URBAN HEAT ISLAND ANALYSIS ON LAND USE PLANNING IN GREATER KUALA LUMPUR THROUGH REMOTE SENSING APPLICATIONS

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ABSTRACT: The process of urban growth gives impacts to the form and structure of an urbanised area and the temperature is increasing due to continuous human activities and development within the area. This paper attempts to study an integrated approach of using remote sensing and GIS techniques in determining the Urban Heat Island (UHI) for Bukit Bintang Kuala Lumpur by analysing the formation and intensity of Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI). The analysis of LST and NDVI are used to determine the relationship between the surface temperature, green spaces and land use developments towards UHI phenomenon with extracting the Landsat TM5. The result shows that Landsat TM5 could provide an accurate map and give detailed descriptions on the LST and NDVI across the study area. Spatial distributions of surface temperature demonstrated that there is a positive and close relationship between the heat islands and urban growth, whereas the LST and NDVI have an indirect relationship with a correlation coefficient of -0.083562. This indicates that the impact of green land on UHI is negative, which suggests that the green land can weaken the UHI effect. However, there is a positive correlation of 0.08386 between LST and Land Use which means that the built-up land can strengthen the UHI effect in the Bukit Bintang study area. The temperature at the centre of urbanization of Bukit Bintang Walk is in the range of 32°C until 34ºC, where the famous crossing is located. The results achieved on the correlation among LST, NDVI and Land Use can be used by governments, agencies, planners to know which operation should be used for various process such as urban growth monitoring.

KEY WORDS: Urban Heat Island, LST, NDVI, Remote sensing and Land Use Planning.

1.0 Introduction

This research is conducted to analyse the formation and intensity of UHI phenomenon within a specific amount of time through remote sensing and GIS techniques. It will discuss on how to generate the LST and NDVI to determine the relationship between the surface temperature, green spaces and land use developments towards UHI phenomenon. These techniques have provided new avenues for the observation through the suite of measurement approaches for studying UHI in urban planning in society, to help the planner, decision makers and public towards a more transparent planning system. Urban Heat Island (UHI) is an urban area that is warmer than the surrounding areas, whereby the heat is build up by the energy from all the people, different range of transports and building density.

Urbanization is affecting climate by changing the physical surface of the land, man and his activities produce a significant amount of heat which contributes to the increased intensity of UHI (Helena *et al.,* 2009. The urban annual air temperature for the 30 year period has positive linear correlation with slope coefficients from as low as 0.01 to as high as 0.12. Evidence for the UHI in Kuala Lumpur is borne out by research that showed the nucleus of heat islands in Kuala Lumpur during three days of the week is located in Bukit Bintang, with a temperature of 27.9°C. Alternative methodologies are combined and used to determine the intensity of the UHI of the city of Kuala Lumpur (Elsayed, 2012). Although *in situ* measurements and field work were applied in most UHI studies in Malaysia, further research of land surface temperature and the method still needs to be refined by using remote sensing and GIS techniques. Further assessment needs to be carried out to confirm and identify the heat island occurrences in order to validate the results obtained from ground observations.

Although GIS and remote sensing had become a prevalent planning tool in many western developed nations, its application in many developing countries is still limited. The process of urban growth gives impacts to the form and structure of Bukit Bintang portrays the evolution of the metropolitan area from past to present conditions. UHI has been concomitantly related to climate change due to their contribution to the greenhouse effect which leads to global warming. The temperature in urbanized area is increasing due to continuous human activities and development within the area. The high intensity of UHI in the city affects the human health and conditions. Due to rapid development in urban settlements, it is essential to know whether, and to what extent, measures of global warming trends can be explained by the growth of the UHI.

2.0 Study Area

The boundary of Bukit Bintang study area was taken from the Urban Design Guidelines for Kuala Lumpur city centre under the enclave in the Bukit Bintang precinct. Bukit Bintang is the strategic zone as it is located in the middle of Kuala Lumpur city centre, which covers 595.8 acres bounded by major highways namely Jalan Tun Razak from the east to the north and Mahameru Highways to the west as shown in **Figure 1**.

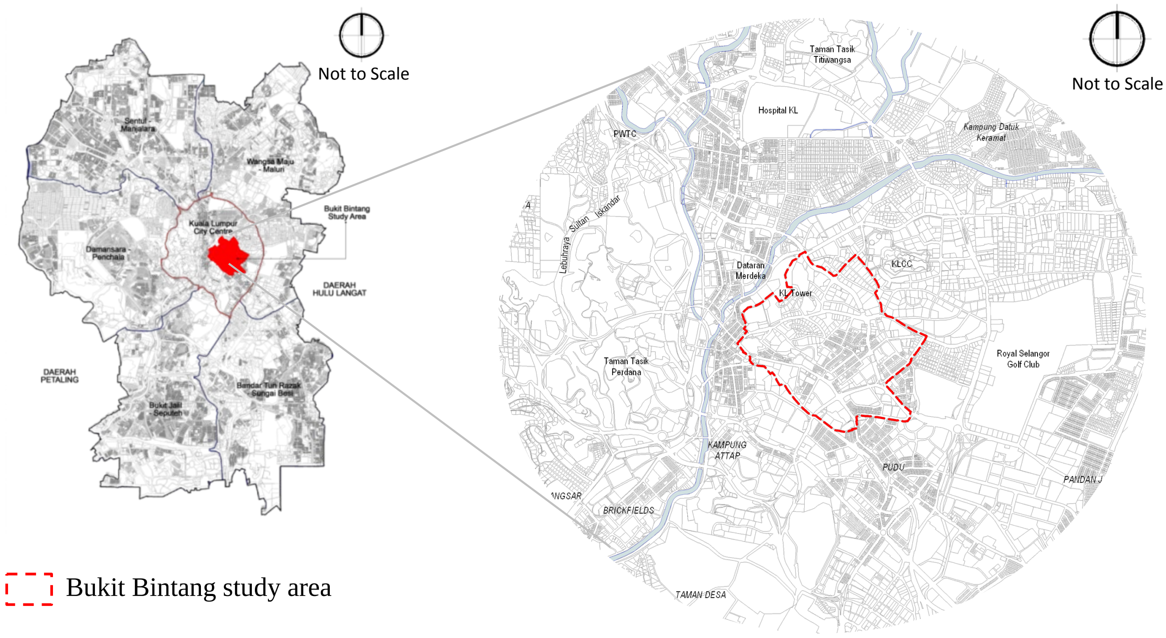

Figure 1: Key Plan and Location Map of Bukit Bintang Study Area

3.0 Research Methodology

This study methodology is based on three main approaches as illustrated in the figure below:

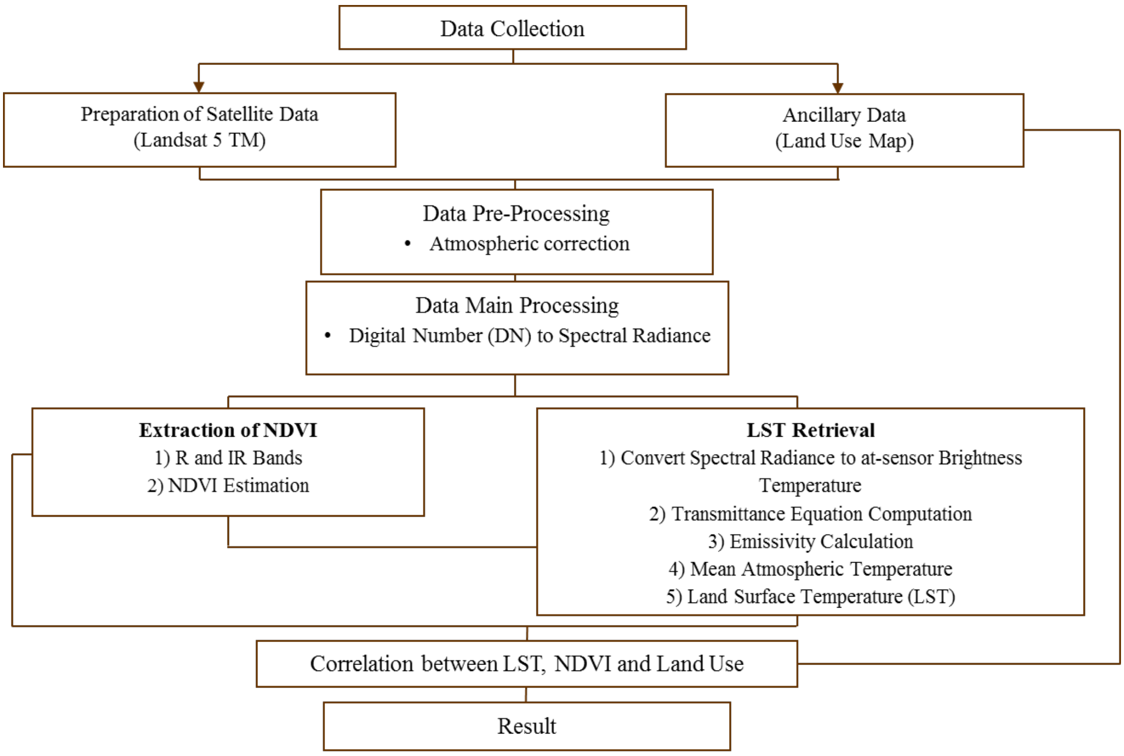

Figure 2: Study Methodology Chart

3.1 Data Collection

3.1.1 Ancillary Data

In spite of the substantial improvement in remote sensing technology and data quality (spatial and spectral resolution) since the 1970s, however, the need for contextual GIS data has increased because remote sensing scientists are creating more complex questions than ever before (Turner, 2002). Kuala Lumpur GIS data year 2012 had been obtained from the Kuala Lumpur City Hall (DBKL) in a MapInfo format.

3.1.2 Satellite Data

The Landsat image has seven bands with band 6 being the thermal infrared band of 60 meters spatial resolution while the other bands are 30 meters. The images consist of seven spectral bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7. Spatial resolution for Band 6 (thermal infrared) is 120 meters, but is resampled to 30-meter pixels. Approximate scene size is 170 km north-south by 183 km east-west (106 mi by 114 mi). Landsat TM5 Band 6 was acquired at 120 meter resolution, but products are resampled to 30 meter pixels.

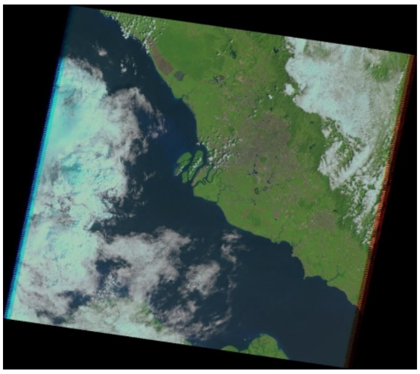

Figure 3: Landsat Image

I. Data Pre-Processing

Each data from Landsat TM 5 is composed of the independent single-band images. The image was radiometric and geometrically corrected by the operation of the subset procedure as the process of “cropping” or cutting out a portion of an image of the study area Bukit Bintang**.** Using the COST method, initial DN_{haze} values were selected through histogram evaluation and then refine using gain and offset values taken from the image Landsat TM 5 Metadata file for each Band.

After retrieving the DN_{haze} values from the histogram of each Band, the refined DN_{haze} values were calculated employing an Excel® spreadsheet, developed by Milton (1994). The Excel® spreadsheet has been constructed using the ideas of (Chavez, 1988) on improving atmospheric correction procedures. DNmin is filled in based on the histogram curve minimum for each Band; the value will display at the bottom of the screen.

II. Data Main Processing

A. Digital Number (DN) to Spectral Radiance

Calculation of radiance is the fundamental step in placing image data from multiple sensors and platforms into a common radiometric scale (Chander and Markham, 1986). For each Landsat TM 5 image, the gains, biases and sun elevations provided in the Metadata file that accompanies the image.In using this model, Digital Number (DN) of the image is first converted to radiance through the following Equation **(1)**, (Chander and Markham, 1986):

$$L = Lmin\lambda + Lmax\lambda - \frac{(Lmin\lambda)}{(255-1)} * DN \quad \textbf{(1)}$$

where;

λ	TM Band number
L	Sensor radiance in watts
*Lmin*λ and *Lmax*λ	Histogram statistics in Metadata file for each Band
DN	DNmin based on histogram curve minimum

Using Equation **(1)** for only Band 6 to convert the Digital Number (DN) to Spectral Radiance as shown in Equation **(2),** (Chander and Markham, 1986):

$$L = (1.238 * \text{Band 6}) + (15.303 * \text{Band 6}) - \frac{(1.238 * \text{Band 6})}{(255-1)} * 134.876 \quad \textbf{(2)}$$

B. Extraction of NDVI

i. R and IR Bands

NDVI provides a crude estimate of vegetation health, and a means of monitoring changes in vegetation over time, and remains the most well-known and used to detect live green plant canopies in multispectral remote sensing data. It is calculated by dividing the difference in the near infrared (NIR) and red colour bands by the sum of the NIR and red colour bands for each pixel in the figure shown below.

$$\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}$$

Figure 4: Ratio of Normalized Difference Vegetation Index (NDVI)

ii. NDVI Estimation

After retrieving the R and IR Bands, thus using ERDAS Imagine software, the NDVI is identified. The study area of Bukit Bintang is then subset from the whole image of Landsat TM5, which had been processed to generate the NDVI.

C. Extraction of LST

i. Convert Spectral Radiance to at-sensor Brightness Temperature

The next step is to convert the spectral radiance to at-sensor brightness temperature (Landsat Project Science Office, 2001) using Equation **(3)** (Qin *et al.,* 2001) below:

$$Tb = K_2 / (\ln (K_1 / L + 1)) \qquad \textbf{(3)}$$

ii. Transmittance Equation Computation

There are two steps to derive the calculation of atmospheric transmittance. The value of water vapour needed to be estimated firstly (Ibrahim *et al.*, 2016). The near surface air temperature was extracted from the Department of Meteorology and Department of Environment. Therefore, by inserting the near surface temperature by which T_0 is 305.533K (Landsat TM 5, 21 January 2009) and relative humidity which is 54%. Water vapour value was estimated using Equation **(4)** (Li, 2006).

$$w^1 = 0.0981 \times \left\{ 10 \times 0.6108 \times \exp \left[\frac{17.27 \times (305.533 - 273.15)}{237.3 \times (305.533 - 273.15)} \right] \times 54 \right\} + 0.1697 \qquad \textbf{(4)}$$

$$w^1 = 2.7654$$

Secondly, the equation for atmospheric transmittance (Qin et al., 2001) Equation **(5)** is shown below:

$$\tau_6 = 1.031412 - 0.11536 \times w_6 \qquad \textbf{(5)}$$

$$\tau_6 = 0.712395456$$

whereby τ_6 is the atmospheric transmittance of Landsat 5 TM and w_6 represents the water vapor content, which had been calculated in the previous equation. Thus, the atmospheric transmittance is 0.712395456.

iii. Emissivity Calculation

The emissivity calculation can be estimated by utilizing NDVI. The NDVI is one of the most widely applied vegetation indices (Liu and Zhang, 2011). In order to calculate emissivity, NDVI needs to be retrieved. NDVI ranges from -1 to +1, whereby 0.55 is usually dense vegetation in the context of urban areas and -1 are water bodies. After retrieving the NDVI image, the percentage of vegetation (pv) needs to be calculated using Equation **(6)** below (Carlson and Ripley, 1997):

$$pv = \frac{(NDVI - NDVI_{min})}{(NDVI_{max} - NDVI_{min})^2} \qquad \textbf{(6)}$$

After retrieving the percentage of vegetation, then can calculate the emissivity using Equation **(7)** below (Sobrino *et al.,* 2004):

$$\varepsilon_i = 0.004pv + 0.986 \qquad \textbf{(7)}$$

iv. Mean Atmospheric Temperature

In order to calculate the mean atmospheric temperature in the tropical region using Equation **(8)** below (Sun *et al.,* 2009):

$$T_\alpha = 17.9769 + 0.91715 (T_o) \qquad \textbf{(8)}$$

T_o for Landsat TM5 2009 (21 January 2009) is 299K. T_o is gathered from the mean ambient temperature by referring the hour and date record for simultaneous capture during the time the satellite Landsat TM5 overpasses the Bukit Bintang study area (Ibrahim *et al.*, 2016). T_α was converted to Kelvin to ensure the calculation is valid. Thus,

$$T_\alpha = 17.9769 + 0.91715\ (299K)$$

$$= 292.20475K$$

v. Land Surface Temperature (LST) Retrieval

After retrieving the mean atmospheric temperature, emissivity and transmittance, the temperature brightness needs to be corrected based on the radiance transfer equation stating that the sensor-observed radiance is impacted by the atmosphere and from emitted ground. The coefficient of the parameter (T_6) in accordance to the temperature ranges between 20° until 50° (Qin *et al.*, 2001). The mono-window algorithm can be calculated using Equation **(9, 10, 11)** below (Qin *et al.*, 2001):

$$T_s = \{a_6\ (1 - C_6 - D_6) + [b_6\ (1 - C_6 - D_6) + C_6 + D_6]\ T_6 - D_6\ T_\alpha\}\ /\ C_6 \quad \textbf{(9)}$$

$$C_6 = \varepsilon_6 \text{ x } \tau_6 \quad \textbf{(10)}$$

$$D_6 = (1 - \tau_6)\ [1 + (1 - \varepsilon_6) \text{ x } \tau_6] \quad \textbf{(11)}$$

The split-window algorithm can be written as Equation **(13)** below (Qin *et al.*, 2001):

$$T_s = \{-67.9542\ (1 - C_6 - D_6) + [0.45987\ (1 - C_6 - D_6) + C_6 + D_6]\ T_6 - D_6\ T_\alpha\}\ /\ C_6 \quad \textbf{(12)}$$

The last step is to retrieve the LST using Equation **(12)**, to simplify and not make any error each equation is calculated separately and then combined after retrieving the result for each equation. LST retrieval was determined using ArcGIS software and calculated with the Raster Calculator.

III. Data Analysis

The results for LST is used to identify the surface temperature in the study area because UHI mainly appeared in the spatial distribution of LST, which is governed by surface heat fluxes and affected by urbanization (Liu and Zhang, 2011). Analysis and examination of the vegetation index is utilized as an indicator to identify the degree of vegetation greenness (Grover and Singh, 2015). After generating the results for each component, it can determine the relationship between surface temperature, green spaces and land use towards UHI phenomenon. The purpose of integrating remote sensing and urban planning is to find a gap in the proper method to make use of the benefits of the remote sensing and GIS technology in town planning's study. Studies from overseas and the application of urban climate studies in town planning are focused on. An urban climatic map is proposed in this research study will be analysed with the results obtained from each method retrieved for Land Use, NDVI and LST.

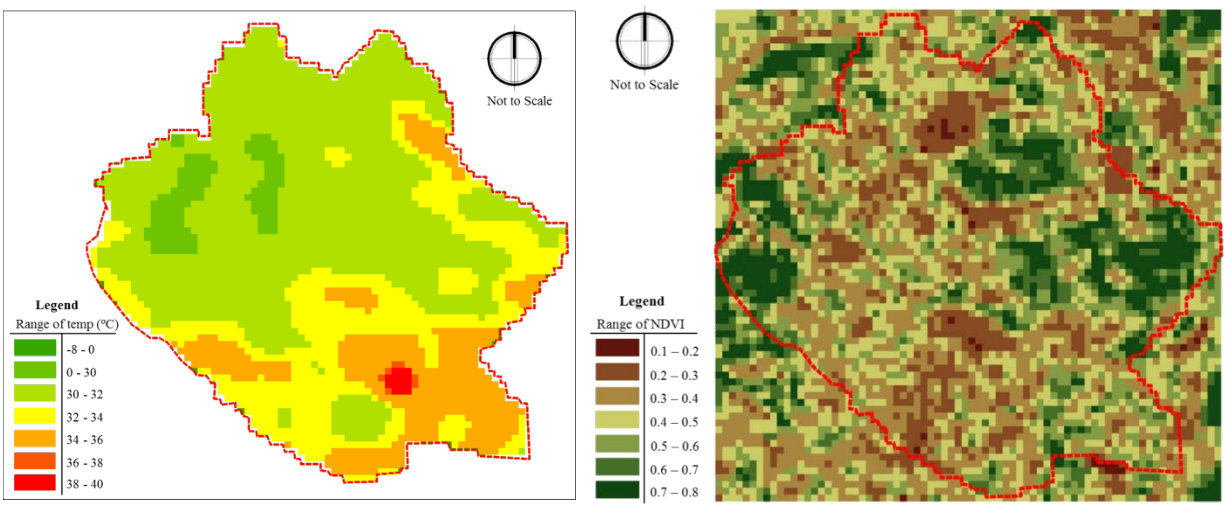

Figure 5: LST results for Bukit Bintang study area in 2009 from Landsat TM5

4.0 Result and Discussion

The analysis and findings will be explained thoroughly based on each method that were generated from image pre-processing and the main processing resulting towards the correlation between LST, NDVI and Land Use.

4.1 Land Use Analysis

The whole study area 595.8 acres are 1.0% from the whole total area of Kuala Lumpur city centre (59848.923 acres). Commercial covers the highest percentage of land use activity which is 51.2% of the whole percentage of Bukit Bintang area, which is 304.70 acres. Open space covers 4.5% of the whole area which is 26.55 acres and education facilities covers only 3.8% of the study area. The lowest percentage of land use activity is infrastructure and utilities which cover only 0.4% of the study area. The area and percentages of land use categories in the study area is shown in **Table 1** and **Figure 6**.

Table 1: Current Land Use Distribution of Study Area

No.	Land Use Categories	Area (acres)	Percentages (%)
1	Residential	16.73	2.8
2	Commercial	304.79	51.2
3	Public Facilities and Institutions	40.57	6.9
4	Infrastructure and Utilities	2.19	0.4
5	Reserved Forest	10.22	1.7
6	Green Area	30.89	5.2
7	Road Transportation	190.41	31.8
	Total	**595.8**	**100.00**

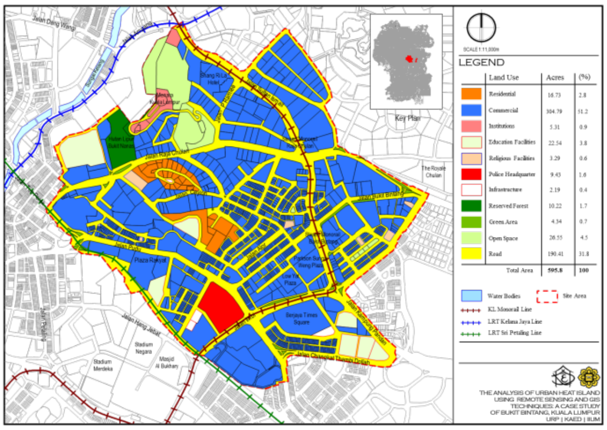

Figure 6: Current land use map

4.2 Extraction of LST and NDVI

In order to reveal the thermal spatial distribution pattern of Bukit Bintang, the thermal infrared images have to be enhanced using several image pre-processing techniques by correcting the atmospheric effect. The land use types such as the commercial, institutional, residential and open space, the number of inhabitants and the size of Bukit Bintang, thermal properties of surface materials and some meteorological factors like wind speed, air temperature, humidity and amount of precipitation further enhance the heat in the area.

4.2.1 Extraction of NDVI

The extraction of NDVI is a prime step in obtaining the final result of UHI. This is because vegetation is very sensitive to the absorption and reflection of the red and infrared bands. In this research study, the relationship between LST and vegetation greenness (NDVI) was examined thus **Figure 7** shows the result of the extraction of NDVI in the study area.

Table 2: Percentage and acreage of NDVI retrieval

Range of Vegetation Index	Percentage (%)	Area (acres)
0.1 – 0.2	0.4	2.38
0.2 – 0.3	13.2	78.65
0.3 – 0.4	**31.2**	**185.89**
0.4 – 0.5	28.5	169.80

0.5 – 0.6	7.0	41.71
0.6 – 0.7	5.8	34.56
0.7 – 0.8	13.9	82.81
Total	**100.00**	**595.8**

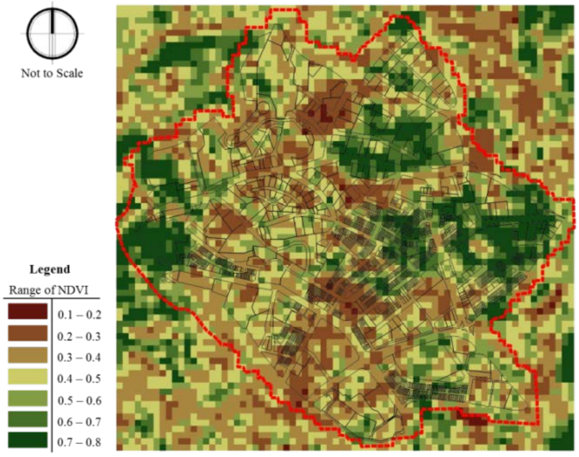

Figure 7: NDVI retrieval map

There were seven ranges of vegetation index calculated and showing the percentage also including acreage. The table was retrieved from the histogram graph data that range **0.3 until 0.4** has the highest percentage of vegetation index which is **31.2%** consists of **185.89 acres**. It can be seen that the NDVI falls between the ranges of 0.1 until 0.8, while for rock and soil, the NDVI values are close to zero, and water bodies give a negative reading for the NDVI value. Usually, the index value of NDVI is in the range of -1 until 1. Therefore, the higher the NDVI value, the denser and healthier the vegetation in that particular area. In terms of absorption, green vegetation is more sensitive to the red band as compared to the NIR band. Thus, the reflectance of the NIR band is larger than that of the red band, which then gives a higher NDVI index. The minimum value of vegetation index is **0.129** and the maximum are **0.894**. Thus, the NDVI is used as an indicator for the biomass and the greenness of the study area's surface.

4.2.2 Extraction of Land Surface Temperature

Remote sensing based LST is determined from thermal emission at wavelengths in either infrared or microwave. There were seven ranges of surface temperature calculated as shown in **Table 3** and showing the percentage also including acreage. The table was retrieved from the histogram graph data showing that range **32°C until 34°C** is the highest percentage of the range of temperature which is **33.4%** consists of **199 acres**. It can be seen that the highest temperature which is the range of temperature **38°C until 40°C** is located between Low Yat Plaza and Berjaya Times Square on Jalan Imbi.

Table 3: Percentage and acreage of LST retrieval

Range of Temperature (°C)	Percentage	Acres
-8.152 - 0	15.5	92.35
0 - 30	0	0
30 - 32	31.8	189.46
32 - 34	**33.4**	**199.00**
34 - 36	18.0	107.24
36 - 38	0.5	2.98
38 - 40	0.8	4.77
Total	**100.00**	**595.8**

Furthermore, it can be seen that the temperature is a bit higher at the center of urbanization of Bukit Bintang Walk, where the famous crossing is located. This is because there are many high density buildings in that area and will be increased in the future because of the current construction in the study area. The heat pockets are indicated by the range of colour from 32°C until 40°C in the LST and are predominantly in the dense built-up spaces. The hot spots in the Landsat TM5 image are found in the high density commercial areas in the Bukit Bintang study area.

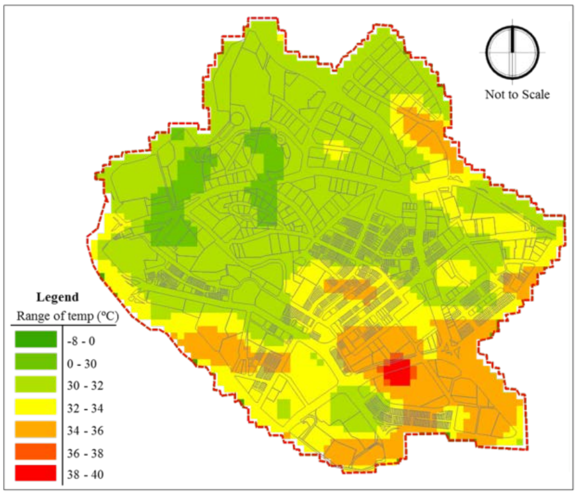

Figure 8: LST retrieval map

The green area ranging from temperature 30°C until 32°C represents the temperature lower than the red, orange and yellow which also can be related to the urban area with low activities like the road, residential area or the low density commercial built-up area as shown in **Figure 8**. The minimum value of land surface temperature is -0.815°C and the maximum is 39.927°C.

4.3 The Correlation Analysis between LST, NDVI and Land Use

To obtain the relationship between LST, NDVI and Land Use, each image is converted into points where it will be measured within the detailed study area. Regression analysis is carried out to determine the correlation between these three parameters using Microsoft Excel. NDVI is one of the most widely applied vegetation indices to strengthen the vegetation information. In order to compare the green land and built-up area to UHI effects which provides useful information for the urban development and environment protection, the correlation between LST, NDVI and Land Use are analysed in **Table 4**.

Table 4: Correlation coefficient between LST, NDVI and Land Use

	LST	NDVI	Land Use
LST	1		
NDVI	-0.083562	1	
Land Use	0.08386	-0.08688	1

The negative coefficient between LST and NDVI indicates that the impact of green land on UHI is negative, which means that the green land can weaken the UHI effect. The relationship between LST and NDVI was investigated for each land cover type. From the obtained result, it is obvious that LST values tend to negatively correlate with NDVI values for all land cover types. In comparison, the positive correlation between LST and Land Use suggests that the built-up land can strengthen the UHI effect in the Bukit Bintang study area. As it can be seen in **Figure 9**, the results indicate the close relationship between UHI and Land Use.

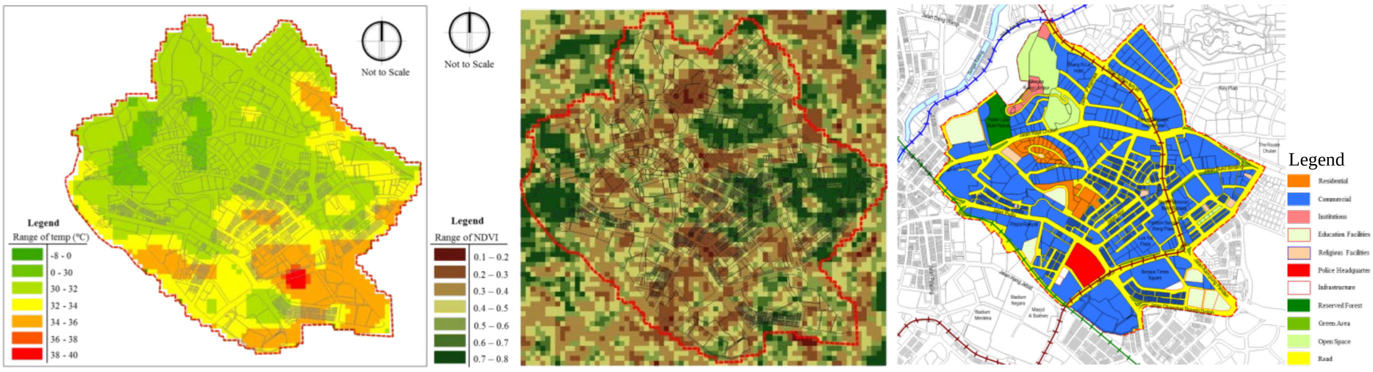

Figure 9: LST retrieval map, NDVI retrieval map and Land Use map

Comparing the LST, NDVI and Land Use outputs, the relationship between the surface temperature and land use can be clearly understood. The hot spots on the LST retrieval map are mainly concentrated in the Bukit Bintang Walk and the adjacent buildings. Spatial distributions of surface temperature demonstrated that there is a positive and close relationship between the heat islands and urban growth, whereas there is a negative relation between LST and NDVI. The temperature is a bit higher at the center of urbanization of Bukit Bintang Walk, where the famous crossing is located. This is because there are many high density buildings in that area and will be increased in the future because of the current construction in the study area.

5.0 Conclusion and Future Outcomes

The relationship between remote sensing and GIS practitioner has traditionally been that of the supplier (remote sensing) and consumer (GIS) (Gahegan and Flack, 1999). Many other indices can be calculated based on LST and NDVI.In this research study, an integrated approach of using remote sensing and GIS techniques was used to determine the UHI for Bukit Bintang study area. The results illustrated that Landsat multi-temporal image or specifically in this study, Landsat TM5 could provide an accurate map and give detailed descriptions on the LST and NDVI across the study area. The result obtained through LST, NDVI and Land Use can be used as essential information for decision-making in land management and policy making.

The urban planners and developers should pay attention to the urban climate specifically while working on urban design and growth. Remote sensing can help urban planners in developing urban areas which can be useful to analyse the Land Use change and to have a plan in a way that has less growth in heat islands. Improvement of the accuracy of the results was achieved by adopting the spatial, textural, relational and contextual information of the objects which proved the efficiency of the method. The resultant maps produced in this research study may be useful for planning and environmental studies for LST, NDVI and Land Use analysis or to an update of current maps and spatial information and resource management. The results achieved on the correlation among LST, NDVI and Land Use can be used by governments, agencies, planners to know which operation should be used for various process such as urban growth monitoring. This kind of study can be applied to regional areas where field investigations are not easy and time consuming. The proposed method can be replicated and applied to other types of satellite sensor data and different study areas.

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