IDENTIFYING AREAS SUSCEPTIBLE TO URBAN HEAT ISLANDS: A CASE STUDY IN KOTA BHARU, KELANTAN

by

NURSAFILAH BINTI ABDUL MANAP

A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Natural Resource Science) with Honours

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2024

DECLARATION

I declare that this thesis entitled "Identifying Areas Susceptible to Urban Heat Islands: A Case Study in Kota Bharu, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : **NURSAFILAH BINTI ABDUL MANAP**

Date : **28 / 07 / 2024**

ACKNOWLEDGMENT

In the name of the Allah, whose boundless grace ignited the flame of inspiration within me, I offer my deepest gratitude. To God, the orchestrator of all things, thank you for guiding my pen and illuminating my path throughout this journey of writing this thesis.

To my beloved parents, whose unwavering prayers and endless reservoirs of moral support have been my steadfast companions, I owe an immeasurable debt of gratitude. Your encouragement has been the cornerstone of my strength, and for that, I am eternally thankful.

To my esteemed supervisor, Ts. Dr. Shaparas Binti Daliman, your dedication and unwavering commitment to nurturing my thesis have been nothing short of exemplary. Your guidance has been instrumental in shaping my thoughts and refining my work, and for that, I am profoundly grateful.

I extend my heartfelt appreciation to my dear friends whose unwavering support and encouragement have buoyed my spirits during moments of uncertainty. Your camaraderie and moral support have been a source of inspiration and strength, and for that, I am sincerely grateful.

In closing, I extend my heartfelt appreciation to all those who have contributed to this endeavour, whether through words of encouragement, guidance, or assistance. Your collective efforts have enriched this journey beyond measure, and for that, I am profoundly grateful. May Allah shower the above cited personalities with success and honour in their life.

Identifying Areas Susceptible to Urban Heat Islands: A Case Study in Kota Bharu, Kelantan

ABSTRACT

Urban Heat Islands (UHIs) represent a significant environmental challenge in urbanized regions, leading to elevated temperatures that impact energy consumption, health, and overall urban livability. This study focuses on identifying and analyzing areas susceptible to UHIs in Kota Bharu, Kelantan, using a combination of remote sensing and Geographic Information System (GIS) techniques. The primary data sources include Landsat-8 imagery and historical meteorological data, which are processed to calculate land surface temperature (LST), normalized difference vegetation index (NDVI), and other relevant indices. The Getis-Ord Gi* statistic is employed to identify statistically significant hot and cold spots, revealing spatial clusters of extreme temperatures. The analysis indicates that red points on the map represent extremely significant hot spots with z-scores greater than 2.58 and p-values less than 0.01, while orange points denote significant hot spots with z-scores between 1.95 and 2.58 and p-values less than 0.05. Yellow points highlight areas with somewhat elevated temperatures, categorized as hot spots with z-scores between 1.65 and 1.95 and p-values less than 0.10. In contrast, blue and dark blue points signify significant and extremely significant cold spots, respectively, indicating areas with notably lower temperatures. The study produces a detailed map illustrating the intensity and distribution of UHIs in Kota Bharu, providing essential insights for urban planners and policymakers. The study emphasize the significance of green spaces and cooling strategies in reducing UHI effects and enhancing urban resilience, highlighting the need for sustainable urban planning to tackle climate change challenges.

Mengenalpasti Kawasan Terdedah Pulau Haba Bandar: Kajian Kes di Kota Bharu, Kelantan

ABSTRAK

Pulau Haba Bandar (UHI) mewakili cabaran alam sekitar yang ketara di kawasan perbandaran, yang membawa kepada suhu tinggi yang memberi kesan kepada penggunaan tenaga, kesihatan dan keseluruhan kebolehdiaman bandar. Kajian ini memberi tumpuan kepada mengenal pasti dan menganalisis kawasan yang terdedah kepada UHI di Kota Bharu, Kelantan, menggunakan gabungan teknik penderiaan jauh dan Sistem Maklumat Geografi (GIS). Sumber data utama termasuk imej Landsat-8 dan data meteorologi sejarah, yang diproses untuk mengira suhu permukaan tanah (LST), indeks tumbuhan perbezaan normal (NDVI) dan indeks lain yang berkaitan. Statistik Getis-Ord Gi* digunakan untuk mengenal pasti bintik panas dan sejuk yang ketara secara statistik, mendedahkan kelompok spatial suhu melampau. Analisis menunjukkan bahawa titik merah pada peta mewakili titik panas yang sangat ketara dengan skor z lebih besar daripada 2.58 dan nilai p kurang daripada 0.01, manakala titik oren menandakan titik panas yang ketara dengan skor z antara 1.92 dan 2.58 dan nilai p kurang daripada 0.05. Titik kuning menyerlahkan kawasan dengan suhu yang agak tinggi, dikategorikan sebagai titik panas dengan skor z antara 1.65 dan 1.95 dan nilai p kurang daripada 0.10. Sebaliknya, titik biru dan biru tua masing-masing menandakan bintik sejuk yang ketara dan sangat ketara, menunjukkan kawasan yang mempunyai suhu yang lebih rendah. Kajian ini menghasilkan peta terperinci yang menggambarkan keamatan dan pengedaran UHI di Kota Bharu, memberikan pandangan penting untuk perancang bandar dan penggubal dasar. Kajian ini menekankan kepentingan ruang hijau dan strategi penyejukan dalam mengurangkan kesan UHI dan meningkatkan daya tahan bandar, menonjolkan keperluan untuk perancangan bandar yang mampan untuk menangani cabaran perubahan iklim.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BT	Brightness Temperature
EC	Error Correction
Esri	Environmental System Research Institute
GIS	Geographic Information System
LST	Land Surface Temperature
NDVI	Normalized Difference Vegetation Index
NIR	Near-Infrared Reflectance
OLI	Operational Land Imager
RED	Red Reflectance
TIR	Terminal Infrared Sensor
TOA	Top Of Atmosphere
UHI	Urban Heat Island
USGS	United State Geological Survey

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Urban Heat Islands (UHIs) are localized areas within cities and urban areas that experience significantly higher temperatures than the surrounding rural areas. The temperature difference is usually larger at night than during the day (Phelan et al.,2015). The definition of urban refers to areas characterized by high population density and infrastructure development, such as cities and towns meanwhile, heat indicates the presence of high temperature or heat energy. The definition of Island in this context, metaphorically describes the local area where these high temperatures occur in the urban landscape (Weng et al., 2001). The significant impact of urban heat islands (UHI) on urban microclimates is widely known as UHI results from a combination of human activities, altered land surfaces and concentrations of heat-absorbing materials in urban environments. These heat islands have become a growing concern due to their various adverse effects on the environment and the well-being of urban residents. In addition, the temperature difference between urban areas and surrounding rural areas can reach five degrees Celsius (Voogt and Oke, 2003).

Kelantan is one of the fourteen states in Malaysia, located in the north-eastern part of Peninsular Malaysia. It is known for its unique cultural heritage, natural beauty, and a rapidly urbanizing landscape. While Kelantan may not be as densely urbanized as major metropolitan areas, it is still subject to the broader impacts of urbanization, including the potential formation of UHIs.

During a case study conducted in Kota Bharu, Kelantan a mix of approaches was required to analyse the differences in temperature as well as the patterns of land use to locate locations that were vulnerable to the effects of urban heat islands (UHI). The following is a concise and accurate description of the procedures will be used including remote sensing and satellite imagery. This remote sensing data collects information on the surface temperature, which makes it possible to identify places with higher temperatures, which indicate the presence of UHI.

1.2 Problem Statement

The development of urban heat islands (UHIs) is determined by a multifaceted interaction of several elements, encompassing urbanization, alterations in land use, and specific climatic conditions within a given locality. Urban Heat Islands (UHIs) can have adverse impacts on urban environments, including augmented energy use, health concerns associated with heat, and degraded livability on a broader scale. Studies indicate that UHIs significantly increase energy consumption for cooling purposes (Taha et al., 1997) exacerbate heat-related health issues (Harlan et al., 2011), and reduce overall urban comfort and sustainability (Emmanuel et al., 2012). Understanding and mitigating the impacts of UHIs is of utmost importance, particularly in areas undergoing rapid urbanization (Voogt et al., 2003).

In the specific case of Kota Bharu, Kelantan, a state in Malaysia experiencing significant urban development, there is an urgent need to identify and characterize areas vulnerable to UHIs. The unique urban and environmental characteristics of Kota Bharu, combined with its tropical climate, present distinct challenges and opportunities for managing UHIs. Despite the potential risks associated with UHI, there is a notable gap in research focused specifically on Kota Bharu, Kelantan, highlighting the importance of conducting case studies to address this critical issue (Santamouris et al., 2015).

By conducting a case study in Kota Bharu, Kelantan, this research aims to fill the gap in knowledge and provide practical insights into addressing UHIs in the region. The findings from this study will be invaluable for urban planners, policymakers, and local communities in Kelantan to develop strategies for a more sustainable and heat-resilient urban environment. This research will support the development of effective measures to mitigate the adverse effects of UHIs and enhance urban livability (Harlan et al., 2011).

1.3 Expected Outcome

The expected results will produce various findings and contributions that will advance the understanding of urban heat islands in the Kota Bharu, Kelantan region. These results will be critical to determine exactly where the effects of UHI are most pronounced and where interventions are most urgently needed. In addition, this research will produce a map of UHI intensity that illustrates temperature variations throughout Kota Bharu, Kelantan. This map will provide a spatial understanding of the severity of the Urban Heat Islands (UHIs) in the region.

In summary, the expected results of this Kota Bharu, Kelantan case study aim to provide a comprehensive understanding of Urban Heat Islands (UHIs) in the region, offer practical solutions for mitigation and adaptation, and contribute to local and global efforts to create a more sustainable and heat-resistant urban environment.

1.4 Objective

i. To generate a map of intensity of Urban Heat Islands (UHIs) in Kota Bharu, Kelantan.

ii. To analyse the spatial distribution and differences of Urban Heat Islands (UHIs) of different area in Kota Bharu, Kelantan.

1.5 Scope of Study

The location of the study is in Kota Bharu, Kelantan. This research will involve an in-depth analysis of various environmental, geographic and anthropogenic variables that influence the spatial distribution of urban heat islands (UHI). This study aims to identify specific areas in Kota Bharu, Kelantan that are most vulnerable to urban heat island (UHI), considering factors such as land use, urbanization patterns, vegetation cover, and local climate conditions. In addition, this study also aims to analyse the spatial distribution and differences of Urban Heat Island (UHI) in Kota Bharu, Kelantan.

1.6 Significant of Study

The study of urban heat islands (UHIs) is crucial for society and the field of urban planning, as it directly impacts the creation of a livable environment. Urban heat islands are a significant issue in Kota Bharu, Kelantan, and numerous other cities globally. They can substantially affect public health, energy consumption, and overall quality of life. By focusing on Kota Bharu, Kelantan as a case study, this research provides an in-depth analysis of the unique factors contributing to UHI in the area. The findings from the study will assist local government and policymakers in Kelantan in developing targeted strategies to mitigate UHI, ultimately improving urban resilience and sustainability (Harlan et al., 2011). Additionally, the insights gained are applicable to other cities facing similar challenges, offering a broader relevance. This study not only contributes to local planning efforts but also enhances global understanding of UHI, promoting informed actions to combat climate change and fostering more resilient urban environments (Santamouris et al., 2015)

CHAPTER 2

LITERATURE REVIEW

2.1 Urban Heat Island

The term "urban heat island" refers to the phenomenon of high air temperature in urban areas compared to rural counterparts (Berges et al., 2016). The country's development is advancing swiftly daily, paralleled by Malaysia's successful establishment of a prominent international reputation. The construction of homes, industrial regions, and commercial center buildings has experienced significant growth in response to the increasing population and its density throughout the years. This scenario encompasses a substantial land area, specifically a hectare of land, and encompasses several activities such as deforestation, vegetation management, hill cleaning, and sea reclamation, among others. The current circumstances have given rise to the occurrence of the urban heat island phenomenon.

The Urban Heat Island (UHI) phenomenon occurs when cities replace natural ground cover with surfaces such as pavement and buildings that have a high capacity to absorb heat. Additionally, it is a form of atmospheric pollution that contributes to the phenomenon of global warming. In comparison to the adjacent rural and suburban regions. UHI elevating the temperature of urban regions, namely city centres (Oke et al., 2012). Urban Heat Island (UHI) is a significant anthropogenic alteration that causes greater temperatures in urban areas compared to non-urban areas.

The Earth's ecosystem is discussed in a study by (Zhou et al. 2014). Urban heat island (UHI) studies primarily depend on air temperature measurements and the extraction of land surface temperature (LST) from thermal infrared remote sensing data, which is utilised in analysing surface UHI patterns. The distinction in air temperature (AT) within the city and AT in the surrounding areas is well known as the Urban Heat Island (UHI) effect.

2.1.1 Cause of Urban Heat Island

According to Santamouris et al., (2007) the following are the causes of UHI it happened because of low amount of evapotranspiration because of less vegetation, absorption of solar radiation due to low albedo, hindrance to the flow of air because of higher rugosity and high amount of anthropogenic heat release. However, there are several factors which contribute to the formation of Urban Heat Islan. Urban centres are warmer than rural areas due to the absorption of solar radiation caused by fast urbanisation, resulting in the conversion of solar radiation into heat. Furthermore, the expansion of the city leads to the depletion of vacant area on its surface, hence causing a reduction in radiation exposure due to restricted availability. Skyscapes can mitigate evaporation from bodies of water, soil, and vegetation, which would otherwise occur due to the presence of urban structures (Berry et al., 2018).

2.1.2 Impact of Urban Heat Island

The urban Heat Island Effect (UHI) is a phenomenon that has significant implications for metropolitan areas, the environment, and public health. As urban areas undergo expansion and progress, they frequently encounter elevated temperatures in comparison to the adjacent rural regions. The rise in temperature can be ascribed to the substitution of natural landscapes with heat-absorbing materials like asphalt and concrete, diminished vegetation coverage, and increased energy use.

The multidimensional nature of urban heat island (UHI) effects is evident. The presence of air conditioning and cooling systems in buildings contributes to elevated energy consumption, resulting in a corresponding rise in greenhouse gas emissions (Santamouris, 2015).

Furthermore, the urban heat island (UHI) phenomenon amplifies the adverse effects of heat on human health, leading to an increased prevalence of heat-related ailments, particularly among susceptible demographic groups (Reid et al., 2009). Another noteworthy outcome is the degradation of air quality, whereby elevated temperatures promote the generation of ground-level ozone and other pollutants, hence exacerbating the impact on human well-being (Arnfield et al., 2003). Moreover, the phenomenon of Urban Heat Island (UHI) has the potential to exert adverse impacts on ecosystems and indigenous fauna, leading to alterations in animal behavioral patterns and the loss of natural habitats (Imhoff et al., 2010). The influence of urban heat island (UHI) phenomenon also has implications for water management, as alterations in the hydrological cycle contribute to instances of urban flooding during periods of intense rainfall and water scarcity during dry seasons (Sharma et al., 2019).

The urban heat island phenomenon as it is commonly known refers to the increase in temperature experienced in urban areas compared to the surrounding rural areas. This phenomenon is mainly caused by the modification of the land surface due to urbanization, which leads to changes in the energy balance and this microclimate. Based on a growing body of scientific evidence, it is evident that climate variability and change pose significant risks to individuals living in metropolitan areas globally, regardless of their economic development status. It also has been identified that this health issue poses a great risk to individual well-being. In addition, (Wong et al.,

2018) have stated that human health is greatly affected by climatic and meteorological conditions. According to a study conducted by (Blok et al., 2012), it was observed that the increase in air pollution has a negative effect on the cooling effect at night. Meanwhile, the adverse effects of urban heat islands on human well-being can be attributed to increased daytime surface temperatures.

2.2 Remote Sensing

Remote sensing has become an important tool in the study and analysis of urban heat island (UHI) effects. This literature review summarizes key studies that highlight the use of remote sensing techniques to understand, measure, and mitigate UHI. According to Weng (2001), this seminal work explores the use of remote sensing and GIS to study UHI. Weng emphasized the importance of remote sensing data, such as Landsat imagery, to detect surface temperature variations and urban heat patterns. This study outlines how GIS integration improves spatial analysis and visualization of UHI phenomena.

In addition, Zhang et al. (2011) conducted a study using Landsat Thematic Mapper (TM) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) data to investigate UHI in Hong Kong. These findings show the relationship between different land cover types and surface temperature, illustrating how remote sensing can effectively map and monitor the spatial distribution of UHI. This past study conducted by Wang et al. (2016) measured UHI intensity in New York City by utilizing Landsat 8 Thermal Infrared Sensor (TIRS) data. The authors analyzed temporal and spatial variations in surface temperature, providing insight into the impact of urbanization on local climate. Their research highlights the utility of high-resolution thermal data in UHI studies. According to Kovács & Unger (2014), using remote sensing data combined with field measurements, their study identified key areas affected by UHI and evaluated various mitigation strategies, such as increasing urban green space. This research shows the practical application of remote sensing in urban planning.

This paper examines the impact of UHI in Addis Ababa using remote sensing techniques to analyze land use/land cover changes over time. The authors used Landsat imagery to detect surface temperature variations and assess the impact of urbanization on UHI intensity (Chanie et al., 2014). This comprehensive research paper discusses various remote sensing techniques and their applications in studying UHI. Mirzaei & Haghighat, (2010) explore different satellite sensors and data processing methods, providing an overview of the strengths and limitations of remote sensing in UHI research. These studies collectively underscore the importance of remote sensing in urban heat island analysis, providing valuable insights into spatial and temporal temperature variations, impacts of urbanization, and effective mitigation strategies.

CHAPTER 3

MATERIAL AND METHOD

3.1 Study Area

The study area is in Kota Bharu, Kelantan. Kelantan is one of the 13 states in Malaysia that is rich in local natural resources and has approximately 2,000,000 inhabitants based on the Quarterly Statistics (2019) with an area of approximately 15,040 km^2 and has latitude and longitude coordinates of 6.127463, 10287.24. northeast of Peninsular Malaysia, facing the South China Sea, and bordering Narathiwat province, Thailand.

While Kota Bharu is the main city for the state of Kelantan. The geographical coordinates are: 6.139872 latitude, 102.242203 longitude with an area of 115 km^2. Kota Bharu, situated in the northern region of Malaysia's Kelantan province, is populous city with approximately 500,000 residents. The city is known for its large Muslim community and the great influence of Islamic religion and culture on the lifestyle of the local population. The city boasts a plethora of tourist attractions, such as exquisite mosques, grand palaces, enchanting gardens, and historic architecture.

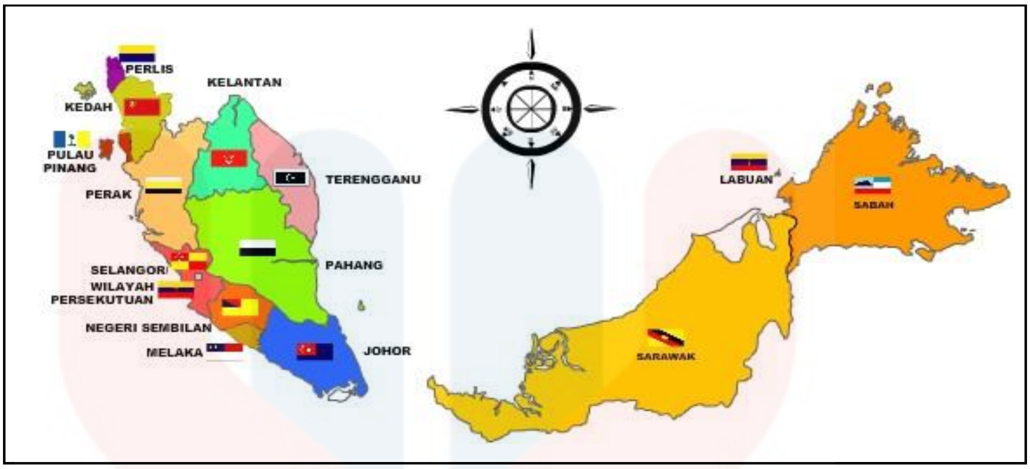

Figure 3.1: Map of Malaysia

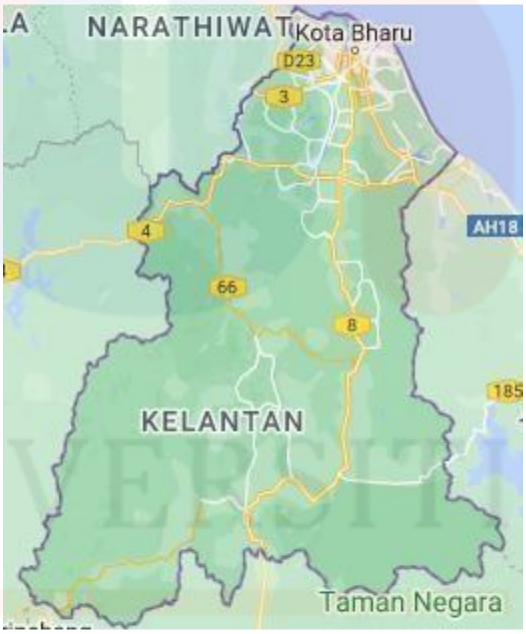

Figure 3.2: Map of Kelantan

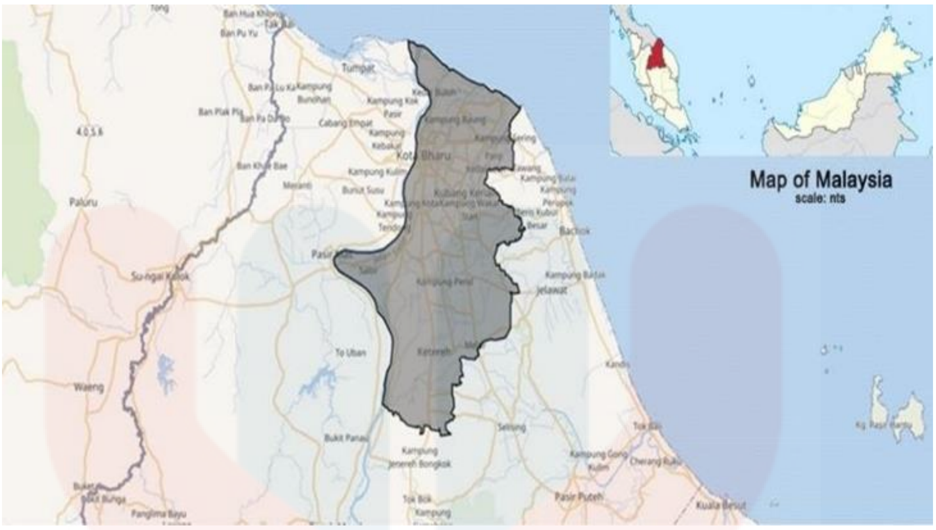

Figure 3.3: Map of Kota Bharu, Kelantan

3.2 Material

3.2.1 United States Geological Survey (USGS)

The data will be acquired via the United States Geological Survey (USGS) Earth Explorer platform. The USGS is the leading public institution dedicated to cartography and earth sciences in the United States. It gathers, monitors, analyses, and provides scientific information on natural resources and related complexities. According to USGS data, a raster is distinct from the geoprocessing tool. While the geoprocessing tool generates a new raster, the raster function directly processes image pixels and raster datasets. Additionally, the proposed formula offers an easily comprehensible user interface with straightforward tools for efficient visualization and examination of images. These tools signatures and examine extensive datasets, facilitate visual comparisons, generate robust 3D visualizations, construct scatter plots, analyse pixel signatures and perform various other tasks efficiently.

3.2.2 Landsat 8

Using the Landsat-8 image of Kota Bharu, Kelantan in 2016 which will serve as the main data source for land cover and temperature analysis. The Landsat-8 is Operational Land Imager (OLI) captures data in multiple spectral bands, including the thermal infrared (TIR) band, which is important for calculating land surface temperatures. The availability of multiple bands allows for more sophisticated land cover classification (Roy et al., 2014). Moreover, Landsat-8 provides a spatial resolution of 30 meters, which provides a balance between capturing fine details in urban areas and covering large study areas. This allows this resolution to be suitable for distinguishing different types of land cover in urban environments. Landsat-8 has a short return period of about 16 days, which means that data can be collected often (Irons et al., 2012). This is very important for detecting changes over time in land cover and land surface temperature, especially in cities that are always changing. Landsat-8, having a long and consistent data archive, allows researchers to conduct historical analysis and monitor changes over long periods.

3.2.3 Meteorological Data

Collecting historical meteorological data of Kota Bahru, Kelantan in 2016 from Local Weather Stations or climate databases can provide this data. Meteorological data is crucial in identifying Urban Heat Islands (UHIs) because it provides information about the atmospheric conditions that influence the urban thermal environment. Various meteorological parameters, such as air temperature, humidity, wind speed, and solar radiation, play a significant role in the development and intensity of UHIs.

The temperature of the air is a major factor in determining the temperature it is in cities. The surfaces of cities receive and retain to solar radiation in different ways than natural landscapes, which makes the air warmer. Monitoring air temperature is fundamental to understanding UHI dynamics. According Arnfield et al. (2003), humidity is the amount of water vapor in the air. If there is a lot of water vapor in the air, the humidity will be high. The higher humidity, the less the evaporation rate, which will make the environment low temperature, especially in areas that have not yet been explored. In cities, there is often less greenery and more concrete or asphalt street paving, which will change humidity levels. The effect of UHI is higher when humidity is low. While wind speed also plays a role in the dispersion of heat and pollutants in urban areas. Low wind speeds can result in the stagnation of warm air, contributing to higher temperatures within the city. Understanding wind patterns is crucial for assessing UHI impacts (Sailor et al., 2011).

Additionally, solar radiation influences surface heating and contributes to the warming of urban areas. The built environment, with its surfaces and materials, absorbs and re-emits solar energy differently than natural landscapes. Monitoring solar radiation helps in quantifying the energy balance in urban heat studies. Furthermore, precipitation affects surface moisture and can have a cooling effect. Urban areas may experience altered precipitation patterns due to the presence of impervious surfaces, which influence the development of UHI (Zhou et al., 2009).

3.2.4 GIS Software

ArcGIS is a powerful Geographic Information System (GIS) program created by the Environmental Systems Research Institute (Esri). It is widely used for mapping, location analysis, and visualization (Longley et al., 2015). It gives people a complete set of tools to combine, analyses and understand different types of location data. ArcGIS can work with both raster and vector data, which means it can be used for a wide variety of jobs, from figuring out land cover types to finding Urban Heat Islands. With an intuitive interface, extensive geoprocessing capabilities, and robust spatial analytics, ArcGIS is favored by professionals in a variety of fields, including environmental science, urban planning, and disaster management, facilitating informed decision-making through spatial insights.

3.2.5 Google Earth Pro

Google Earth Pro provides high-resolution satellite imagery and 3D visualization, allowing users to validate remote sensing data with ground truth data through visual comparison, coordinate matching, and measurement verification. It supports importing custom data layers, aiding in the accurate analysis and documentation of geographic features and changes.

3.3 Method

3.3.1 Data Collection

The first data required is Landsat-8 in the Kota Bharu, Kelantan area in 2016 and historical meteorological data for the entire temperature and weather conditions in 2016. Landsat 8 data acquisition (Operational Land Imager/Thermal Infrared Sensor Collection 2 Level 2, OLI/TIRS C2 L2) is important for analyzing urban heat island (UHI). Landsat 8 provides high-quality image data with sufficient temporal and spatial resolution to detect variations in surface temperature. This data allows researchers to map heat distribution in urban areas, understand the impact of urbanization, and identify the regions most affected by UHI.

3.3.2 Data Preprocessing

Data preprocessing is a critical step in Urban Heat Island (UHI) analysis, which involves multiple tasks to improve data quality and usability. The following are the main steps in the preprocessing of UHI data. After obtaining the data by obtaining high-resolution satellite imagery that is Landsat-8 and meteorological data for the study area (Jensen, 2007). Next, make atmospheric correction. By using atmospheric correction techniques on satellite imagery to remove atmospheric effects and improve the accuracy of land surface temperature (LST) calculations. The next process is Spatial Alignment. Align different data sets spatially to ensure accurate stacking and comparison. This is important when combining layers such as land cover and temperature data.

3.3.3 Temperature Analysis

Temperature data was analyzed to identify temperature variations across the study area and calculated temperature differences between urban and non-urban areas. Analyzing temperature data using ArcGIS involves several steps to understand temperature variation across the study area and calculate temperature differences, which are important for identifying Urban Heat Islands (UHIs). The first step is to import the data, temperature data is imported into ArcGIS. This includes ground-based temperature measurements, satellite-derived land surface temperature (LST) or other temperature-related data sets. Next is spatial analysis. By using spatial analysis tools in ArcGIS to visualize and analyze temperature variations spatially. The next process is Hotspot Analysis (Getis-Ord G_i^*) Uses hotspot analysis to identify statistically significant temperature hot spots or cold spots. This helps determine areas with high or low temperature clustering (Getis & Ord, 1992).

The last step in this process is the UHI Index Calculation. Urban Heat Island index (UHI) calculation is by subtracting the temperature of non-urban areas from urban areas. This measure measures the temperature difference between these two types of land cover (Oke, 1982). Analyzing the temperature variation and calculating the temperature difference between urban and non-urban areas is the basis for UHI identification. UHI is characterized by high temperatures in urban areas compared to non-urban environments. Therefore, this analysis helps in measuring and mapping these temperature differences, providing an overview of the intensity and spatial distribution of UHI (Arnfield, 2003).

3.3.4 Spatial Analysis

Spatial analysis using ArcGIS for the Urban Heat Island (UHI) study involves overlaying land cover and temperature data, using statistical and spatial techniques such as the Normalized Difference Vegetation Index (NDVI) to assess the effects of vegetation. The first step in this process is entering the data. Import land cover and temperature datasets into ArcGIS. Make sure the data set is formatted correctly and aligned according to space. The next step is Stack Analysis. using the overlay analysis tool in ArcGIS to combine land cover and temperature data. This involves cross spacing or overlaying different layers to assess the relationship between land cover classes and temperature and using zonal statistics tools to calculate sample statistical measures such as mean, standard deviation, temperature in each land cover zone helping to calculate temperature variation in different land cover types.

Formula to calculate urban heat heat island using the following formula:

TOA (Top of Atmosphere) Radiance: Denoted as L_{TOA}, it represents the radiant energy measured by sensors at the top of the Earth's atmosphere. It's influenced by both the reflectance of the Earth's surface and the atmospheric conditions.

$$L_{TOA} = \frac{L_{sensor}}{\cos(\theta)} \tag{3.1}$$

L_{TOA} is the radiance at the top of the atmosphere, L_{sensor} is the radiance measured by the sensor and $\cos(\theta)$is the solar zenith angle.

BT (Brightness Temperature): Brightness temperature is the temperature of a surface that emits thermal radiation in a specific wavelength range. It's usually expressed in Kelvin (K). In remote sensing, BT often refers to the temperature of the Earth's surface as measured by satellite sensors, particularly in the thermal infrared spectrum.

$$T_B = \frac{C_2}{\lambda \ln\left(\frac{C_1}{L_\lambda \lambda^5} + 1\right)} \tag{3.2}$$

c_1 is 8.7418×10^{-16}Wm^2(watts per square meter), c_2 is 1.4388×10^{-2}Mk (milliKelvins). While, λ is the wavelength in meters and ln is the spectral radiance.

NDVI (Normalized Differences Vegetation Index): NDVI quantifies vegetation greenness or health based on the difference in reflectance between near infrared (NIR) red wavelengths.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (3.3)$$

NIR is the reflectance in the near-infrared band and RED is the reflectance in the red band.

PVI (Perpendicular Vegetation Index): PVI is another vegetation index that characterizes vegetation density or biomass. It's calculated as the difference between the reflectance in the near-infrared (NIR) and red bands.

$$PVI = \frac{(NIR - a)\ (RED - b)}{\sqrt{1 + a^2}} \quad (3.4)$$

NIR is the reflectance in the near-infrared band, RED is the reflectance in the red band. While, α is the slope of the soil line and b is the intercept of the soil line.

LST (Land Surface Temperature): LST is the temperature of the Earth's surface as measured by satellite sensors. It provides valuable information about surface energy fluxes and environmental conditions. Various methods exist to estimate LST, including thermal infrared remote sensing techniques.

$$LST = \frac{T_B}{1 + \left(\frac{\lambda \times T_B}{hc}\right) Ln(\epsilon)} \quad (3.5)$$

T_B is the brightness temperature, λ is the wavelength in meters is the wavelength of emitted radiance. While, h is Planck's constant, c is the speed of light and ϵ is the emissivity of the surface.

Each of these parameters serves different purposes in remote sensing and environmental monitoring, providing insights into various aspects of the Earth's surface and atmosphere.

3.3.5 Mapping

At this stage after carrying out all the processes above, the next step is to draw a UHI vulnerability map using ArcGIS involving the integration of temperature data, land cover information and other relevant factors to visually identify areas with higher temperatures and potential UHI hotspots in Kelantan. By calculating the UHI vulnerability index by combining the normalized temperature and other relevant factor layers using assigned weights. The index represents the overall vulnerability of each area to the effects of UHI and the last step in this process is mapping. Draw a thematic map that represents the UHI vulnerability index and use a colour scheme to visually highlight areas with higher vulnerability. The need to create a UHI vulnerability map helps identify areas that are exposed to higher temperatures and UHI effects. It allows urban planners and policy makers to prioritize interventions in areas of increased vulnerability, contributing to effective UHI mitigation strategies (Arnfield, 2003).

3.3.6 Validation

Validation using ground truth data is essential in validating the identification of Urban Heat Islands (UHI) through ArcGIS analysis. Ground truth data provides direct measurements in the field that can be compared with remote sensing or model derived results, ensuring the accuracy and reliability of UHI assessments. There are several ways to verify ground truth data. One of them is to make a point-to-point comparison. This measurement method is ground truth temperature measurement and corresponding values obtained from remote sensing or spatial analysis in ArcGIS (Arnfield, 2003). In addition to being able to create land permission data to use Statistical analysis. uses statistical analysis techniques, such as correlation coefficients or error metrics, to quantitatively assess the agreement or disagreement between the ground truth and the model data.

Lastly, validation metrics were calculated, including accuracy, precision, sensitivity, and specificity, to evaluate the performance of the UHI identification process (Congalton & Green, 2009). Ground truth data serves as a reference point to verify the accuracy of remote sensing or GIS-based UHI identification. It provides measurements and real-world conditions, allowing researchers to validate their models and ensure that observed temperature patterns align with on-site reality (Arnfield, 2003).

3.3.7 Statistical Analysis

The analysis chosen in this study is using statical analysis Getis Ord-G_i^*. The Getis Ord-G_i^* statistic is used to measure the spatial clustering of high or low values. Hot spot analysis has been achieved by calculating the Getis-Ord G_i^* statistic for surface temperature in context with neighbouring cell temperatures. The G_i^* value is an z-score and shows where characteristics with high or low values are clustered. To be a statistically significant hot spot, a feature will have a high value and at the same time it will be surrounded by other features with high values.

The formula for calculating the Getis Ord-G_i^*

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}\, x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \tag{3.6}$$

The Getis Ord G_i^* statistic is a measure used to identify spatial clustering of high or low attribute values within a dataset. It is calculated for specific location *i* and uses theattribute values and spatial weights of neighbouring features. In the formula, G_i^* represents the Getis-Ord statistic for location $_i$. The attribute value for features $_j$ is denoted by *xj*, and w_{ij} represents the spatial weight between features *i* and features $_j$. The total number of features in the dataset is indicated by *n*. While, ̄x is the mean of the attribute values and *S* is the standard deviation of the attribute values. This statistic helps in determining whether hig or low values are spatially clustered, thereby providing insights into spatial patterns within in data.

The output of the G_i^* statistic (the z-score) represents the statistical significance of clustering for a specified distance. The z score was compared with the range of the values for seven confidence levels which -0.01 (values less than -2.58), -0.05 (values with range from -2.58 to -1.95), -0.1 (values with range from -1.96 to -1.65), 0 (values with range from -1.65 to 1.65), 0.1 (values with range from 1.65 to 1.95), 0.05 (values with range from 1.95 to 2.58) and 0.01 (values greater than 2.58). The seven levels correspond to seven classes that LST values were assigned to most important for analysing are the "very cold spot" and "very hot spot", classes that defines the areas with extreme values.

3.4 FLOW CHART

Method Flow Chart of Urban Heat Island

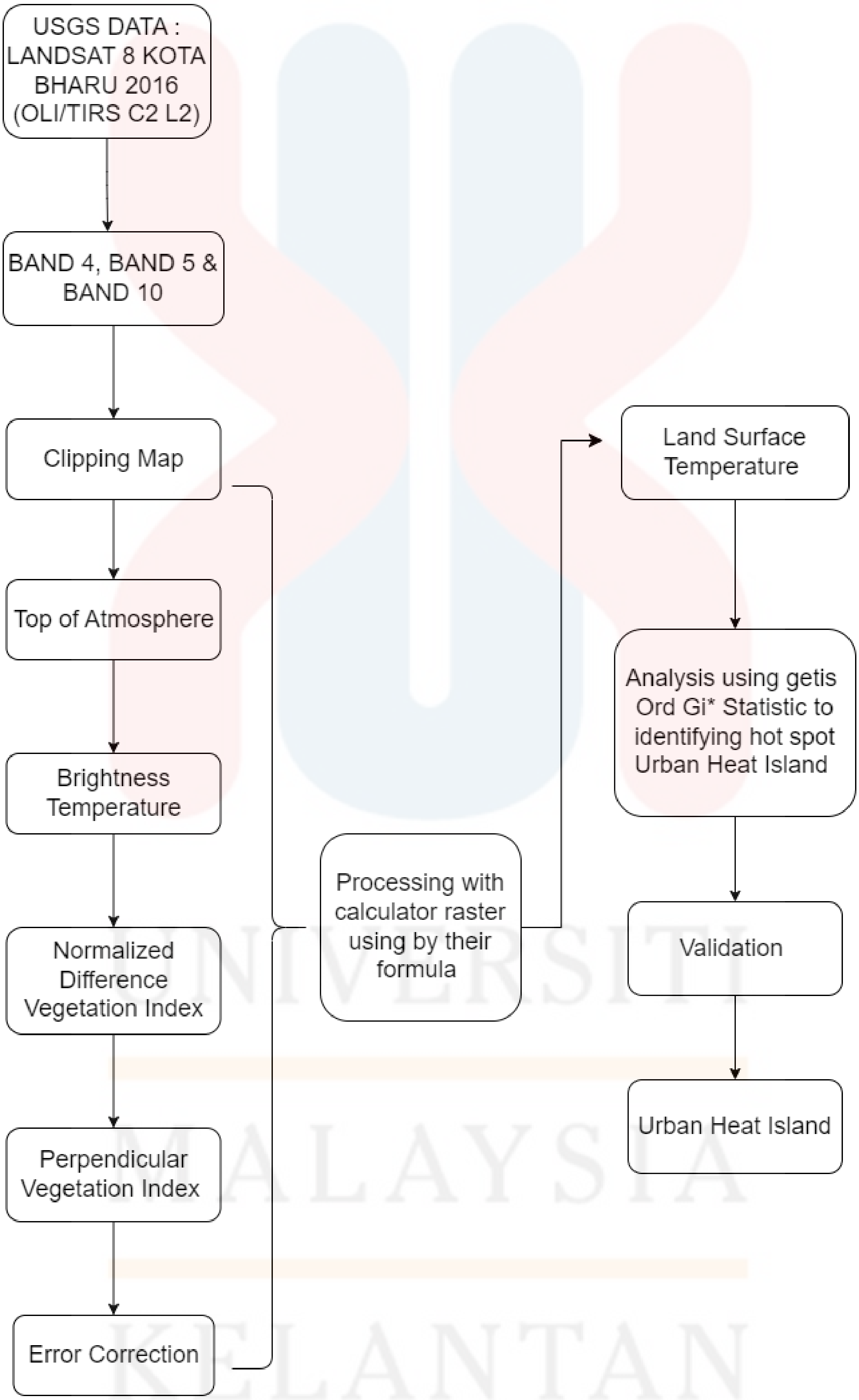

Figure 3.4: Flow Chart Method

3.5 RESEARCH FLOW

Research Flow Chart thesis of Urban Heat Island

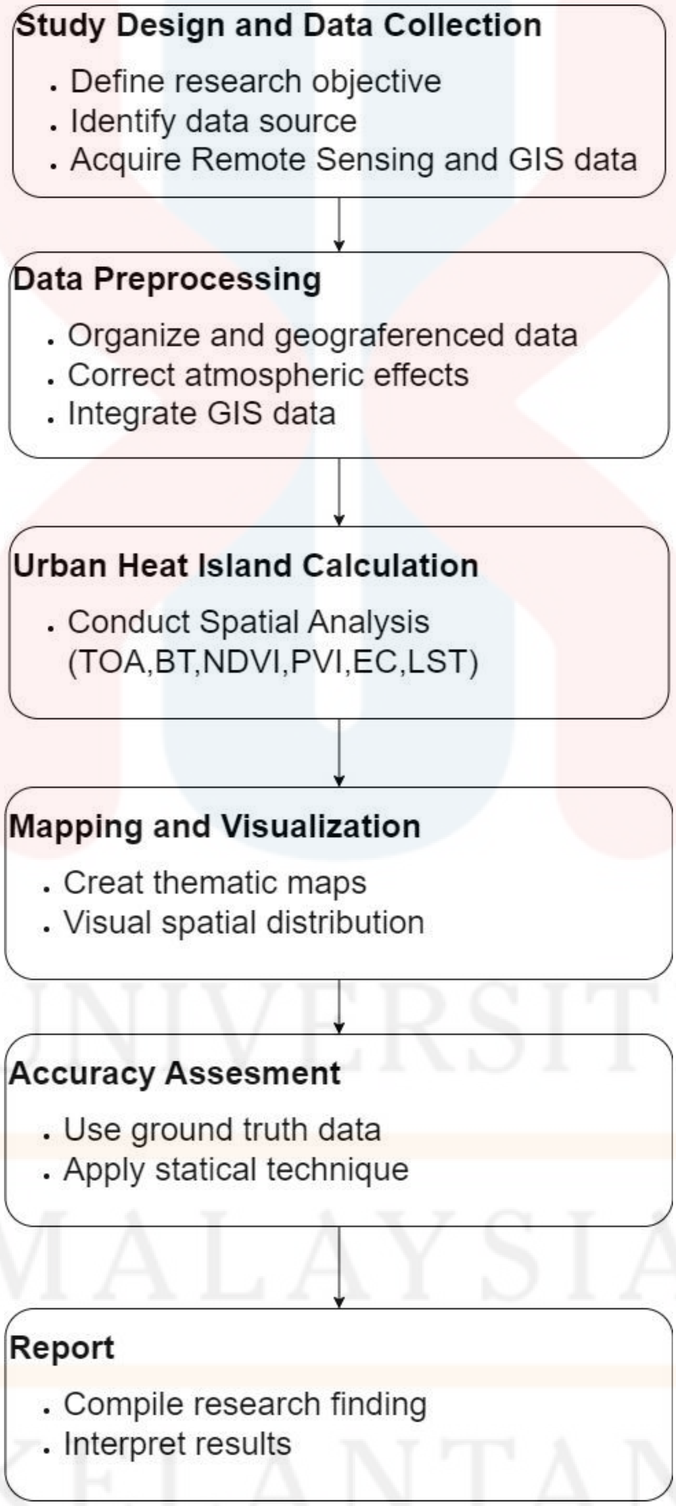

Figure 3.5: Research Flow

CHAPTER 4

RESULT AND DISCUSSION

4.1 Average Temperature and Rainfall

The average temperature of Kota Bharu, Kelantan in 2016 has been recorded as 27.9°C. As depicted in Figure 4.1, this demonstrates that Kota Bharu constantly encounters elevated temperatures throughout the year, which is indicative of Malaysia's characteristic tropical climate. The elevated temperature plays a crucial role in the investigation of the urban heat island phenomenon, which refers to the tendency of urban regions to have higher temperatures compared to their less developed surroundings. Weather and data collected from space can be used to see UHI through land surface temperatures. Before remote sensing data were created, UHI was widely observed in the field (Oke, 1982).

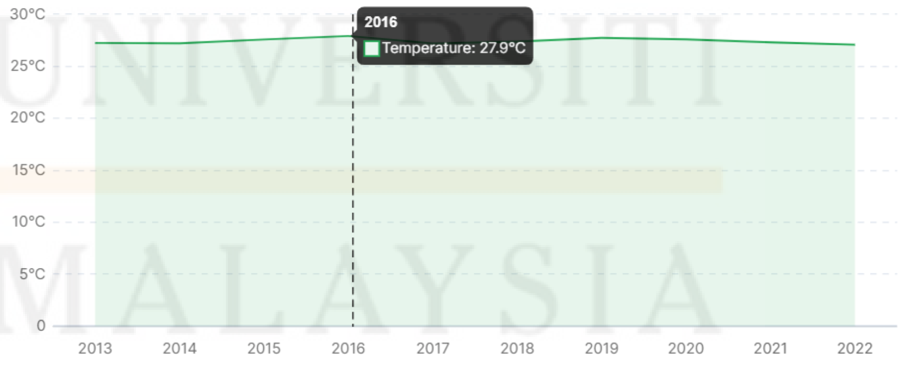

Figure 4.1: Average temperature of Kota Bharu, Kelantan (2016)

In 2016, Kota Bharu, Kelantan recorded an average annual rainfall of 2,641.4 mm. As shown in Figure 4.2, this high amount of rain shows the typical humid tropical climate in Malaysia, with a lot of rain throughout the year. Rain is an important factor in controlling the surface temperature and humidity of an area which in affects the UHI phenomenon.

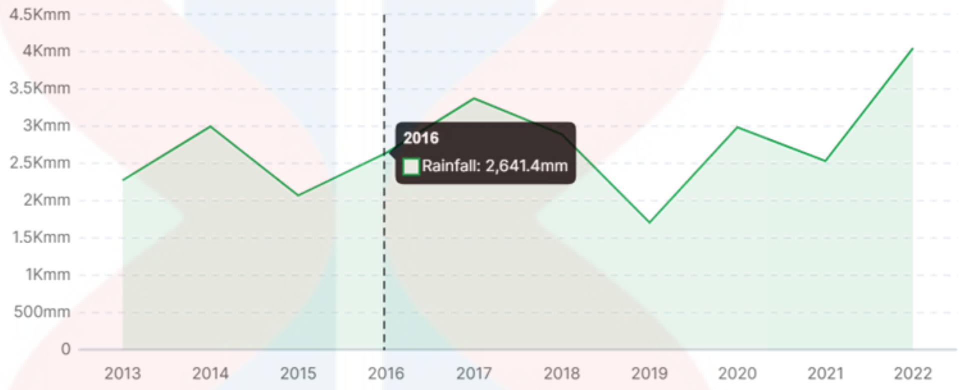

Figure 4.2: Average of rainfall of Kota Bharu, Kelantan (2016)

4.2 Top of Atmosphere

This map provides an overview of the surface value in Kota Bharu, Kelantan in 2016. The maximum value was recorded at 10.7703, while the minimum value was 9.33194. The area with the maximum value of 10.7703 indicates the hottest area in this map. Usually, these areas are areas that are heavily developed or have less plant cover. On the other hand, the area with the minimum value of 9.33194 is the coldest area in this map. These areas may have a lot of green space or be underdeveloped.

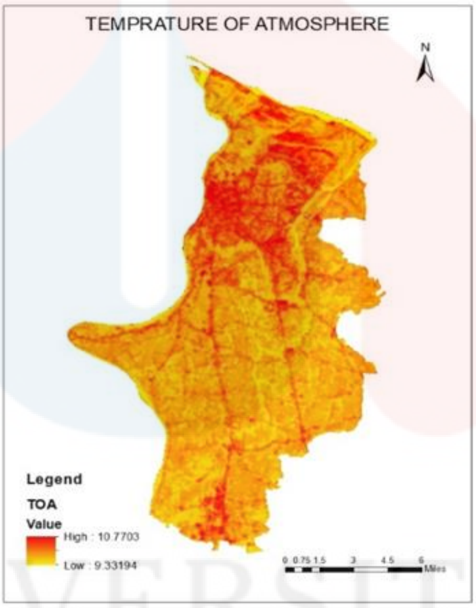

Figure 4.3: Top of Atmosphere Kota Bharu,Kelantan (2016)

4.3 Brightness Temperature

Based on Figure 4.3, the variation of brightness temperature in Kota Bharu, Kelantan in 2016. The temperature is measured in Celsius units (°C), where the maximum value recorded is 36.79°C. This shows the hottest area in this map. These areas are usually very developed areas or areas with less plant cover. On the other hand, the minimum temperature value of 26.77°C indicates the coldest area in this map. These areas may have a lot of green space or are less developed areas.

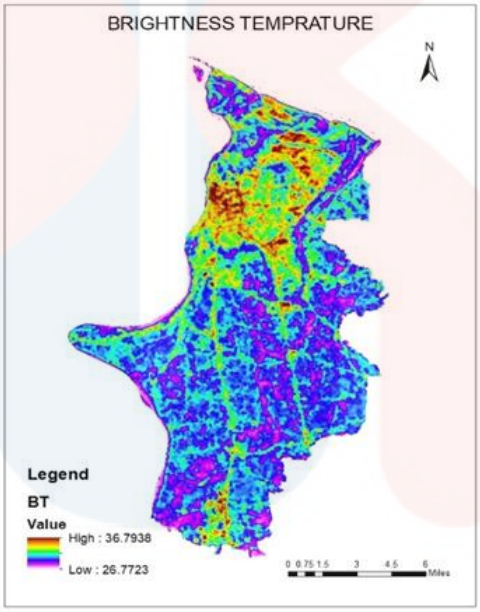

Figure 4.4: Brightness Temperature of Kota Bharu, Kelantan (2016)

4.4 Normalized Difference Vegetation Index

Figure 4.4 shows, the maximum value of NDVI is 0.604048, which indicates an area with very dense and healthy vegetation. The minimum value of NDVI is -0.269689, which indicates an area with little vegetation or no vegetation at all (for example, urban areas, water, or arid areas). Areas with high NDVI values (marked in darker green) indicate areas with good vegetation cover. This may include areas of forests, parks, and healthy agricultural areas. Conversely, areas with low NDVI values (marked with lighter green or almost white) indicate areas with little or no vegetation. This may include urban areas, residential areas, roads, and developed areas.

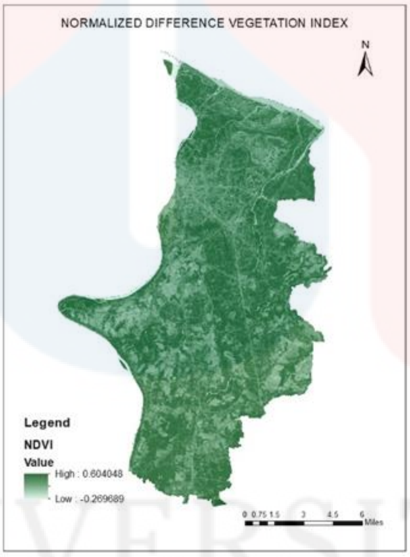

Figure 4.5: Normalized Difference Vegetation Index of Kota Bharu, Kelantan (2016)

Table 4.1: NDVI value classification for vegetation density

NDVI Value	Vegetation Class
-1.00 -0.00	No vegetation
0.01-0.30	Slightly density
0.31-0.60	Moderately density
0.61-1.00	Highly density

4.5 Perpendicular Vegetation Index

The Perpendicular Vegetation Index (PVI) map for Kota Bharu, Kelantan for the year 2016 shows the variation in vegetation cover in the area. PVI measures vegetation cover by calculating an index perpendicular to the ground line in near infrared and red-light reflectance graphs. This index is less affected by soil and humidity variations, making it more accurate in certain conditions. The maximum PVI value in this map is 0.716741, which indicates an area with very dense and healthy vegetation cover. The minimum PVI value is 2.91006e-014, which indicates an area with very little vegetation or no vegetation at all examples, urban areas, water, or arid areas. Areas with high PVI values (marked in green) indicate areas with good vegetation cover. This may include areas of forests, parks, and healthy agricultural areas. Areas with low PVI values (marked in brown) indicate areas with little or no vegetation. This may include urban areas, residential areas, roads, and developed areas.

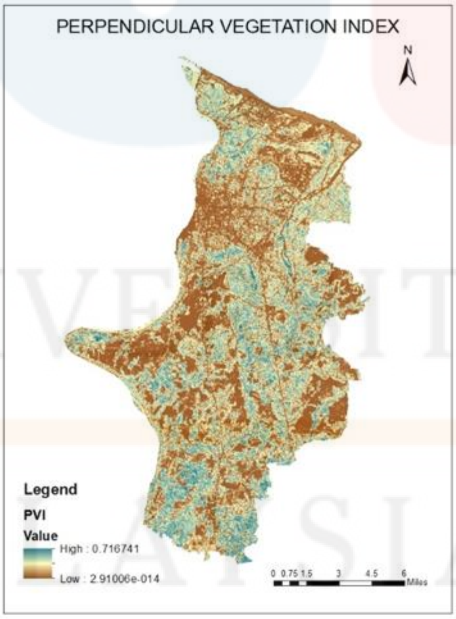

Figure 4.6: Perdicular Vegetation Index of Kota Bharu, Kelantan (2016)

4.6 Land Surface Temperature

Land Surface Temperature (LST) variations in Kota Bharu, Kelantan for 2016 are shown on the map, which is color-coded according to the legend for various temperature categories. Dark Green (26.78 - 28.67°C). The dark green area covers the area with the lowest surface temperature. This zone is most likely an area with a lot of vegetation or less developed areas that can maintain lower temperatures. For example, urban forest areas, large parks, or suburban areas with significant plant cover. The presence of many plants helps in cooling the surface temperature through the process of evaporation and transpiration. Light Green (28.67 - 29.45°C). Light green areas reflect areas with slightly higher temperatures than dark green. This area may be a transition between green areas and areas that are beginning to experience development. These areas can include small parks, farms, or residential areas that have trees and good green cover but not as large as dark green areas. Greenish Yellow (29.45 - 30.16°C) these areas with higher temperatures are most likely more urban areas with higher human activity. These areas may involve dense residential areas or commercial areas that are beginning to develop with little green space available. Yellow (30.16 - 31.02°C). The yellow area indicates a significant increase in surface temperature. These may be commercial areas or areas with dense development but still have some green space. Examples of these areas include business centers, highly dense residential areas, or commercial areas with limited open spaces. Next, Orange (31.02 - 32.02°C). Orange areas are warmer areas, most likely denser urban areas with little green space. These areas typically include tall buildings, wide roads, and urban infrastructure that absorb and store more heat. Red (32.02 - 33.07°C). Red areas indicate very hot areas. This may be a very dense urban area with lots of buildings and infrastructure, but little or no green space. For example, downtown areas that have many commercial and industrial buildings. The last one is Bright Red (33.07 - 36.81°C). The bright red area is the hottest area in this map. This area is a completely urban area with no vegetation cover, possibly even an industrial area. Examples of these areas include factory areas, port areas, or large commercial centers with little or no vegetation to cool the surface temperature. Land Surface Temperature (LST), also known as radiometric or "skin" temperature, refers to the direct measurement of the earth's surface temperature. LST provides detailed analysis of surface temperature in different environments such as displaying temperatures in areas with dense vegetation, sparse vegetation, and bare ground (Agam et al.,2008).

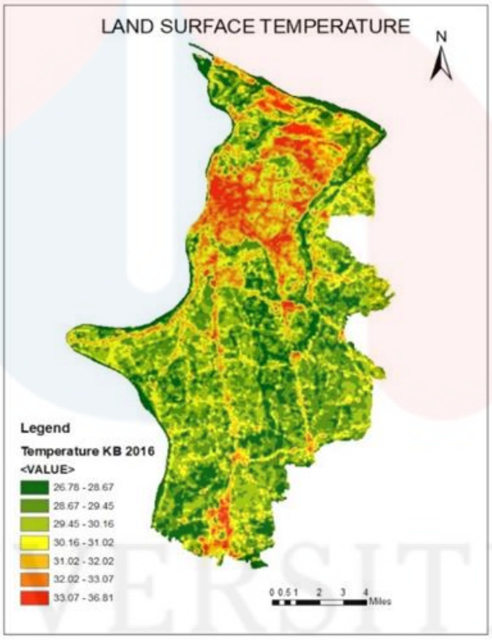

Figure 4.7: Land Surface Temperature of Kota Bharu, Kelantan (2016)

4.7 Hot Spots Urban Heat Island

Figure 4.8 shows, map illustrates the distribution of urban heat island hot spots and cold spots, utilizing a color-coded scheme to differentiate areas based on their temperature intensity. Extremely significant hot spots, represented by red points, exhibit the highest temperatures with z-scores greater than 2.58 and p-values less than 0.01, indicating intense heat clusters with a probability of less than 1% that this clustering is random. Significant hot spots, denoted by orange points, have z-scores ranging from 1.92 to 2.58 and p-values less than 0.05, showing notably higher temperatures compared to their surroundings with a probability of less than 5% that this clustering is random. Hot spots, highlighted by yellow points, are characterized by z-scores between 1.65 and 1.95 and p-values below 0.10, indicating areas somewhat warmer than average with a less than 10% chance of this temperature pattern being random. Inconspicuous regions, represented by light green points, have z-scores between -1.6 and 1.65 and exhibit average temperature values, not standing out as significant hot or cold spots. Cold spots, indicated by light blue points, with z-scores between -1.95 and -1.65 and p-values under 0.10, are slightly cooler than average with a less than 10% probability of this cooling pattern being random. Significant cold spots, signified by blue points, have z-scores ranging from -2.58 to -1.95 and p-values below 0.05, indicating notably cooler areas with a probability of less than 5% that this clustering is random. Extremely significant cold spots, represented by dark blue points, have z-scores less than -2.58 and p-values below 0.01, marking the coolest areas with a less than 1% probability that this clustering is random.

In summary, the map uses color gradation to effectively visualize the distribution of hot and cold spots in urban areas, highlighting significant temperature variations based on z-scores and p-values. The red and orange points indicate areas of intense heat, while the blue and dark blue points show regions of significant cooling, providing a clear depiction of urban heat island effects.

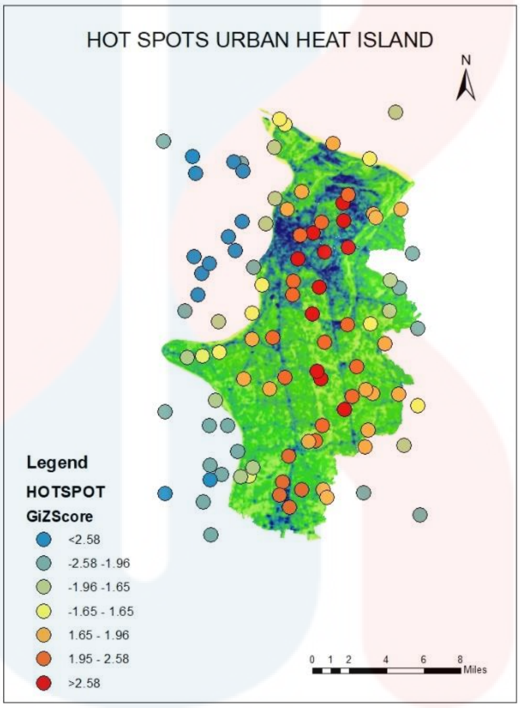

Figure 4.8: Hot and Cold spots of Urban Heat Island in Kota Bharu, Kelantan (2016)

Table 4.2: Classification of Hot and Cold Spot Level, z-Score and p-value

Hot/Cold Spot Level	z-Score	p-value
Extremely significant hot spots	>2.58	<0.01
Significant hot spots	1.95 - 2.58	<0.05
Hot spots	1.65 - 1.95	<0.10
Inconspicuous regions	-1.6 - 1.65	-
Cold spots	-1.95 - 1.65	<0.10
Significant cold spot	-2.58 – 1.95	<0.5
Extremely Significant cold spots	<2.58	<0.01

4.8 Validation

Figure 4.9 shows, map illustrates the urban heat island (UHI) vulnerability in Kota Bharu, Kelantan. The red points indicate areas with intense development, which are likely UHI hotspots due to extensive urban infrastructure and lack of vegetation. These regions are more susceptible to higher temperatures and adverse UHI effects. On the other hand, the blue points represent densely forested or vegetated areas that have not undergone significant development. These zones benefit from natural cooling effects provided by the greenery, contributing to lower temperatures and reduced UHI impacts. The contrast between the red and blue points underscores the importance of preserving and enhancing green spaces to mitigate UHI effects and improve urban resilience in Kota Bharu.

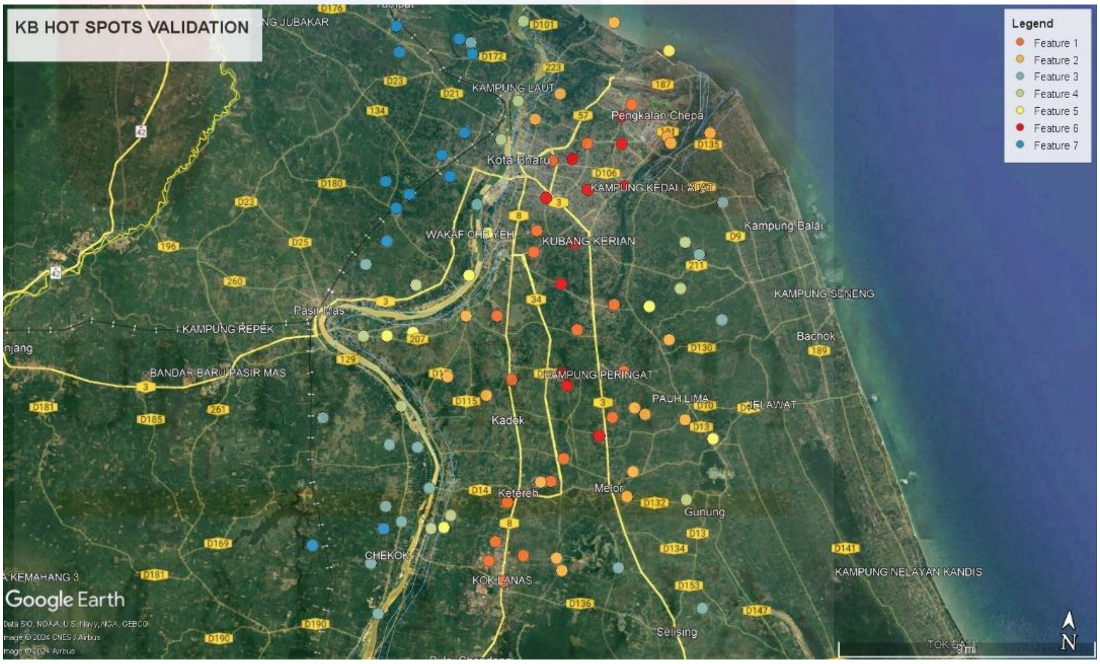

Figure 4.9: Hot Spots Validation Kota Bharu by Using Google Earth Pro

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this writing is to "Identify Areas Susceptible to Urban Heat Island: A Case Study in Kota Bharu, Kelantan" has successfully addressed the significant environmental challenges of Urban Heat Island (UHI) in this region. Using remote sensing techniques and Geographic Information Systems (GIS), this study has provided a valuable insight into the intensity and distribution of UHI in Kota Bharu. These findings emphasize the importance of incorporating green spaces and implementing cooling strategies to reduce the impact of UHI and improve urban resilience.

The research not only fills the knowledge gap specific to Kota Bharu, Kelantan but also contributes to a broader understanding of UHI dynamics in tropical urban environments. Expected outcomes from this study include a comprehensive understanding of UHI in the region, practical solutions for mitigation and adaptation, and valuable contributions to sustainable urban planning efforts.

Overall, this thesis serves as an important resource for urban planners, policy makers, and local communities in Kelantan to develop strategies to create a more sustainable and heat-resistant urban environment. The findings and recommendations presented in this study have the potential to inform decision-making processes and contribute to global efforts in addressing the challenges posed by climate change and urbanization.

5.2 Recommendations

Based on the findings of this study on identifying areas susceptible to Urban Heat Islands (UHI) in Kota Bharu, Kelantan, several recommendations can be made to mitigate adverse effects and enhance urban resilience. These include enhancing green spaces and urban vegetation by implementing parks, community gardens, green roofs, and promoting urban forestry. Sustainable urban planning should prioritize the use of reflective roofing materials and permeable pavements. Developing comprehensive UHI mitigation policies and providing incentives for property owners to retrofit buildings with mitigation measures are essential. Enhancing public awareness through educational campaigns and community engagement in urban greening projects is critical. Regular monitoring of urban temperatures and supporting further research on UHI dynamics and cooling technologies are necessary for long-term success. Integrating UHI mitigation into broader climate adaptation plans and promoting sustainable urban development practices will enhance overall climate resilience. By adopting these recommendations, urban planners, policymakers, and local communities in Kota Bharu can effectively mitigate UHI effects, leading to a more sustainable, resilient, and liveable urban environment.

REFERENCES

Agam, N.; Kustas, W.P.; Anderson, M.C.; Li, F.; Colaizzi, P.D. Utility of thermal image sharpening for monitoring field-scale evapotranspiration over rainfed and irrigated agricultural regions. Geophys. Res. Lett. (2008), 35, 1–7.

Arnfield, A. J. (2003). *Two decades of urban climate research: A review of turbulence, exchanges of energy and water, and the urban heat island.* International Journal of Climatology, 23(1), 1-26.

Baatz, M., & Schäpe, A. (2000). Multi-Resolution Segmentation: An Optimization Approach for High-Quality Multi-Scale Image Segmentation. Strobl, J., Blaschke, T., & Griesebner, G. (Eds.),Angewandte Geographische Informationsverarbeitung XII, 12-23.

Berges R, Piorr A, Krikser T (2016) *Contributing to food security in urban*: differences between urban agriculture and peri-urban agriculture in the Global North. Agric Human Values 33:341–58.

Berry P, Enright P M, Shumake-Guillemot J, Prats E V, Campbell-Lendrum D (2018) Assessing health vulnerabilities and adaptation to climate change: *A review of international progress*. Int J Environ Res Public Health 15.

Block A H, Livesley S J, and Williams N S G (2012) Responding to the Urban Heat Island : *A Review of the Potential of Green Infrastructure*.Vic Cent Clim Chang Adapt 1–62.

Chanie, E., Ewnetu, T., & Tadesse, A. (2014). Urban heat island effect and land use/land cover change in Addis Ababa, Ethiopia. Journal of Environmental Science and Water, 3(6), 123-131.

Cole D, Dietsch N, Gero G, Hitchcock D, Lewis M, Magee J, et al (2008) *Heat Island ReductionActivities. Reducing Urban Heat Islands Compend Strateg* 1–23.

Congalton, R. G., & Green, K. (2009). Assessing the Accuracy of Remote Sensing Data: Principles and Practice (2nd ed.). CRC Press.

D. Zhou, S. Zhao, S. Liu, L. Zhang, and C. Zhu (2014) Surface Urban Heat Island in China's 32 major cities: *Spatial patterns and drivers, Remote Sens*. Environ., vol. 152, no. 7, pp. 51–61,Sep., doi: 10.1016/j.rse.2014.05.017.

Emmanuel, R., & Krüger, E. (2012). Urban heat island and its impact on climate change resilience in a shrinking city: The case of Glasgow, UK. Building and Environment, 53, 137-149.

Getis, A., & Ord, J. K. (1992). Spatial Association Analysis with the Use of Distance Geographical Analysis, 24(3), 189-206.

Herold, M., Goldstein, N. C., & Clarke, K. C. (2003). The spatiotemporal form of urban growth: measurement, analysis and modeling. Remote Sensing of Environment, 86(3), 286-302.

Huang, L., Cao, G., & Wang, S. (2019). *The challenge and opportunity of urban heat mitigation in a cold climate city:* The case of Harbin, China. Sustainable Cities and Society, 48, 101557.

Harlan, S. L., & Ruddell, D. M. (2011). Climate change and health in cities: Impacts of heat and air pollution and potential co-benefits from mitigation and adaptation. Current Opinion in Environmental Sustainability, 3(3), 126-134.

I, D. Stewart and T. R. Oke (2012) *Local Climate Zones for Urban Temperature Studies*, Bull. Am Meteorol. Soc., vol. 93, no. 12, pp. 1879–1900.

Imhoff, M. L., Zhang, P., Wolfe, R. E., & Bounoua, L. (2010*). Remote sensing of the urban heat island effect across biomes in the continental USA*. Remote Sensing of Environment, 114(3), 504-513.

Irons, J. R., Dwyer, J. L., Barsi, J. A., & Alley, R. E. (2012). The next Landsat satellite: The Landsat Data Continuity Mission. *Remote Sensing of Environment, 122*, 11-21.

Jensen, J. R. (2007). Environmental Remote Sensing: An Earth Resources Perspective. Pearson Education.

Jiménez-Muñoz, J. C., Cristóbal, J., Sobrino, J. A., Sòria, G., & Ninyerola, M. (2009). Review of a Single Channel Algorithm for Land Surface Temperature Retrieval from Landsat Thermal Infrared Data. IEEE Transactions on Geoscience and Remote Sensing, 47(1), 339-349.

Kovács, G., & Unger, B. (2014). Assessment of urban heat islands and mitigation strategies in Gödöllő, Hungary. Hungarian Geographical, 63(1), 27-41.

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2015). Geographic Information Science & Systems. John Wiley & Sons.

Mirzaei, P. A., & Haghighat, F. (2010). Remote sensing of urban heat islands: Techniques and applications. Buildings and Environment, 45(9), 2192-2201.

Oke, T. R. (1982). Urban Heat Island Energy Foundation. Quarterly Journal of the Royal Meteorological Society, 108(455), 1-24.

Oke, T.R. The energetic basis of the urban heat island. Q. J. R. Meteorol. Soc. (1982), 108, 1–24.

Phelan, Patrick E.; Kaloush, Kamil; Miner, Mark; Golden, Jay; Phelan, Bernadette; Silva, Humberto; Taylor, Robert A. (2015). "Urban Heat Island: Mechanisms, Implications, and Possible Remedies". Annual Review of Environment and Resources. 40 (1): 285–307.

Reid, C. E., O'Neill, M. S., Gronlund, C. J., Brines, S. J., Brown, D. G., Diez-Roux, A. V., & Schwartz, J. (2009). *Mapping community determinants of heat vulnerability*. Environmental Health Perspectives, 117(11), 1730-1736.

Richards, J. A., & Jia, X. (2006). Remote Sensing Digital Image Analysis: An Introduction (4th ed.). Springer.

Rouse, J. W., Haas, R. H., Schell, J. A., & Deering, D. W. (1974). Monitoring Vegetation Systems in the Great Plains with ERTS. Third ERTS Symposium, 309-317.

Roy, D. P., Wulder, M. A., & Loveland, T. R. (2014). Landsat-8: Science and product vision for terrestrial global change research. Remote Sensing of Environment, 145, 154-172.

Sailor, D. J. (2011). A review of methods for estimating anthropogenic heat and moisture emissions in the urban environment. International Journal of Climatology, 31(2), 189–199.

Santamouris, M. (2015). *Using cool pavements as a mitigation strategy to fight urban heat island—a review of the actual developments*. Renewable and Sustainable Energy Reviews, 52, 1-12.

Santamouris, M. (2015). Analyzing the heat island magnitude and characteristics in one hundred Asian and Australian cities and regions. Science of The Total Environment, 512-513, 582-598.

Sharma, A., Shankar, S., & Kumar, M. (2019). *Implications of urban heat island on sustainable urban development: A review*. Environment, Development and Sustainability, 21(6), 2873-2889.

Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. Proceedings of the National Academy of Sciences, 104(52), 20666-20671.

Taha, H. (1997). Urban climates and heat islands: albedo, evapotranspiration, and anthropogenic heat. Energy and Buildings, 25(2), 99-103.

Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. Remote Sensing of Environment, 86(3), 370–384.

Wang, C., Myint, S. W., Wang, Z., Song, J., & Fan, C. (2016). Quantifying urban heat island intensity in New York City using Landsat 8 TIRS data. Remote Sensing, 8(3), 211.

Weng, Q. (2001). The urban heat island: remote sensing and GIS perspective. Taylor & Francis.

Weng, Q. (2009). Thermal Infrared Remote Sensing for Urban Climate and Environmental Studies: Methods, Applications and Trends. ISPRS Journal of Photogrammetry and Remote Sensing, 64(4), 335-344.

Wong L P, Alias H, Aghamohammadi N, Aghazadeh S, Sulaiman N M N (2018) Physical, Psychological, and Social Health Impact of Temperature Rise Due to Urban Heat Island Phenomenon and Its Associated Factors. *Biomed Environ Sci* 31:545–50.

Wulder, M. A., White, J. C., Masek, J. G., Dwyer, J., & Roy, D. P (2011). Continuity of Landsat observations: Short term considerations. *Remote Sensing of Environment*, 745–751.

Zhang, L., et al. (2011). Analisis Pulau Haba Bandar Menggunakan Data Landsat TM dan Data ASTER: Kajian Kes di Hong Kong. Penderiaan Jauh, 3(7), 1535-1552.

Zhou, Y., Shepherd, M., & Golden, J. (2009). Urbanization effect on hurricane rainfall. Geophysical Research Letters, 36(3), L03703.