.051	100%	37.384

Table 5: Estimated LST value if both parameters are decreased by 25%, 50%, 75% and 100% of the current built-up area and green area in Kampung Baru.

Tables 6 and 7 show the estimated LST values in Bukit Damansara using manipulated values of built-up areas and green vegetation. The same increment values used for Kampung Baru were applied to Bukit Damansara. Based on both tables, Bukit Damansara has a lower effect of urban heating as compared to Kampung Baru. Nevertheless, serious urban heating can also occur in Bukit Damansara if rapid developments take place. From the estimation, the best measure to reduce the LST value in this site is to increase the green area. Therefore, Bukit Damansara should maintain its greenery areas to balance the urban heating within the residential areas. Based on Table 6, the effect of the increment of built-up area in Bukit Damansara will elevate the LST value up to 2.9°C. The increase in green vegetation will reduce the LST value up to 2.3°C.

Increase built-up area by	Estimated LST (°C)	Increase green cover by	Estimated LST (°C)
25%	34.047	25%	32.750
50%	34.657	50%	32.063
75%	35.267	75%	31.376
100%	35.876	100%	30.689

Table 6: Estimated LST value if both parameters are increased by 25%, 50%, 75% and 100% of the current built-up area and green cover values in Bukit Damansara.

The effect of reducing the built-up area in Bukit Damansara is able to reduce 2°C of LST value. On the other hand, the increase in green vegetation will reduce the LST value by 3.2°C.

Decrease built-up area by	Estimated LST (°C)	Decrease green cover by	Estimated LST (°C)
25%	32.827	25%	34.124
50%	32.217	50%	34.811
75%	31.608	75%	35.498
100%	30.998	100%	36.185

Table 7: Estimated LST value if both parameters are decreased by 25%, 50%, 75% and 100% of the current built-up area and green cover values in Bukit Damansara.

5 CONCLUSION AND RECOMMENDATION

This study has shown that the built-up area and green areas are the most important parameters which could balance the LST of a city such as Kuala Lumpur city. Strong correlations between the LST and both urban parameters were identified in this study. Positive correlation between the LST and built-up area indicates that this parameter contribute to urban heating, whereas, negative correlation between LST and green cover shows positive effects of urban cooling.

Through the MLR, about 70% of LST variations in Kuala Lumpur city can be explained by the built up area and green area. The estimation of LST using the proposed model on the two selected test sites has shown that Kampung Baru will be severely affected if there is no initiatives to mitigate the urban heating are taken. Bukit Damansara was found to a have lower effect of urban heating due to mature vegetation existed in the area. This study only investigates the effect of two urban parameters on the LST of Kuala Lumpur. Future studies should include more urban parameters in the model to explain the variations of LST for better accuracy of estimation.

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