# THE IMPACT OF URBAN EXPANSION ON LAND SURFACE TEMPERATURE AND VEGETATION COVER FOR CLIMATE CHANGE ADAPTATION IN PASIR MAS, KELANTAN, MALAYSIA

by

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**THESIS DECLARATION**

I hereby declare that the work embodied in this Report is the result of the original research and has not been submitted for a higher degrees to any universities or institutions.

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**The impact of urban expansion on Land Surface Temperature and vegetation cover for climate change adaptation in Pasir Mas, Kelantan, Malaysia**


## ABSTRACT

In global, urban temperature increase day by day. This climatic condition called Urban Heat Island (UHI) which is one of the indicator of climate change phenomenon. Pasir Mas district, Kelantan, Malaysia is one of the district that in the phase of developing city which is lead to urban expansion. . The objective of this research is to determine relationship between urban expansion, Land Surface Temperature (LST) and vegetation cover. The relationship between LST and Land Cover types in Pasir Mas, Kelantan, Malaysia was studied using data gathered from three satellite images from Landsat-5 (02th of May 1999), Landsat-5 (14th of June 2009) and Landsat-8 (28th of July 2019). There were four categories of land use: built-up area, green area, bare land and water sources. ArcGIS software was used to calculate the value of LST. In 1999, Pasir Mas, Kelantan in Malaysia comprised 74.86% green area, 14.69% bare land, 8.29% built-up area and 2.16% water sources. By 2009, the green area decreased to 72.41%, bare land increased to 15.1%, built up increased to 8.99% and water sources increased to 3.51%. In 2019, green area decreased to 66.18%, bare land decreased to 11.69, built up increased to 19.84% and water sources decreased to 2.29%. Moreover, in 1999 the mean LST was 18.99 °C for built up areas, 17.93 °C for green area, 17.5 °C for water sources and 18.57 °C for bare land. However, by 2009 the LSTs had increased for each category: 25.41 °C for built up areas (+6.42 °C), 24.31 °C for green area (+6.38 °C), 23.97 °C for water sources (+6.47 °C) and 25.14 °C for bare area (+6.57 °C). By 2019 the LSTs slightly increased for each category: 26.08 °C for built-up area (+0.67 °C), 24.94 °C for green area (+0.63 °C), 24.03 °C for water sources (+0.06 °C) and 25.48 °C for bare area (+0.34 °C). The findings indicate that the LSTs increased with the pace of urbanization and changes in land use. Polynomial regression revealed that built-up area, green area and bare area had a high correlation with LST.

**Kesan pembangunan pesat terhadap suhu permukaan tanah dan tumbuhan untuk perubahan iklim di Pasir Mas, Kelantan, Malaysia**



## ABSTRAK

Di peringkat global, suhu bandar meningkat setiap hari. Keadaan iklim ini dinamakan Bandar Heat Island (UHI) yang merupakan salah satu penunjuk fenomena perubahan iklim. Daerah Pasir Mas, Kelantan, Malaysia adalah salah satu daerah yang dalam fasa membangun bandar yang membawa kepada perkembangan bandar. . Objektif kajian ini adalah untuk menentukan hubungan antara pengembangan bandar, suhu permukaan tanah (LST) dan perlindungan tumbuhan. Hubungan antara jenis LST dan Land Cover di Pasir Mas, Kelantan, Malaysia telah dikaji menggunakan data yang dikumpulkan dari tiga imej satelit dari Landsat-5 (02 Mei 1999), Landsat-5 (14th Jun 2009) dan Landsat-8 (28th Julai 2019). Terdapat empat kategori penggunaan tanah: kawasan binaan, kawasan hijau, tanah kosong dan sumber air. Perisian ArcGIS digunakan untuk mengira nilai LST. Pada tahun 1999, Pasir Mas, Kelantan di Malaysia terdiri daripada 74.86% kawasan hijau, 14.69% tanah kosong, 8.29% kawasan binaan dan 2.16% sumber air. Menjelang 2009, kawasan hijau berkurangan kepada 72.41%, tanah terdahulu meningkat kepada 15.1%, dibina meningkat kepada 8.99% dan sumber air meningkat kepada 3.51%. Pada tahun 2019, kawasan hijau berkurangan kepada 66.18%, tanah terdahulu berkurangan kepada 11.69, dibina meningkat kepada 19.84% dan sumber air berkurangan kepada 2.29%. Selain itu, pada tahun 1999, purata LST adalah 18.99 ° C untuk kawasan dibina, 17.93 ° C untuk kawasan hijau, 17.5 ° C untuk sumber air dan 18.57 ° C untuk tanah yang terdedah. Walau bagaimanapun, pada tahun 2009, LST telah meningkat bagi setiap kategori: 25.41 ° C untuk kawasan dibina (+6.42 ° C), 24.31 ° C untuk kawasan hijau (+6.38 ° C), 23.97 ° C untuk sumber air (+6.47 ° C ) dan 25.14 ° C untuk kawasan kosong (+6.57 ° C). Menjelang tahun 2019 LST meningkat sedikit untuk setiap kategori: 26.08 ° C untuk kawasan binaan (+0.67 ° C), 24.94 ° C untuk kawasan hijau (+0.63 ° C), 24.03 ° C untuk sumber air (+0.06 ° C) dan 25.48 ° C untuk kawasan kosong (+0.34 ° C). Penemuan menunjukkan bahawa LST meningkat dengan kadar pembandaran dan perubahan penggunaan tanah. Regresi linear menunjukkan bahawa kawasan binaan, kawasan hijau dan kawasan kosong mempunyai korelasi positif dengan LST.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| GIS | Geographic Information System |
| RS | Remote Sensing |
| TM | Thematic Mapper |
| OLITIRS | Operational Land Imager Thermal Infrared Sensor |
| LULC | Land Use Land Cover |
| NDVI | Normalized Difference Vegetation Index |
| LST | Land Surface Temperature |
| USGS | U.S. Geological Survey |
| TIR | Thermal Infrared |
| UHI | Urban Heat Island |

## LIST OF SYMBOLS

| | |
|---|---|
| % | Percentage |
| ° C | Degree Celcius |
| km | Kilometer |

# CHAPTER 1

# INTRODUCTION

Urbanization process can lead to the global environment impact that related to the climate change (Chapman, Watson, Salazar, Thatcher, & McAlpine, 2017). Urbanization also give impact to the local scale such as increasing in depletion number of forest (Hojas-Gascon et al., 2016), carbon budget, water and surface energy (Bounoua et al., 2015) and reduce the air quality of the environment (Fang, Liu, Li, Sun, & Miao, 2015). These phenomenon lead to the Urban Heat Island (UHI). UHI strongly related to the increasing of the heat due to the manmade production materials such as building, pavement and asphalts (Mohajerani, Bakaric, & Jeffrey-Bailey, 2017). The important parameters that affecting the UHI is Land Surface Temperature (LST) and UHI shows the closed relationship to the LST (Bokaie, Zarkesh, Arasteh, & Hosseini, 2016).

## 1.1 Background of Study

Pasir Mas is located in north-western Kelantan, Malaysia which is a town in Pasir Mas District. Pasir Mas in one of the biggest city in Kelantan after Kota Bharu and Tanah Merah and it was one of the regional economy that can generate income for the Kelantan state as the area is 139 $km^2$ and the population density is 180, 878. Due to the higher population and increasing in the business activity, the development of building also increase and it give impact to the green areas such as vegetation and forest. To follow the government agendas which was to improve the city and economy, this encourage to the development of tall building, development of the road and bridge to ease the movement of economic activities. This activities contributes to the reducing number of trees that can increase carbon emissions, Green House Gases emissions that will lead to the climate change phenomenon.

**1.2 Problem Statement**

Rapid urbanization process have impact to the environment that related to the reduction of the number of green areas such as vegetation cover and forests (Zhou & Wang, 2011). Green areas have strong relationship between reducing the number of vegetation cover can increase the temperature which can lead to the UHI (Wong & Yu, 2005). To study the climate change phenomenon, LST is of the important parameter to as it heat directly contact to the surface of the earth (Eleftheriou et al., 2018).

This study aims to fill the knowledge gap to reveal the lack of understanding and analysis on the relationship between urbanization, LST and vegetation cover. This study will directly address the issue of occupant prosperity's economy, social and physical. In past research, there is no experimental evidence of subjective and quantitative information review. The result of this exploration would create enormous evidence on the effect of urban expansion on soil surface temperature and vegetation cover for environmental change, and in the meantime can help to create a superior structure and arrange reasonable improvement in Malaysia's urban communities, especially in Pasir Mas, Kelantan.

## 1.3 Objectives

The research objectives of this study are as follows:

- To determine the Land Surface Temperature in Pasir Mas.
- To determine the relationship between urban expansion, land surface temperature and vegetation cover.

## 1.4 Scope of Study

Scope of this study is focus on determination of the impact of urban expansion on land surface temperature and vegetation cover for climate change in Pasir Mas. Below is the framework for this research study:

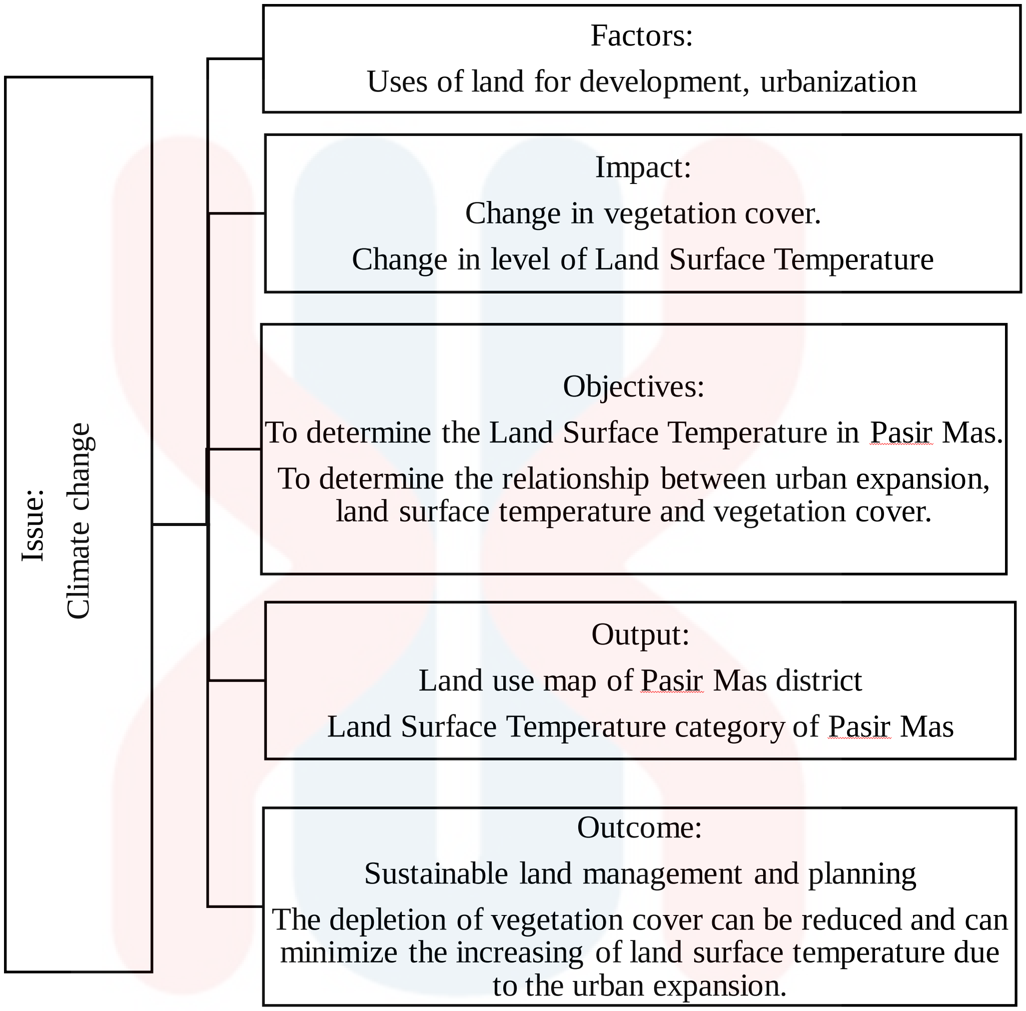


**Figure 1.1** Research Framework

In Pasir Mas, Kelantan, this study will focus on quantifying land surface temperature and determining vegetation cover for climate change. This study analyzes changes in the land surface temperature in a series of years from 1999, 2009 to 2019 using remote sensing and application of GIS.

### 1.5 Significant of Study

In this research, the techniques from remote sensing were used to analyze LST by using Landsat Thematic Mapper ™ of satellite images which were Landsat TM 5 1999 and 2009 and Landsat 8 OLITIRS 2019. Thermal band that used in this study are band 6 for satellite image of 1999 and 2009. While for year 2019, Band 10 was used to get the value of LST. LST was used to demonstrate thermal change within Land Cover (LC). Zonal statistic was used to analyze the mean temperature over the each class of LC changes in 1999, 2009 and 2019 of Pasir Mas. The integration application of remote sensing and GIS were used in order to find the relationship between LST, vegetation cover and urban expansion.

This investigation will help the understanding to give the measurable description of information following urban development in Pasir Mas, Kelantan using GIS and remote sensing application to create the map of land use. In addition, the Land Surface Temperature analysis in this review will be a commitment of evidence to assist the chief with the issue. This will also open opportunity for the development and re-evaluation of the current district physical arrangement so that the strategies of development can be improved to the sustainable development and sustainable strategies. The finding will produce substantial evidence on the impact of urban expansion on the temperature of the land surface and the cover of vegetation for climate change. It can help improve sustainable development design and planning in Malaysia's cities, particularly in Pasir Mas, Kelantan.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Climate Change

Climate change is the change of the composition of the atmosphere that happens in extended periods or takes long times to happens usually decades. This phenomenon occurs due to the anthropogenic activities and natural activities (Unfccc, n.d.). Based on the previous research, there are few of causes that lead to the climate change which are human influences, magnetic field strength and ocean variability, volcanism, orbital variations and solar output (Zhong, 2016). The biggest contributor to the climate change phenomenon was human influences that relates to the urbanization rates and population density. The increasing in human activities increase the Green House Gases concentration due to the emission of carbon dioxide gas from the fuel combustion of transportation, factories and energy consumption (Hao, Chen, Wei, & Li, 2016). This GHG emissions increase the air temperature and lead to the global warming issues that relates to the climate change phenomenon (Jang & Hart, 2015).

Greece which is the country of Mediterranean was identified as an area that main hot spot for the climate change projection. The research had been conducted to identify the LST in seasonal day time and nighttime for the climate change implications. The results indicates that the pattern of the LST annually for daytime was decreased in the majority areas and increase in a few places while the LST showed increase in night time. Overall, the results shows that the LST trend in Greece showed the decrease over the period (Eleftheriou et al., 2018).

**2.2 Urbanization**

Urbanization is one of the process which is rural areas change to urban areas (Hegazy & Kaloop, 2015). Urbanization process has prompted the decrease of green zones as created with private and business sectors. Two dominant impacts resulting from the urbanization are the decrease of the quantity of green plants and the expansion in surrounding temperature of the zone (Qihao Weng & Lu, 2008). There is a previous research that study the impact of urbanization on LST and its interaction with vegetation cover and impervious surface in Indianapolis, United States. The finding of the research states that urbanization has inverse relationship to vegetation cover and impervious surface and LST had high correlation to the vegetation cover and impervious surface(Qihao Weng & Lu, 2008).

Urbanization indicates that increasing in built up areas and human activities that lead to the changing in properties of surface and changing in the circulation of the atmospherics (Zhang et al., 2009). This will make the city's zone extend and grow its size. In any case, the utilization of this development procedure must be in accordance with urbanization Policy. This strategy will guide and organize the arranging and advancement of urbanization so as to be progressively productive and orderly. In accordance with the development of this new city area, human action has additionally expanded and particularly expanded.

Business sectors, trade, the travel industry, transportation, etc cause changes in temperature patterns and daily precipitation in urban areas (Gu, Hu, Zhang, Wang, & Guo, 2011). The activities of these sectors will likewise discharge contaminations into the air, for example, carbon dioxide ($CO_2$), nitrogen oxide ($NO_2$), responsive hydrocarbons (HC) and others.

The urbanization process can also influence the stream and hydrological cycling in the urban landscape by changing the rate of evapotranspiration, changing the examples of overflow, impenetrable surfaces, water pollution and expanding water use (Hashemi, Mahmud, & Ashraf, 2015).

There is previous research that indicated that the LSTs increased with the pace of urbanization and changes in land use where linear regression revealed that built-up land had a positive correlation with LST, where a 1% increase in built up area increased its LSTs by 0.146594 °C (Chotchaiwong & Wijitkosum, 2019). Previous study combine Landsat and MODIS data in a land model to assess the impact of urbanization on US surface climate. For cities built within forests, daytime urban land surface temperature (LST) is much higher than that of vegetated lands. The research find that the choice and amount of tree species in urban settings play a commanding role in modulating cities' LST. At continental and monthly scales, impervious surfaces are 1.9°C ± 0.6 °C warmer than surroundings during summer and expel 12% of incoming precipitation as surface runoff compared to 3.2% over vegetation. The research also show that carbon lost to urbanization represents 1.8% of the continental total, a striking number considering urbanization occupies only 1.1% of US land. With a small extent area, urbanization has significant effects on inform upon policy options for improving urban growth including heat mitigation and carbon sequestration (Bounoua et al., 2015).

## 2.3 Vegetation Cover

The most important component in terrestrial ecosystem is vegetation. Roles of vegetation area conserving water and soil and prevent desertification (W. Sun et al., 2015). The research was conducted to evaluate the spatial distributions and temporal variations of vegetation cover using NDVI in Loess Plateau over three decades. The research also determine the relationship between vegetation cover and climate variables (temperature and precipitation). The results showed that the density of vegetation cover in Loess Plateau increase from northwest to southeast. The NDVI increase from 1981 to 2010 in the Plateau. The increasing in density of vegetation cover in Loess Plateau due to the Grain to Green programs that promoted ecological restoration. There is significant and positive correlation between temperature and vegetation in the southeast Loess Plateau because the findings state that the higher temperature increase the growth of vegetation in the area that has less water stressed area. The vegetation having degradation in Loess Plateau due to the climate and global warming that caused the degradation in the water content.

Some studies was conducted to determine the relationship between LST and vegetation cover in Tabriz urban area, Iran. The study was conducted because there was changes in land use land cover in urban areas. The rapid changes can give the environmental impact such as depletion number of vegetation cover and increasing the Urban Heat Island. So, better management plan need to be encounter in order to mitigate the environmental issues. The finding of research showed the inverse relationship between LST and vegetation cover as the higher density of the vegetation cover, the lower the LST. Vegetation cover is a good indicator to mitigate the increasing of LST (Amiri, Weng, Alimohammadi, & Alavipanah, 2009)

Regeneration of vegetation helps to improve the ecosystem of environment and control soil erosion (Xin, Yu, & Lu, 2011). Increasing human activities such as land clearing for the development of the area brings to the depletion number of vegetation that can lead to the land degradation and give serious impact to the ecological environment (García-Ruiz, 2010). The previous study attempts to assess the effects of vegetation growth on land surface temperature (LST) distribution in urban areas. An area within the city of Shah Alam, Selangor has been selected as the study area. Land use/land cover and LST maps of two different dates are generated from Landsat 5 TM images of the year 1991 and 2009. Only five major land cover classes are considered in this study. Mono-window algorithm is used to generate the LST maps. Landsat 5 TM images also used to generate the NDVI maps. Results from this study have shown there are significant land use changes within the study area. Although the conversion of green areas into residential and commercial areas significantly increase the LSTs, matured trees will help to mitigate the effects of UHI. There is strong negative correlation between LST and NDVI, which indicates vegetation helps to reduce the LST of an area (Buyadi, Mohd, & Misni, 2014)

### 2.4 Land Surface Temperature

LST plays important role in determine the radiative energy of the earth surface. Longwave radiation between land and atmosphere helps in monitoring soil moisture content and evapotranspiration (Anderson, Norman, Mecikalski, Otkin, & Kustas, 2007). LST is one of the important climate variables as it act as indicator to the surface warming trends from climate change (Schneider & Hook, 2010). LST was also used as indicator in determine the climate change variables such as air temperature and tropospheric water vapor (Seemann, Borbas, Knuteson, Stephenson, & Huang, 2008). LST data had been demonstrated in scientific study to monitor global warming over lakes (HALL & JONES, 2010) and identify the UHI effects (Dousset & Gourmelon, 2003).

Based on the theoretical basis in remote sensing of LST the total radiative energy that emitted by the ground surface increase with the increasing in the temperature according to Planck's law. LST is refers to the radiometric temperature which is different to surface air temperature. LST is directly measure the cold and hot of earth surface. LST of the bare soil is temperature that measured in the top of micrometer of the soil surface, while for the vegetation its measure the temperature of the canopy, limbs, branches and soil surfaces (Hulley et al., 2019).

Due to the economic growth and development of technology, rapid cities development has occurred in Zhujiang Delta of South China. The study had been conducted by (Q Weng, 2001) that integrate the use of remote sensing and GIS in order to evaluate the urban expansion and assess the impact of urban expansion on LST in region of the study. To identify the change detection in LULC of Zhujiang Delta of South China, study was used the remote sensing application by using multi temporal Landsat Thematic Mapper data. Pattern of the urban growth was analyzed by using GIS application. In order to analyze the impact of urban expansion to the LST, the application of remote sensing and GIS was integrated to get the better results and findings. The finding indicate that rapid growth was occurred in Zhujiang Delta of South China. The development caused the LST of urban area increased by 13.01 K.

## 2.5 Remote Sensing, GIS and its application

The Remote Sensing and Geographic Information System (GIS) is used as a tool that considers land determination using spatial distribution and the difference in multi-temporal identification (Hegazy & Kaloop, 2015). Remote sensing is seen as a strategy to collect data from a separation without contact with the objects being observed (Verstraete & Pinty, 1996). Because of their preferences, the remote sensing center around the ground uses the board, for example, have higher spatial and temporal resolution images, easier access to these data, an improved overall picture area and lower cost usage (Guo, Li, Sheng, Xu, & Wu, 2017).

The use of remote sensing and GIS can encourage legitimate activity and best choice to address the impact of the assessment (*International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281*, n.d.). The origination of ecologically sensitive zones and the map of high-restriction zones using demonstration of GIS base would be particularly helpful in making the decisions. In order to better understand the elements of urban development, the combination of urban simulation display, geographic data frameworks (GIS) and remote sensing was effectively used to anticipate urban planning activities (Al-Darwish, Ayad, Taha, & Saadallah, 2018). The methodology for estimating and estimating resistant zones is satellite images and land survey. Resistant region of inclusion regarded as an index for estimating urban spread in basic condition.

The previous paper reports an investigation into the application of the integration of remote sensing and geographic information systems (GIS) for detecting urban growth and assessing its impact on surface temperature in the region. Remote sensing techniques were used to carry out land use/land cover change detection by using multi-temporal Landsat Thematic Mapper data. Urban growth patterns were analyzed by using a GIS-based modelling approach. The integration of remote sensing and GIS was further applied to examine the impact of urban growth o surface temperature. The results revealed a notable and uneven urban growth in the study area, Zhujiang Delta, China. This urban development had raised surface radiant temperature by 13.01 K in the urbanized area. The integration of remote sensing and GIS was found to be effective in monitoring and analyzing urban growth pattern and in evaluating urbanization impact on surface temperature.

# CHAPTER 3

# METHODOLOGY

## 3.1 Study Area

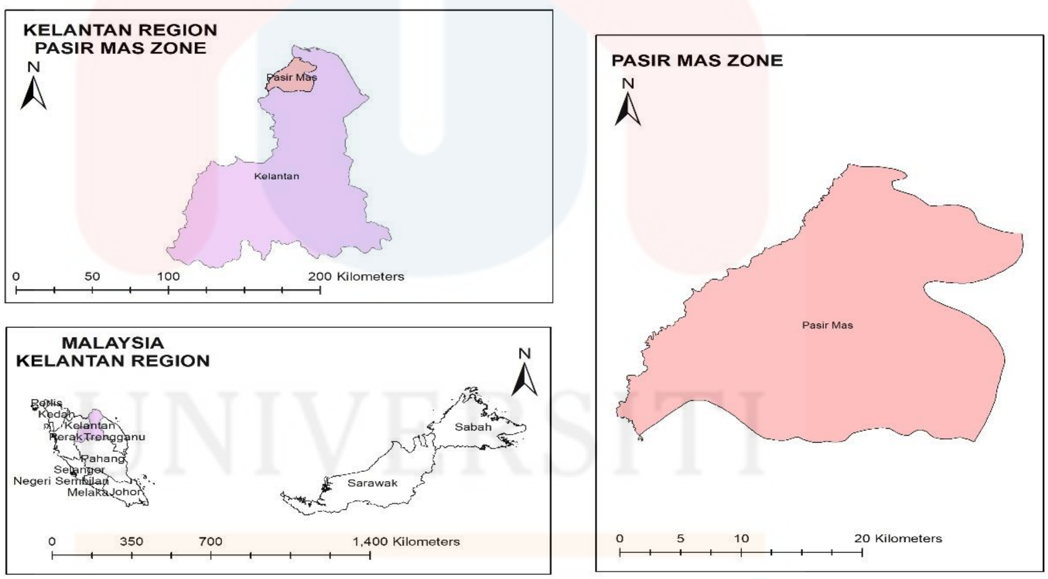


**Figure 3.1** The study area of Pasir Mas, Kelantan (Source: gadm.org)

Kelantan is one of Malaysia's states with Kota Bharu as its main city located in the north-east of the peninsula. This state included ten districts including Kota Bharu, Pasir Mas, Tumpat, Bachok, Pasir Puteh, Tanah Merah, Kuala Krai, Gua Musang, Machang, and Jeli. The state of Kelantan occupied 15,099 km2 of land. In 2011, the state's total population was 1.6 million, with an average annual population growth rate of 1.6 %. The state's population included several ethnic groups. Malaysian (95 %), Indian (3 %), Chinese (1.9 %) and others (0.1 %). Unlike Malaysia's western coast, Kelantan has not experienced rapid industrialization and thus economic growth.

Pasir Mas is located in the north of Kelantan, based on Pasir Mas District Council's official portal (2018). It borders northward Tumpat, southward Tanah Merah, eastward Sungai Kelantan and eastward Kota Bharu and westward Sungai Golok, westward Thailand. Most of the area consists of flatlands. Pasir Mas town is connected to the main road between Bandar Sungai Golok, Thailand and the state capital. The road is also the main road connection for East Coast states to Kota Bharu. Because of its geographical location, it serves as the main gateway to Thailand from the eastern coast of Malaysia and is also crossed by major road transport routes from the west coast to Kota Bharu state capital. Pasir Mas district was originally part of Kota Bharu district. Pasir Mas City and its surrounding areas were separated from Kota Bharu in 1918 and granted their own local government.

The main factor in selecting the Pasir Mas as a study area is that it was one of Kelantan's rapidly expanding developing districts. The total population of residents of the Pasir Mas District Council was around 185,741, the second largest district in Kelantan after Kota Bharu, based on data from 2010. The density is 300/km2 and the Pasir Mas district coordinate is 6.0424 ° N, 102.1428 ° E.

The case study method was used with three basic steps to conduct this research in order to collect data, process data and analyze data. Land use maps were generated using image satellite interpretation, which is then recorded at the end in the soft copy and hard copy forms.

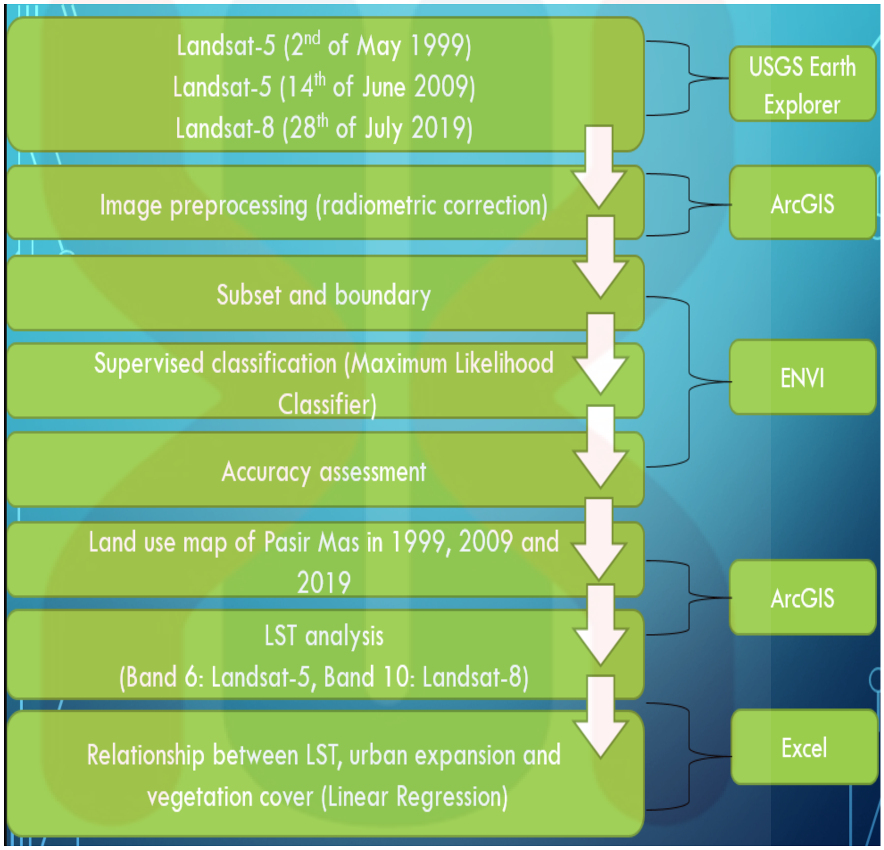


**Figure 3.2** Methodological Framework

## 3.2 Data Collection

Data acquisition has played a very important role in statistical analysis. Satellite image were used for the selected study area to acquire data on land use cover (LULC). The satellite images of U.S. Geological Survey were downloaded in year of 1999, 2009, and 2019 with high resolution image of Landsat 5 Level 1 and Landsat 8 OLI Level 1. Landsat satellite imagery has been used worldwide successfully to monitor urban landscapes and LST (Duncan et al., 2019). Information of the satellite image were shown in the table below.

**Table 3.1** Details of Landsat data collected

| Date of images | Satellite/sensor | Resolution | Reference/system/path/row |
|---|---|---|---|
| 02/05/1999 | Landsat 5 TM | 60 meters | WRS/127/056 |
| 14/06/2009 | Landsat 5 TM | 60 meters | WRS/127/056 |
| 28/07/2019 | Landsat 8 OLITIRS | 60 meters | WRS/127/056 |

Three geocoded satellite images were processed using ENVI and ArcGIS to produce Land Use Land Cover (LULC) maps for the district of Pasir Mas in 1999, 2009 and 2019. Then the satellite images will be subset to extract the area of interest from the image by using the boundaries obtained from the Global Administrative Areas. Furthermore, the selection of a satellite image must be emphasized. The satellite images to be selected must have good quality and less cloud coverage around it for all three selected years in 1999, 2009, and 2019. This is because high resolution images can produce more accurate results when analyzing the landscape of urban green spaces (Kabisch, Selsam, Kirsten, Lausch, & Bumberger, 2019).

In the classification process, Google Earth pro was used as a reference. The verification of ground truth was carried out using field work to evaluate the accuracy of the maps generated by land use (Carrasco, O'Neil, Morton, & Rowland, 2019). This is an effective way of ensuring that a very large area is evaluated and that there are limited costs. Precise assessment produced statistical results to verify the quality of the classification results. The main purpose of error analysis and accuracy evaluation in this study was to analyze the quantitative comparisons of various interpretations.

ArcGIS was used to convert vector format raster data. Lastly, the LULC maps were analyzed to study the spatial pattern evolution of Land Surface Temperature.

### 3.3 Image Classification

Image classification is the process that classify all pixels of the image into the specific LULC patterns. There are two types of digital classification which were supervised classification and unsupervised classification. The common classifiers are minimum distance to mean classifier and maximum likelihood classification (MLC) (Pradhan & Zahabi, 2017). According to the factors that influence the performances and values, MLC is the most used in the process of classification in remote sensing. This produce the better and good results in the classification (Foody, Campbell, & Trodd, n.d.).

In this research, the process of classification was conducted using ENVI classic software. The images of 1999, 2009 and 2019 were classified into four classes which were (1) Bare land, (2) Built up area, (3) Green area and (4) Water sources. These classification based on the USGS Circular 671: bare land (wasteland, unused areas), built up areas (community areas and buildings), green areas (agricultural land, forest and rangeland) and water sources (natural water sources and built up water bodies) (*A Land Use And Land Cover Classification System For Use With Remote Sensor Data*, 2001).

### 3.4 LST Retrieval

#### 3.4.1 Conversion of digital number into spectral radiance

Digital number of Landsat Thermal TM infrared spectrum band was converted into the spectral radiance by using Eq. (3.1) (Chander, Markham, & Barsi, 2007).

$$L\lambda = \text{Gain} * \text{DN} + \text{Bias} \tag{3.1}$$

Where Lλ = at sensor radiance, Gain = slope of the radiance (Table 3.2), Bias = intercept of the radiance (Table 3.3) and DN = digital number (pixel values).

Table 3.2 DN conversion coefficients

| Sensor | Band | Gain | Bias |
|---|---|---|---|
| TM | 6L | 0.055158 | 1.2378 |
| TIRS | 10L | 0.000334 | 0.10000 |

### 3.4.2 Conversion of Spectral Radiance to Top of Atmosphere Brightness Temperature

The value of spectral radiance were converted to top of atmosphere brightness temperature by using Eq. 3.2 (Chander et al., 2007).

$$LST = \frac{K2}{\ln \frac{K1}{L\lambda + 1}} \tag{3.2}$$

Where LST = LST at brightness temperature (K), Lλ is the spectral radiance from Eq. 3.1 and $K_1$ and $K_2$ are the two calibration constants according to launching (Table)

Table 3.3 Thermal band calibration constant

| Sensor | $K_1$ (W m−2 sr−1 μm−1) | $K_2$ (K) |
|---|---|---|
| TM | 607.76 | 1260.56 |
| TIRS | 774.8853 | 1321.0789 |

The term calculated in Eq. (3.2) Brightness temperature or satellite brightness. Using LST derivation algorithms and atmospheric data, to achieve higher accuracy, the result from the equation can be further processed.

The resulting images were then classified using Jenks' natural breaks method into different temperature classes which can determine the best arrangement of values inti classes (Q. Sun, Wu, & Tan, 2012).

### 3.4.3 Conversion of LST from Kelvin into degree Celcius

To get the value of LST of Kelvin into degrees the LST in Kelvin must be subtracted with 273.15 (Hua & Ping, 2018).

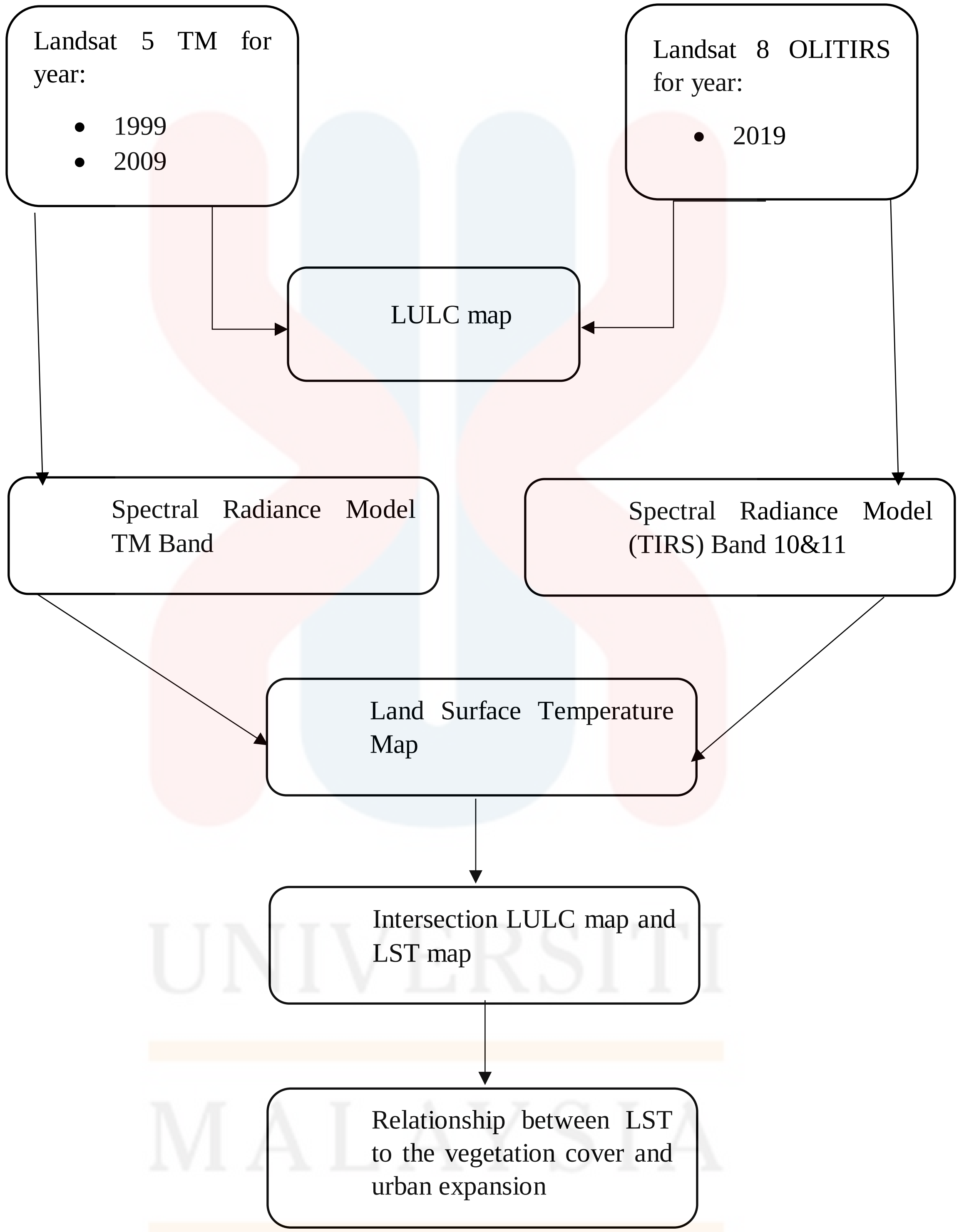


**Figure 3.3** Methodological Framework adopted for analysis variation in land surface temperature distribution that influence by urban expansion and vegetation cover using spectral radiance model (TIRS, Landsat 8 and TM, Landsat 5) in Pasir Mas, Kelantan.

# CHAPTER 4

# RESULTS AND DISCUSSION

The main objective of this research is to determine the changes in LST and vegetation cover due to the process of urban expansion that experiencing in Pasir Mas District. The values of LST were extracted for the year 1999, 2009 and 2019.

## 4.1 Land Cover Classification Results

Four LC classified image (Built-up area, Bare area, Green area and Water sources) from Landsat satellite image that using Maximum Likelihood Classification in ENVI Classic software were shown in Figure 4.1. Yellow color indicates bare area, red indicate built up area, green indicate green area and blue indicate water sources for the each year of 1999, 2009 and 2019. Based on Figure 4.1, the visual analyzed of the classifications showed an expansion in 2009 and 2019 of built-up areas, which is quite noticeable when compared to the built up areas in 1999. The green areas was dominated area for the three years of the study. Table 4.1 show the overall classification accuracy in percentage and Kappa coefficient of Landsat image using Maximum Likelihood Classification. Based on the result, the Landsat image in year 1999 had the highest accuracy and kappa coefficient followed by 2009 and 2019. Accuracy considered reliable because the data were accordance with previous research focusing on overall accuracy of identifying land use category using satellite imagery.

A report from the north-western coastal desert of Egypt cited an overall accuracy of 92.53% (1988), 93.77 (1999) and 97.30% (2011) (Halmy, Gessler, Hicke, & Salem, 2015). Figure 4.2 show changes of each land cover area from 1999 to 2009 to 2019. Green areas has the highest percentage of the area for the three years, followed by bare area, built up areas and the lowest percentage area is water bodies. The result indicates from 1999 to 2009 has slightly increase in built up areas which is 0.7 %, while 2009 to 2019 the built up areas increase to 10.85 %. Inversely, vegetation decreases by 2.45 %, 6.23 % from 1999 to 2009 and 2009 to 2019 respectively. Bare area increase from year 1999 to 2009, but decrease from 2009 to 2019. Decreasing of bare area and green areas due to its conversion to built-up areas (Buyadi et al., 2014). The urbanization trend in Pasir Mas district has increased in the period of 20 years as shown in the Figure 4.1

**Table 4.1** The overall Maximum Likelihood Classification accuracy and Kappa coefficient

| Year | Overall classification accuracy (%) | Kappa coefficient |
|---|---|---|
| 1999 | 99.00 | 0.9867 |
| 2009 | 97.51 | 0.97 |
| 2019 | 93.24 | 0.89 |

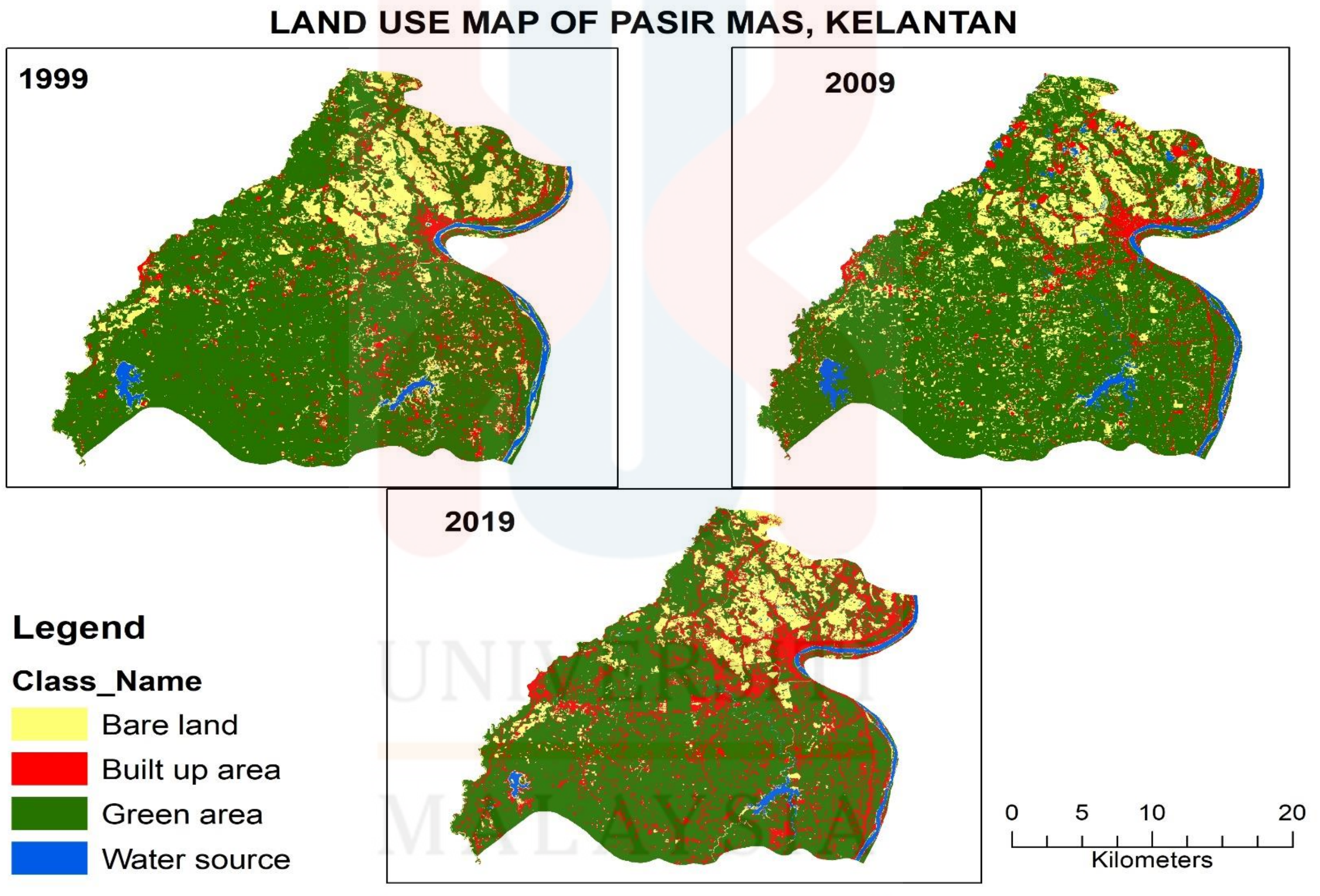


**Figure 4.1** The classified land cover map obtained using maximum likelihood classifier for study area

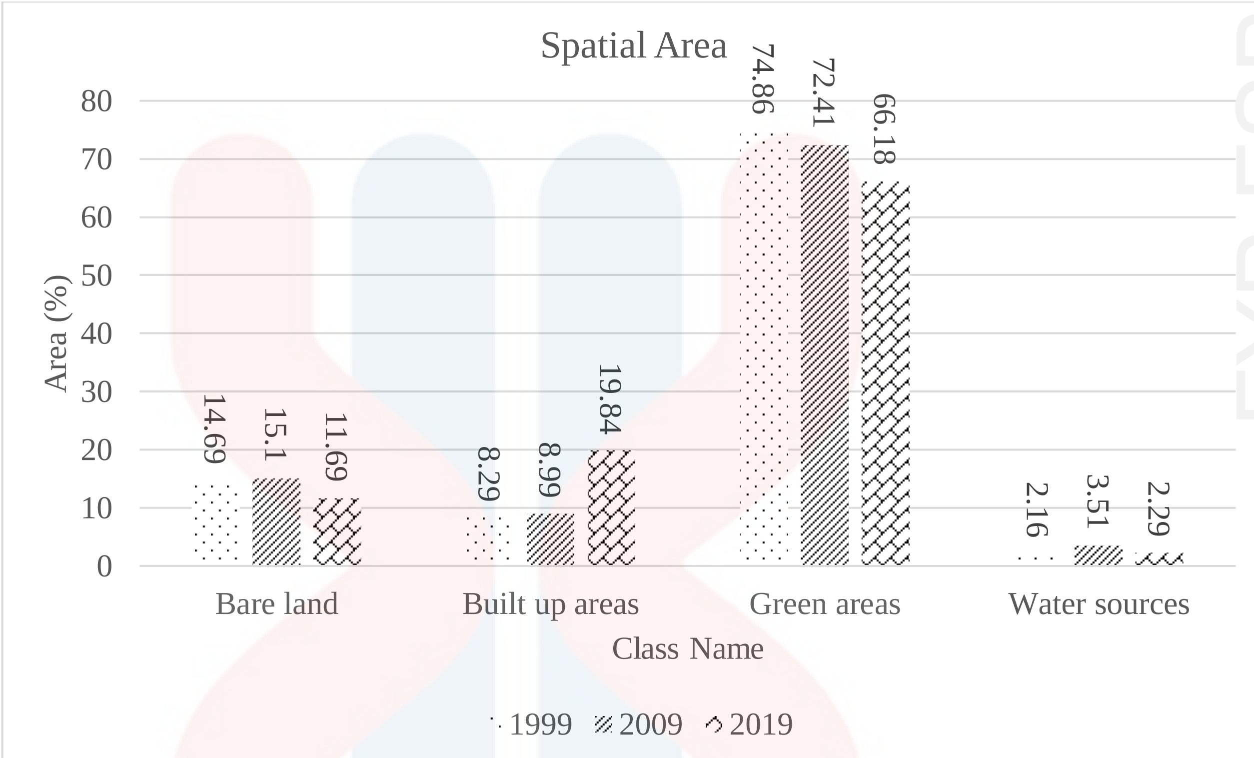


**Figure 4.2** Changes of each land cover area from 1999 to 2009 to 2019

### 4.2 Relationship between LST and Land Cover Types

Retrieval of LST was derived by using raster calculator in ArcGIS software. The map generated by different colors based on the code was shown in Figure 4.3. The changes of temperature over LULC was investigated in order to study the impact of urbanization on the thermal environment. Based on the Figure 4.3, the highest temperature in 1999 is 30 °C and the lowest temperature is -9.18. In 2009, the highest temperature is 31.65 °C and the lowest temperature is 18.83 °C which is increase from 1999. In 2019, the highest temperature is 33.25 °C and the lowest temperature is 22.04 °C which is also increase from 2009. So, over 20 years the LST of Pasir Mas is increase. As shown in Figure 4.3 most areas of the 1999 image are observed in yellow and dark green color, which indicates significantly low temperature as the maximum value of the LST is the lowest compared to 2009 and 2019. Inversely, most areas of the 2009 and 2019 images are observed bright green and increasing in red color, which indicates significantly high temperature as the maximum value of LSTs is increase 31.65 to 33.25 from 2009 to 2019 compared to 2009.

By using zonal statistic in ArcGIS software, mean temperature of each land class was calculated in order to analyze the changes of LST over the LC types during the 20 years. Based on Table 4.2, the highest mean temperature for the three years is built up areas, followed by bare land, green areas and water bodies is the lowest mean temperature. Mean temperature of built up areas is increase for the three years 1999, 2009 and 2019 which were 18.99 °C, 25.41 °C and 26.08 °C respectively. From 1999 to 2009 the mean temperature of built up areas increase up to 6.42 °C while from 2009 to 2019, the mean temperature slightly increase up to 0.67 °C. The lowest mean temperature for the three years is water sources which were increase from 17.50 °C to 23.97 °C to 24.03 °C in 1999, 2009 and 2019 respectively. From 1999 to 2019 the mean temperature of water sources increase up to 6.47 °C while from 2009 to 2019, the mean temperature of water slightly increase only 0.06 °C. This finding supported by the previous research by (Pradhan & Zahabi, 2017) that shows the lowest mean temperature for the land use is water bodies compared to the other research that the lowest mean temperature for the land use is vegetation cover (Chotchaiwong & Wijitkosum, 2019).

Bare land and vegetation not directly affect the LST, but it can change due to the increasing in the urban expansion. When the bare land change to the buildings, the reflectivity is depends on the materials such as concrete that have high reflectivity. Water sources have the lowest mean temperature because of water evaporation that have cooling effect from the water surface (Chotchaiwong & Wijitkosum, 2019).

The study support the hypothesis which is the LST increase when the density of the urbanization increase especially the increasing in the buildings and community areas. The finding supported by the previous research showing that urban area with high density have the highest average temperature that found in the large concrete buildings and large concrete constructions that community areas, car parks and shopping malls (Argüeso, Evans, Fita, & Bormann, 2014). High opportunities of the buildings for solar energy to be absorbed due to the highest reflection of the tall buildings. Furthermore, these area also will consume high energy such as air conditioner and combustion of fossil fuel that will lead to the increasing in the LST (Rinner & Hussain, 2011).

**Table 4.2** Mean LST in °C and area (%) for different land cover

| | Built up area | | Bare area | | Green area | | Water sources | |
|---|---|---|---|---|---|---|---|---|
| | Area (%) | LST (°C) | Area (%) | LST (°C) | Area (%) | LST (°C) | Area (%) | LST (°C) |
| 1999 | 8.29 | 18.99 | 14.69 | 18.57 | 74.86 | 17.93 | 2.16 | 17.5 |
| 2009 | 8.99 | 25.41 | 15.1 | 25.14 | 72.41 | 24.31 | 3.51 | 23.97 |
| 2019 | 19.84 | 26.08 | 11.69 | 25.48 | 66.18 | 24.94 | 2.29 | 24.03 |

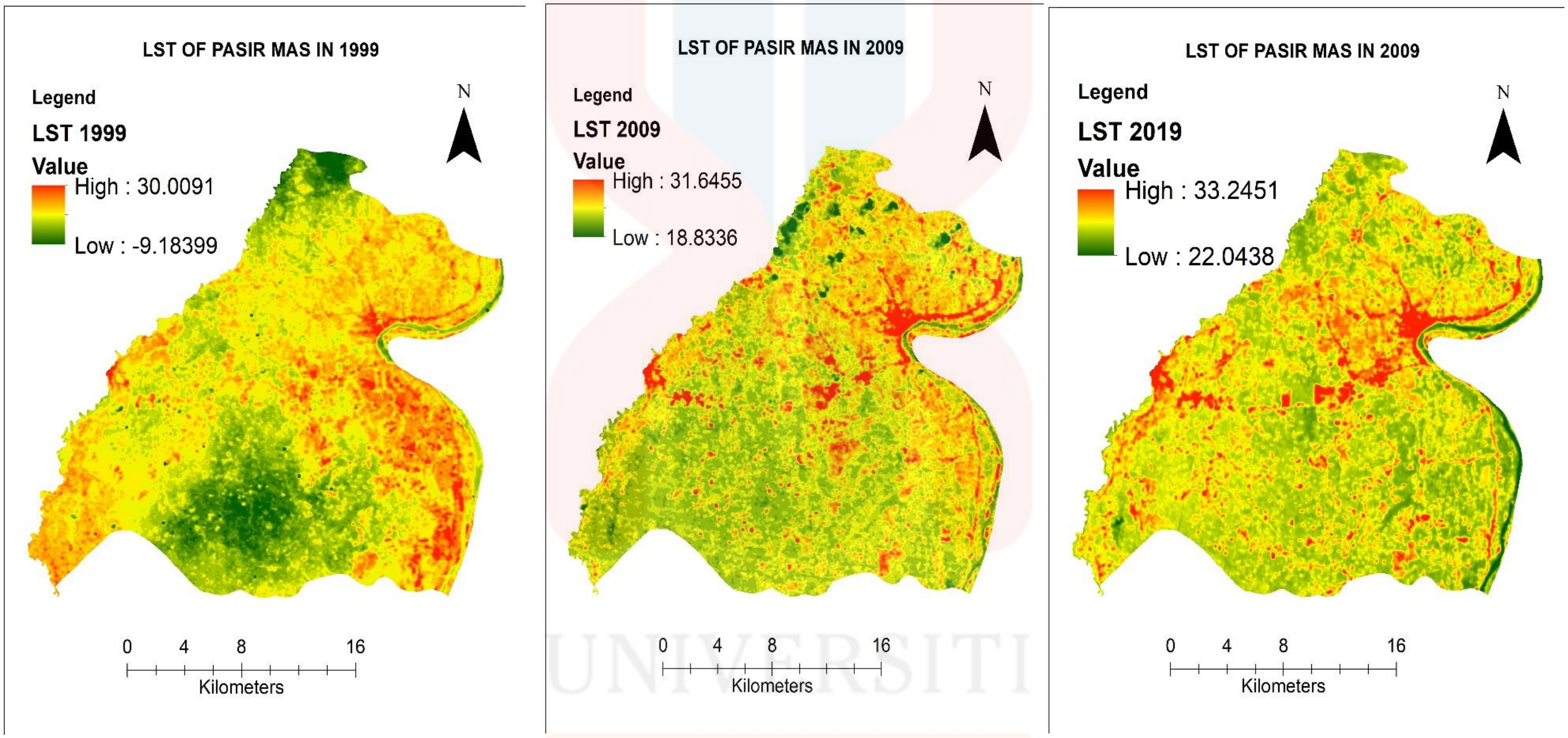


**Figure 4.3** The retrieved LST map based on ArcGIS

### 4.3 Relationship between LST, Built up area, Green area and Bared area

To show quantitative relationship between LST with built up area, green area and bared area the study used Regression Polynomial to calculate correlation matrix (Appendix). The study used the LSTs of green area (GA), built up area (BA) and bared area (BA) using excel for statistical computing. The relationship were analyzed for GA to BU to BU, BA to BA to BU and BA to GA to GA from year 1999 to 2009 and 2019 respectively.1000 points from land use map and LST map were extracted with the coordinate x and coordinate y. From 1000 points, there are 47 points of class transition from GA to BU to BU, 9 points for BA to BA to BU and 7 points for BA to GA to GA.

Figure 4.4 shows scattered plot of value LST transition from GA to BU to BU area from year 1999 to 2009 to 2019 respectively. The scattered plot shows the LSTs of green area in 1999 were in range of 17 °C to 21 °C, LSTs of built up area in 2009 were in range of 23 °C to 27 °C and LSTs of built up area in 2019 were in range of 24 °C to 27 °c. This indicated the LSTs were increases from green area to built-up area to built-up area in the year 1999 to 2009 to 2019 respectively. To make more understanding on this transition, take one point from 47 points of the scattered of GA to BU to BU. From 1999 the class is GA with the LST is 17.93, then in 2009 the class change to BU with the LSTs is 24.97 and in 2019 the class still remain as GA with the LSTs is 26.34 that shows the temperature is increasing from class of GA to BU to BU from 1999 to 2009 to 2019. This result can be supported by the previous research in Penang Island, Malaysia that revealed the urban areas with high density resulted shown the highest LST between different LULC changes. From classified of LULC changes, urban areas with high density gives the highest value of average LST 43.71 °C (Tan, Lim, MatJafri, & Abdullah, 2009). Urban development usually gives rise to a dramatic change of the Earth's surface, as natural vegetation is removed and replaced by non-evaporating and non-transpiring surfaces such as metal, asphalt and concrete. This alteration will inevitably result in the redistribution of incoming solar radiation, and induce the urban-rural contrast in surface radiance and surface temperature resulting increasing of LST from GA to BU to BU (Q Weng, 2001). The lowest value of the LSTs in GA because vegetation can be effective as it delivers several mechanisms of cooling simultaneously and in a complimentary manner. High density of the vegetation reduces heat island through shading and evapotranspiration (Alavipanah, Wegmann, Qureshi, Weng, & Koellner, 2015). Shading is reducing the penetration of sunlight and reduces the energy storage in the soil (Vaz Monteiro, Handle, Morison, & Doick, 2019). At the same time, the evaporation processes in which the plants convert liquid water to water vapor is energy intensive and is reducing therefore the sensible heat (Oke, 2002). In consequence, vegetated areas show lower LST value. Higher temperature of built up areas due to the material used in buildings and pavement construction absorbs more energy causing urban surfaces and the air immediately around them to warm faster than surrounding vegetated areas, creating an UHI. A high correlation between LSTs of GA to BU to BU with the values of $R^2 = 0.9418$ which is a good fit of the line to the data.

Figure 4.5 shows scattered plot of value LST transition from BA to BA to BU area from year 1999 to 2009 to 2019 respectively. The scattered plot shows the LSTs of bare area in 1999 were in range of 16 °C to 19 °C, LSTs of bare area in 2009 were in range of 24 °C to 27 °C and LSTs of built up area in 2019 were in range of 24 °C to 27 °c. This indicated the LSTs were increases from bare area to bare area to built-up area in the year 1999 to 2009 to 2019 respectively. To make more understanding on this transition, take one point from 9 points of the scattered of BA to BA to BU. From 1999 the class is BA with the LST is 17.93, then in 2009 the class remain BA with the LSTs is 25.40 and in 2019 the class change to BU with the LSTs is 26.18 that shows the temperature is increasing from class of BA to BA to BU from 1999 to 2009 to 2019. The increasing in the value of bare area from 1999 to 2009 because bare soil has a high reflectance intensity due to the presence of Fe203, sand and clay which had significant influence on the LST. The results can be supported by the previous research that analyzed the correlations between the classes of land cover and LST. The positive correlation was found between bare areas and temperatures between 23 °C and 33°C (Ogashawara & Bastos, 2012). Then in 2009 to 2019, the value of LST (BA) 25.4 increase to (BU) to 26.18. The increasing of LST from BA to BU because when bare area is transferred to community settlements or buildings their reflectivity is dependent on the materials used to cover the bare land. Building materials such as concrete have a high reflectance (Chotchaiwong & Wijitkosum, 2019). Cities use construction materials such as concrete and asphalt, which do not allow water to penetrate and absorb a large amount of heat, thereby increasing in urban temperatures (Gusso et al., 1985). The increasing in the value of LST from bare area to built-up area supported by the previous research that conducted in Florence and Naples city, Italy that found LSTs increase with the increase in built-up areas and bare land whereas it decreases with the increase in forest, cropland, wetland and water bodies (Guha, Govil, Dey, & Gill, 2018) High correlation between LSTs of BA to BA to BU with the value of $R^2 = 0.9758$ which is a good fit of the line to the data.

Figure 4.6 shows scattered plot of value LST transition from BA to GA to GA from year 1999 to 2009 to 2019 respectively. The scattered plot shows the LSTs of BA in

1999 were in range of 14 °C to 21 °C, LSTs of GA in 2009 were in range of 24 °C to 26°C and LSTs of GA in 2019 were in range of 24 °C to 28 °C. This indicated the LSTs were increases from BA to GA to GA in the year 1999 to 2009 to 2019 respectively. To make more understanding on this transition, one point from 7 points was taken from data of the scattered of BA to GA to GA. From 1999 the class is BA with the LST is 19.28 °C, then in 2009 the class change to GA with the LSTs is 25.4 °C and in 2019 the class still remain as GA with the LSTs is 25.6 that shows the temperature is increasing from class of BA to GA to GA from 1999 to 2009 to 2019. The increasing of temperature from BA to GA is due to the decreasing area of area of vegetation from year 1999, 2009 and 2019 (74.86%, 72.41% and 66.18%) as high vegetation can help to reduce the high radiant temperature of the built up area. This result supported by the previous study that found when the proportion of the green areas increased, LST decreased (Yue, Xu, Tan, & Xu, 2007) which associate reductions in LST with increasing ground covering vegetation (Wong & Yu, 2005). A high correlation between LSTs of BA to GA to GA with the value of $R^2$ = 0.9021 which is a good fit of the line to the data.

Table 4.3 shows the polynomial regression and Correlation Coefficient, $R^2$ based on LSTs transition of land use class of GA to BU to BU, BA to BA to BU and BA to GA to GA from 1999 to 2009 and 2019 respectively. The three categories of transition shows high correlation which is a good fit of the line to the data. This study found a correlation between LST and the proportion of green area, built up area and bare area land use. The LSTs increasing over the period of 1999 to 2009 and 2019. The green areas is the lowest of temperature compared to the bare area and built up area is the highest temperature.

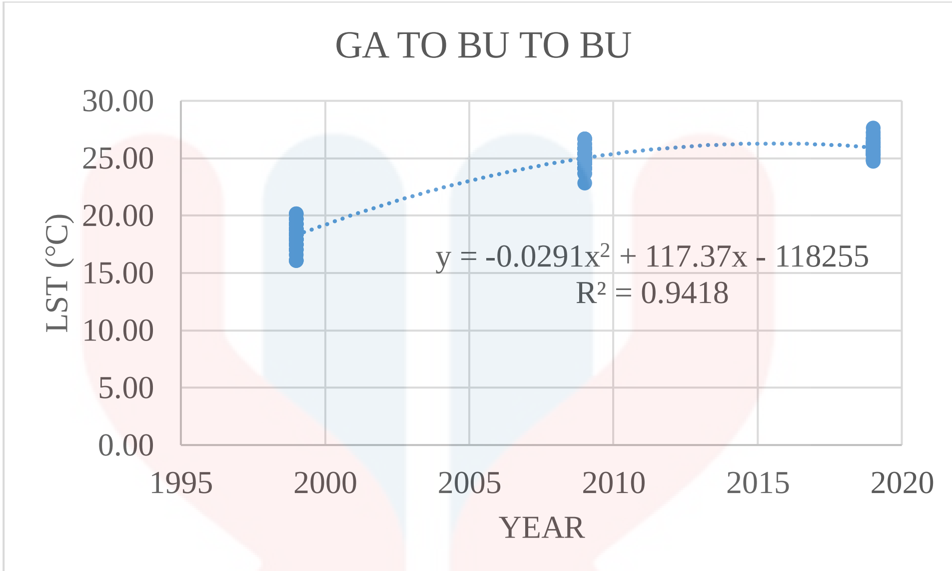


**Figure 4.4** Polynomial regression green area to built-up to built-up from 1999 to 2009 to 2019

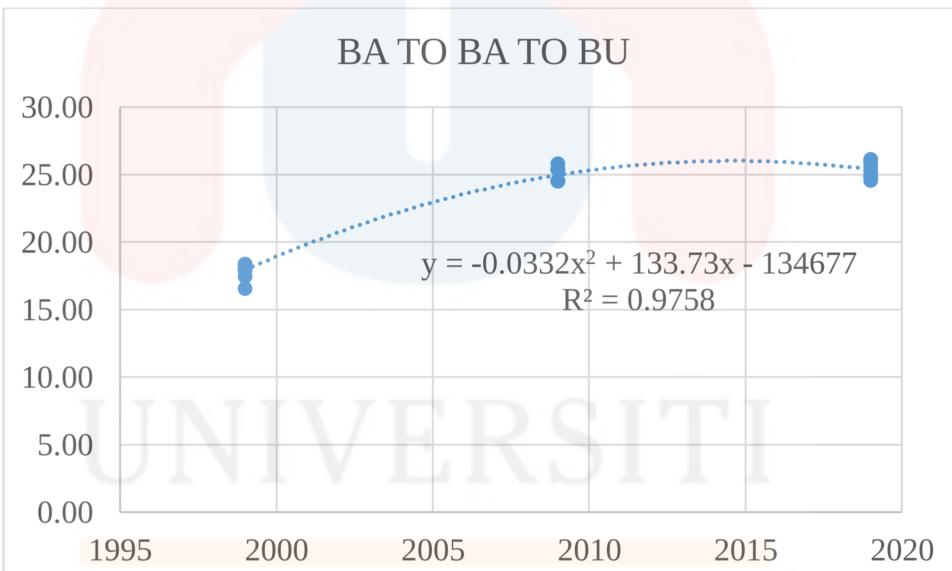


**Figure 4.5** Polynomial regression bare area to bare area to built-up from 1999 to 2009 to 2019

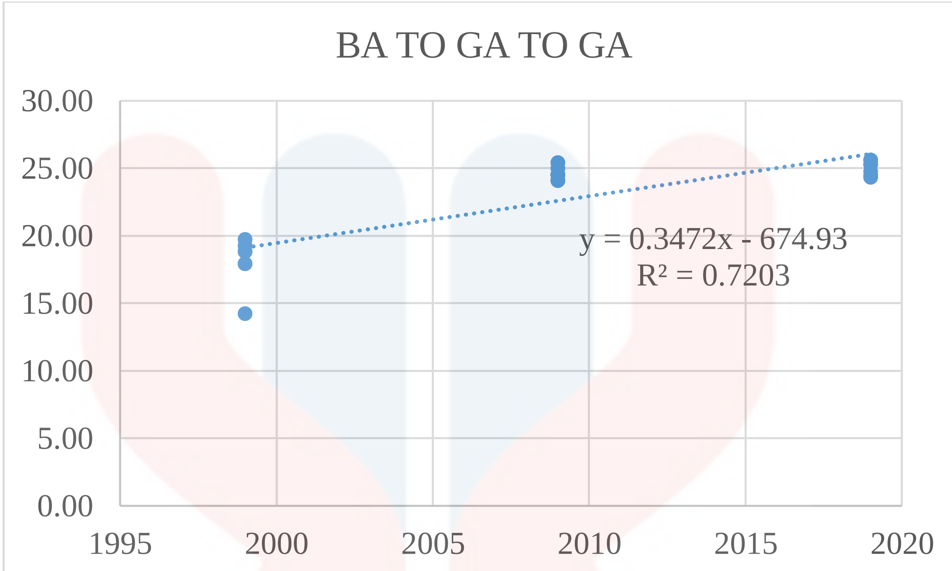


**Figure 4.6** Polynomial regression bare area to green area to green area

**Table 4.3** Polynomial Regression and Correlation Coefficient, $R^2$ based on land use class LST Transition

| Transition | Polynomial Regression | Correlation Coefficient, $R^2$ |
|---|---|---|
| GA TO BU TO BU | $y = -0.0291x^2 + 117.37x - 118255$ | $R^2 = 0.9418$ |
| BA TO BA TO BU | $y = -0.0332x^2 + 133.73x - 134677$ | $R^2 = 0.9758$ |
| BA TO GA TO GA | $y = -0.0302x^2 + 121.73x - 122606$ | $R^2 = 0.9021$ |

## CHAPTER 5

## CONCLUSIONS AND RECOMMENDATIONS

### 5.1 Conclusion

LST maps were produced from satellite image and data analysis to represents surface temperature distribution in each land use class. LST analysis has shown the highest temperature in built up and bare land areas and low in water bodies and green areas in three years period of study. The maximum LST observed in each year 1999, 2009 and 2019 were 30.00 °C, 31.65 °C and 33.25 °C respectively. 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 Pasir Mas. Strong correlations between the LST and both parameters were identified in this study. High correlation between the LST built up area, green area and bare area indicates that this parameter contribute to urban heating. The polynomial regression equation was created with LST of (1. Green area and built up area, 2. Bare area and built up and 3. Bare area and green area) which can be used to monitor and elevate the urban thermal environment based on LULC.

Through zonal statistic, LST variations in Pasir Mas can be explained by the built up area, green area and bare area. Green area was found to have a lower effect of urban heating due to mature vegetation existed in the area. Qualitative and quantitative analysis results show that the land use will influence LST. Therefore, with appropriate land use planning, urban heat island could be mitigated.

This investigation will help the understanding to give the measurable description of information following urban development in Pasir Mas, Kelantan. It can help improve sustainable development design and planning in Malaysia's cities, particularly in Pasir Mas, Kelantan.

## 5.2 Recommendations

This study only investigates the effect of two urban parameters on the LST of Pasir Mas. Future studies should include more urban parameters to explain the variations of LST for better accuracy of estimation.

In the future research, up to date data can be applied through the Department of Meteorological Malaysia for the good reference in getting Land Surface Temperature data for the result validation.

Good management and sustainable planning for the urban development in the future can prevent from the reduction number of green areas and minimize the increasing in the LST over the period so that can reduce the environmental impact such as climate change.

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**APPENDICES**

APPENDIX A

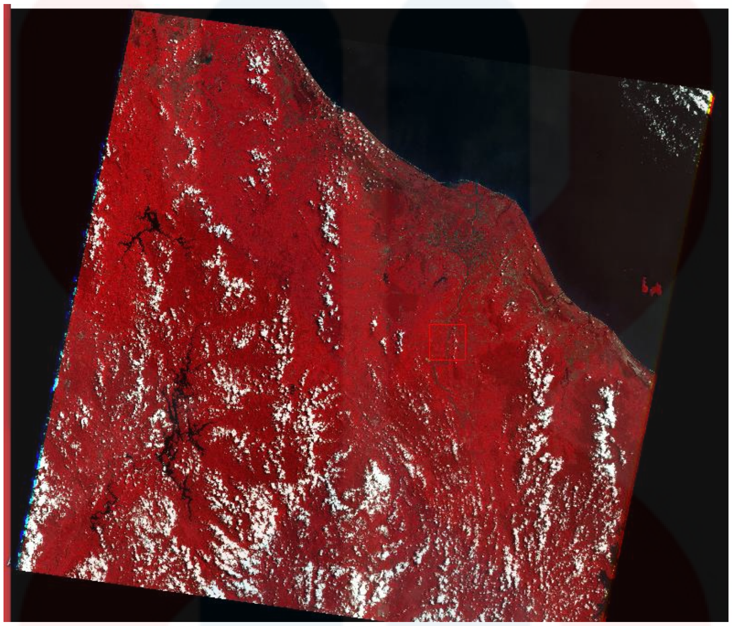

**Figure 1** Raw data from Landsat TM 5 2 May 1999

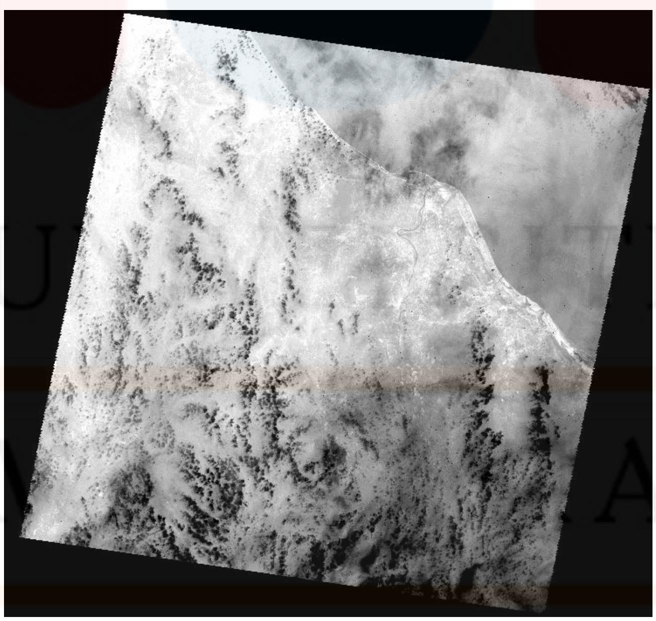

**Figure 2** Raw data of thermal band from satellite image Landsat TM 5 1999

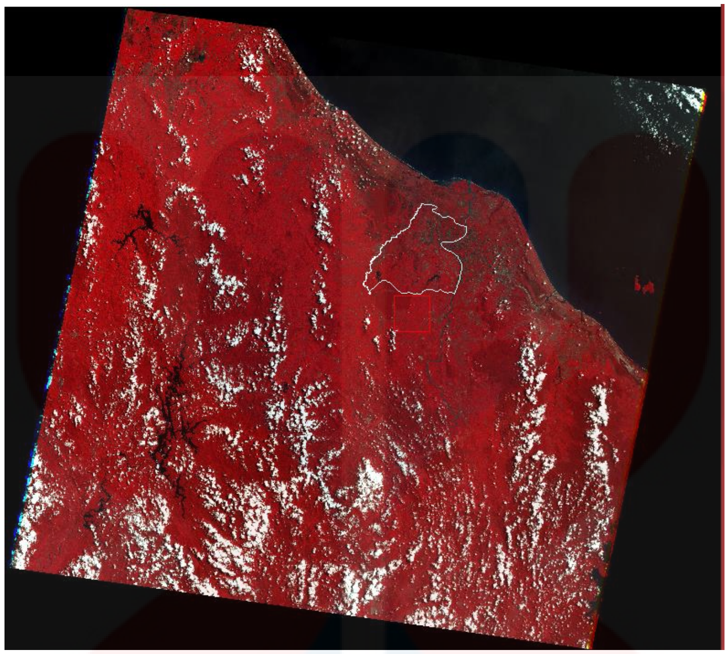

**Figure 3** Addition of boundary

**Figure 4** Subset of ROI

APPENDIX B

Table 1 Accuracy assessment results in 1999

| Types | Reference data | | | | | | |
|---|---|---|---|---|---|---|---|
| Classification | Built up area | Green area | Water sources | Bare land | Classified total | Producer accuracy (%) | User accuracy (%) |
| Built-up area | 297 | 0 | 0 | 5 | 302 | 99.00 | 98.34 |
| Green area | 0 | 300 | 0 | 1 | 301 | 100.00 | 99.67 |
| Water sources | 0 | 0 | 297 | 0 | 297 | 99.00 | 100.00 |
| Bare land | 3 | 0 | 3 | 294 | 300 | 98.00 | 98.00 |
| Reference total | 300 | 300 | 300 | 300 | 1200 | | |
| Overall accuracy (%) = 99.00 | | | | | | | |
| Kappa statistics = 0.9867 | | | | | | | |

Table 2 Accuracy assessment results in 2009

| Types | Reference data | | | | | | |
|---|---|---|---|---|---|---|---|
| Classification | Built up area | Green area | Water sources | Bare land | Classified total | Producer accuracy (%) | User accuracy (%) |
| Built-up area | 298 | 0 | 0 | 0 | 298 | 99.33 | 100.00 |
| Green area | 0 | 301 | 7 | 1 | 309 | 99.34 | 97.41 |
| Water sources | 0 | 0 | 288 | 13 | 301 | 96.00 | 95.68 |
| Bare land | 2 | 2 | 5 | 286 | 295 | 95.33 | 96.95 |
| Reference total | 300 | 303 | 300 | 300 | 1203 | | |
| Overall accuracy (%) = 97.51 | | | | | | | |
| Kappa statistics = 0.9667 | | | | | | | |

Table 3 Accuracy assessment results in 2019

| Types | Reference data | | | | | | |
|---|---|---|---|---|---|---|---|
| Classification | Built up area | Green area | Water sources | Bare land | Classified total | Producer accuracy (%) | User accuracy (%) |
| Built-up area | 296 | 2 | 2 | 2 | 302 | 99.00 | 98.34 |
| Green area | 0 | 296 | 0 | 0 | 296 | 100.00 | 99.67 |
| Water sources | 0 | 2 | 288 | 8 | 298 | 99.00 | 100.00 |
| Bare land | 4 | 0 | 10 | 290 | 304 | 98.00 | 98.00 |
| Reference total | 300 | 300 | 300 | 300 | 1200 | | |
| Overall accuracy (%) = 97.5000 | | | | | | | |
| Kappa statistics = 0.9667 | | | | | | | |

TABLE 4 GA TO BU TO BU

| X | Y | 1999 | 2009 | 2019 |
|---|---|---|---|---|
| 835901.43 | 659375.57 | 17.93 | 24.97 | 26.34 |
| 849568.84 | 658656.86 | 19.28 | 24.55 | 24.79 |
| 849054.40 | 671683.71 | 18.83 | 24.97 | 25.98 |
| 854412.78 | 673936.21 | 19.28 | 24.97 | 25.31 |
| 835788.88 | 655548.12 | 17.02 | 25.40 | 26.66 |
| 838707.15 | 667916.64 | 17.48 | 24.55 | 25.01 |
| 831929.75 | 659205.22 | 17.93 | 24.12 | 26.02 |
| 828389.45 | 659086.96 | 19.73 | 24.12 | 27.24 |
| 842083.16 | 668599.91 | 17.93 | 25.83 | 26.54 |
| 834143.53 | 668262.31 | 17.48 | 24.97 | 25.54 |
| 828560.23 | 662954.39 | 18.38 | 24.97 | 26.38 |
| 832451.08 | 666687.26 | 18.38 | 25.40 | 26.25 |
| 835146.24 | 657898.59 | 16.10 | 24.97 | 25.36 |
| 846335.86 | 653852.82 | 18.83 | 25.83 | 26.36 |
| 852418.78 | 675472.80 | 19.73 | 25.83 | 27.25 |
| 843858.69 | 676002.51 | 17.02 | 25.83 | 25.26 |
| 841183.93 | 673335.44 | 17.93 | 24.55 | 25.21 |
| 849826.00 | 659355.48 | 18.83 | 24.55 | 24.81 |
| 852535.92 | 652552.70 | 20.18 | 24.97 | 25.97 |
| 834247.97 | 667811.07 | 17.93 | 23.68 | 25.40 |
| 850800.22 | 658366.44 | 20.18 | 25.40 | 26.00 |

| | | | | |
|---|---|---|---|---|
| 838068.80 | 672677.81 | 18.38 | 25.83 | 25.49 |
| 832860.59 | 659571.11 | 17.93 | 24.55 | 26.18 |
| 836572.68 | 663973.25 | 18.38 | 24.55 | 25.44 |
| 834958.70 | 665087.01 | 17.93 | 24.12 | 25.54 |
| 845004.23 | 667255.27 | 18.83 | 26.25 | 26.50 |
| 826279.35 | 655416.43 | 18.38 | 23.68 | 25.67 |
| 846669.58 | 669105.18 | 19.28 | 25.83 | 26.78 |
| 835348.21 | 655698.46 | 16.10 | 24.55 | 25.92 |
| 846415.57 | 670251.95 | 18.38 | 26.67 | 26.72 |
| 851259.31 | 675223.26 | 19.28 | 24.12 | 26.10 |
| 842230.11 | 679837.54 | 16.10 | 24.12 | 24.72 |
| 847133.08 | 675099.04 | 19.73 | 25.40 | 26.31 |
| 836100.52 | 654943.34 | 17.02 | 24.12 | 25.68 |
| 845170.87 | 677747.27 | 17.48 | 25.83 | 26.75 |
| 843231.07 | 665594.86 | 18.38 | 22.82 | 26.38 |
| 846398.27 | 672614.25 | 18.83 | 26.25 | 25.96 |
| 841532.11 | 664942.85 | 19.28 | 26.67 | 27.61 |
| 844836.67 | 678241.22 | 16.56 | 24.97 | 24.83 |
| 850700.00 | 661437.45 | 18.83 | 24.97 | 25.26 |
| 846289.82 | 670108.85 | 18.83 | 26.67 | 27.03 |
| 846522.11 | 669606.64 | 18.38 | 25.40 | 26.00 |
| 833527.01 | 657284.79 | 17.48 | 24.97 | 25.69 |
| 839134.86 | 671592.22 | 18.38 | 25.40 | 26.17 |
| 844121.49 | 675860.07 | 17.48 | 24.97 | 25.80 |
| 833217.34 | 665676.27 | 17.93 | 24.12 | 25.47 |
| 852600.14 | 674807.48 | 18.83 | 24.55 | 25.35 |

TABLE 5 BA TO BA TO BU

| X | Y | 1999 | 2009 | 2019 |
|---|---|---|---|---|
| 842945.29 | 670721.58 | 18.38 | 24.55 | 25.32 |
| 843762.91 | 668885.95 | 18.38 | 24.55 | 26.08 |
| 838570.29 | 669592.54 | 17.93 | 25.40 | 26.18 |
| 845332.68 | 674207.92 | 17.48 | 24.55 | 25.06 |
| 844515.94 | 674554.08 | 18.38 | 24.55 | 24.58 |
| 842500.86 | 671110.16 | 18.38 | 24.55 | 25.60 |
| 846074.93 | 675332.00 | 17.93 | 25.83 | 24.83 |
| 846958.77 | 679373.16 | 16.56 | 25.40 | 24.85 |
| 845295.21 | 668890.18 | 17.93 | 25.40 | 25.90 |

TABLE 6 BA TO GA TO GA

| X | Y | 1999 | 2009 | 2019 |
|---|---|---|---|---|
| 826617.18 | 659711.82 | 19.73 | 24.12 | 25.63 |
| 837125.82 | 668998.10 | 18.83 | 24.97 | 25.27 |
| 849491.96 | 673558.67 | 18.83 | 24.12 | 24.33 |
| 841982.40 | 662692.14 | 17.93 | 24.55 | 24.48 |
| 844892.35 | 673555.10 | 19.28 | 25.40 | 25.60 |
| 842350.17 | 653493.83 | 17.93 | 24.55 | 25.31 |
| 843947.15 | 679992.04 | 14.25 | 24.55 | 24.78 |