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URBAN GREEN SPACE SPATIO-TEMPORAL CHANGE INFLUENCES ON LAND SURFACE TEMPERATURE IN KUALA LUMPUR, MALAYSIA

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By

JUNAINAH BINTI ABU KASIM

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Chairman : Associate Professor Gs. Mohd Johari bin Mohd Yusof, PhD
Faculty : Design and Architecture

Urban green space (UGS) is a nature-like environment established in the urban structure of a city. It plays a vital role in providing vegetation cover to provide shade and act as a natural cooling eco-system to reduce the city's heat by releasing oxygen for sustaining a healthy ecological environment. However, given the developments brought about by urbanisation, UGS has been sacrificed to allow for the urban growth activity. The continual development of new construction, road networks and buildings has eradicated UGS areas thus contributing to the rising of land surface temperature (LST). Accordingly, this study aims to monitor the UGS changes and LST pattern in Kuala Lumpur (KL) for the past six years and to develop an automated prediction model of these scenario for the year 2025 via temporal and spatial variation, using high-resolution aerial imagery data supported by the use of advanced technology mapping. The research utilised high-resolution aerial imagery for 2014, 2016, and 2019 that firstly used to map the spatial-temporal evolution of UGS over the past six years and to examine the UGS loss within the boundary of KL city. Secondly, to assess the pattern of LST change for the past six years and investigating the correlation between UGS changes and the effect on the LST. Thirdly, to develop an automated spatial prediction model that could potentially predict the UGS changes and their effect on the LST pattern. This research also tested the suitability of object-based classification methods of high-resolution aerial imagery using the support vector machine (SVM) classifier regarding its capability to correctly classify and recognise UGS patterns. The study also applied land surface emissivity (LSE) algorithm to determine the LST value extracted from the Band 10 parameter of Landsat 8 OLI/TIRS. A linear regression technique was employed to investigate the correlation between both scenarios using spatial statistical analysis and further predicting the UGS pattern and LST gradient for 2025 using the Artificial Neural Network - Cellular Automaton (ANN-CA) model. This model confidently predicted these scenarios logically, in which the expansion of built-up areas (BUA) in KL for following six years increased by 11.62%, the UGS decreased by 28.88%, and water body areas (WBA) slightly decreased by 4.57%. This led to an increase in the mean LST gradient for 2025 (32.15°C, which was about 3.22°C higher than the value recorded in 2019 (28.93°C). The prediction model employed in this study provides a significant benefit in monitoring the UGS changes and impact on the LST pattern for the past, present and future scenarios. The new automated model utilising high-resolution aerial imagery has great potential to assist city planners and professionals in extracting, updating and detecting land use changes, particularly for UGS by applying a comprehensive procedure through a geographical information system (GIS) platform. The broad range of output generated from the multiple temporal of high-resolution aerial imagery could henceforth improve the reliability of collected data and develop a high-performance outcome in interpreting real visualised scenarios.

Keywords: GIS, Kuala Lumpur; Land surface temperature; Land use land cover change; Remote Sensing, Urban planning

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGARUH PERUBAHAN RERUANG KAWASAN HIJAU BANDAR TERHADAP SUHU PERMUKAAN TANAH DI KUALA LUMPUR, MALAYSIA

Oleh

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Kawasan hijau bandar merupakan asas produktiviti semula jadi di dalam struktur perbandaran. Ia memainkan peranan penting sebagai tunjang penyerapan haba bandar serta mengawal suhu sekitar melalui proses pembebasan oksigen ke udara. Walaubagaimanapun, perbandaran yang pesat mengakibatkan kawasan hijau telah diceroboh dan dibenarkan untuk tujuan aktiviti pembangunan. Kemerosatan kawasan hijau yang berterusan telah menyumbang kepada peningkatan permukaan suhu tanah. Oleh itu, kajian ini bertujuan untuk memantau perubahan kawasan hijau dan corak perubahan suhu permukaan tanah dalam bentuk reruang dengan variasi tempoh masa, menggunakan imej data beresolusi tinggi dan dibantu oleh sistem teknologi pemetaan yang canggih bagi membangunkan satu bentuk automasi model yang berupaya meramalkan perubahan kawasan hijau bandar serta mengkaji kesannya terhadap suhu permukaan tanah bagi tahun 2025. Proses analisis ini dilaksanakan berdasarkan tinjauan imej beresolusi tinggi bagi tahun 2014, 2016, dan 2019, bertujuan yang pertama adalah untuk memetakan perkembangan perubahan kawasan hijau secara reruang bagi tempoh enam tahun yang lepas dan mengkaji peratusan kemerosotannya secara keseluruhan di dalam sempadan Kuala Lumpur; kedua adalah untuk mengkaji corak perubahan suhu permukaan tanah serta menyiasat hubung kait antara perubahan kawasan hijau dan kesannya secara lansung terhadap suhu permukaan tanah; ketiga, untuk membangunkan satu bentuk automasi model yang berpontesi untuk membuat ramalan perubahan kawasan hijau dan pengaruhnya terhadap corak suhu permukaan tanah pada masa hadapan.Penyelidikan ini menggunapakai kaedah klasifikasi pengesanan objek sebenar di dalam imej beresolusi tinggi melalui pengkelasan teknik *support vector machine* (SVM), berikutan kemampuannya untuk mendefinasikan kawasan hijau bandar serta mengkaji corak perubahan yang berlaku sepanjang tempoh tersebut dengan tepat. Kajian ini juga menggunakan algoritma *land surface emissivity* (LSE) dalam menentukan suhu permukaan tanah melalui kiraan parameter yang terdapat di dalam band 10 satelit 8 OLI/TIRS. Seterusnya, kaedah regresi linear digunakan untuk menyiasat hubung kait antara kedua-dua peristiwa tersebut melalui analisis statistik reruang. Penyelidikan ini kemudian diteruskan untuk meramalkan corak perubahan kawasan hijau bandar dan keadaan suhu permukaan tanah yang akan berlaku pada tahun 2025 menggunakan model *Artificial Neural Network- Cellular Automaton (ANN-CA).* Secara keseluruhannya, model yang digunakan mampu meramalkan peristiwa perubahan yang akan berlaku pada masa hadapan dengan logik, dimana berdasarkan pengembangan litupan permukaan bandar pada tahun 2025, ianya akan meningkat sebanyak 11.62% dari jumlah kawasan yang direkodkan pada tahun 2019, manakala kawasan hijau terus mengalami penurunan iaitu sebanyak 28.88%, dan badan air mengalami sedikit penurunan iaitu pada 4.57%. Senario ini membawa kepada peningkatan purata suhu permukaan tanah pada tahun 2025 (32.15°c) sebanyak 3.22°c lebih tinggi dari nilai suhu yang direkodkan pada tahun 2019 (28.93°c). Model ramalan yang digunapakai ini mampu memberikan manfaat di dalam proses pemantauan perubahan kawasan hijau dan kesannya terhadap corak suhu permukaan tanah untuk peristiwa masa lepas, sekarang dan masa hadapan. Model ramalan automasi yang baru dengan aplikasi penggunaan imej beresolusi tinggi mempunyai pontensi yang baik dalam membantu perancang bandar serta bidang professional yang berkaitan untuk membuat pengemaskinian data, mengolah data serta mengesan perubahan penggunaan tanah terutamanya kawasan hijau melalui prosedur analisis reruang yang terdapat di dalam aplikasi sistem maklumat geografi.

Kata Kunci: Aplikasi penderiaan jauh, GIS, Kuala Lumpur; Perancangan Bandar; Perubahan guna tanah dan litupan bumi; Suhu permukaan tanah.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

AHP	Analytical hierarchy process
AI	Artificial Intelligent
ANN	Artificial Neural Network
AST	Air Surface Temperature
BUA	Built-up Area
BUAI	Built- up Area Indices
BT	Brightness Temperature
CA	Cellular Automata
CBEM	Classification-Based Emissivity
CLUD	Change of Land Use Distribution
CSGS	Change Space of Green Space
CSI	Classification Success Index
DEM	Digital Elevation Model
DL	Deep Learning
DN	Digital Number
DOSM	Department of Statistics Malaysia
EPA	Environmental United States Protection Agency
FNEA	Fractal Net Evolution Approach
GCI	Green Cool Islands
GDM	Geocentric Datum Malaysia
GHG	Greenhouse Gas
GIS	Geography Information System
GUI	Graphical User Interface
GWR	Geographical Weighted Regression

JUPEM	Department of Survey and Mapping Malaysia
KL	Kuala Lumpur
KLCC	Kuala Lumpur City Centre
KLCH	Kuala Lumpur City Hall
KLCP 2020	Kuala Lumpur City Plan 2020
KL LCSB 2030	KL Low Carbon Society Blueprint 2030
KLSP 2020	Kuala Lumpur Structure Plan 2020
LR	Logistic Regression
LSE	Land Surface Emissivity
LST	Land Surface Temperature
LUTI	Land Use Transport Interaction
LULC	Land Use Land Cover
LUSH	Landscape for Urban Spaces and High-rise
MA	Multi-angle
MCE	Multi-Criteria Evaluation
ML	Machine Learning
MLC	Maximum Likelihood Classification
MMD	Malaysia Meteorological Department
MMU	Minimum Unit of Mapping
MNDWI	Modified Normalized Difference Water Index
MODIS	Moderate Resolution Imaging Spectroradiometer
MOLUSCE	Modules of Land Use Change Evaluation
MT	Multi-threshold
MRT	Mass Rapid Transit
NASA	Nasional Aeronautics and Space Administration
NBEM	NDVI-Based Emissivity Method

NDBI	Normalized Difference Built-up Index
NDBal	Normalized Difference Bare Land Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NIR	Near Infrared Reflectance
OBIA	Object-based Image Analysis
OLI	Operational Land Imager
OLS	Ordinary Least Square
PM	Particulate Matter
PV	Proportion of Vegetation
QGIS	Quantum Geographical Information System
QT	Quad Tree-based
RGQ	Red Green Blue
ROL	River of Life
RS	Remote Sensing
RUMAWIP	Rumah Mampu Milik Wilayah Persekutuan
SC	Single channel
SPOT	Satellite for Observation of Earth
SUHI	Surface Urban Heat Islands
SUKE	Sungai Besi-Ulu Klang Elevated Ekspressway
SVM	Support Vector Machine
SWR	Square Wave Response
SWT	Split Window Techniques
TIRS	Thermal Infrared Sensor
TM	Thematic Mapper
TRX	Tun Razak Exchange

UBL	Urban Boundary Layer
UCI	Urban Cool Islands
UCL	Urban Cool Layer
UCS	Urban Control System
UGS	Urban Green Space
UGSC	Urban Green Space Climatic
UHI	Urban Heat Island
UI	Urban Indices
UN	United Nation
UNRID	United Nations Research Institute for Social Development
URA	United States
US	Urban Redevelopment Authority
USGS	United States Geological Survey
VWAI	Vegetation-water Area Index
WBA	Water Bodies Area
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background Information

1.1.1 Urban green space change

Urbanisation remains as one of the main factors globally leading towards the destruction of the earth's surface. Rapid urbanisation is linked to population growth and population inflow to city areas, which has led to changes in land use and land cover (LULC). To date, the United Nations estimates that approximately 3.5 billion people are living in cities and has forecasted that almost 60% of the world's population will transition into urban areas by 2030 (United Nation [UN], 2019). The high population density of cities contributes to the rapid development and activities within these cities, placing increasing pressure on the demand for land. For example, the development of new housing zones, expanding road networks and providing high-grade facilities and services to serve the well-being of urban dwellers (Che Khalid, 2014). Understanding the trend of urbanisation; the urban green space (UGS) is merely the potential space to be developed in a compact city (Haaland and van den Bosch, 2015). The change in UGS areas was believed to have been caused by negligence in the enforcement of development controls, the UGS land ownership and low priority of its use in urban planning (Mensah, 2014).

Nowadays, the transgression of the population from rural areas to urban areas has aggressively occurred in East-Southeast Asia, including Malaysia. As a developing country, Malaysia, especially and Kuala Lumpur (KL) (refer to Figure 1.1), is the fastest-growing metropolitan area of the nation, and not unlike other developing countries is no exception to the impact of urbanisation. The Department of Statistics Malaysia reported that in 2019, the population in Malaysia had reached 1.8 million people, an increase of 1.88% from the population in 2000 of 1.4 million (Department of Statistic Malaysia [DOSM], 2020). There is no doubt that the population in this city (KL) will continue to increase and achieve a population of around 2.2 million by 2020, as reported in the Kuala Lumpur Structure Plan 2020 (Kuala Lumpur City Hall [KLCH], 2004). The large-scale development and multi-directional human movement have consequently filled every space in covering an area of 243 km^2 in KL, including the residual UGS areas. Moreover, according to Kanniah (2017), the pressure on the city's land has led to a reduction in providing UGS per person in the city, from 13 sq.m per inhabitant in 2010 reducing to 8.5 sq.m in 2014. The UGS per person recorded was below the minimum requirement of 9 sq.m, as suggested by the World Health Organisation (WHO) (Maryanti, Khadijah, Uzair, & Ghazali, 2016).

It is also believed that a city with high densification of the population in an urban area which is equal or more than the standard UGS amount, could improve the quality and well-being of urban dwellers regarding the economic, social, environmental and aesthetic elements to the surrounding area (Maryanti et al., 2016). As such, accepting this viewpoint, drastic changes in the UGS areas in the city of KL needs to be monitored. Especially, in alerting those responsible for responding to land changes that could impact human life concerning air and water pollution, risk of landslides as well as disturbance to the natural habitat and susceptibility of the population residing in this city. Accordingly, it is important to map, monitor and analyse the spatial-temporal changes in LULC, particularly for UGS transition. Furthermore, the quantification of the UGS scenario can be used to manage the land within KL in the future to control the tension between this space and human needs and consumption. The information derived from visualised mapping could act in establishing a baseline and direction for land utilisation to assist city planners and as reasonable function for each living element in this city.

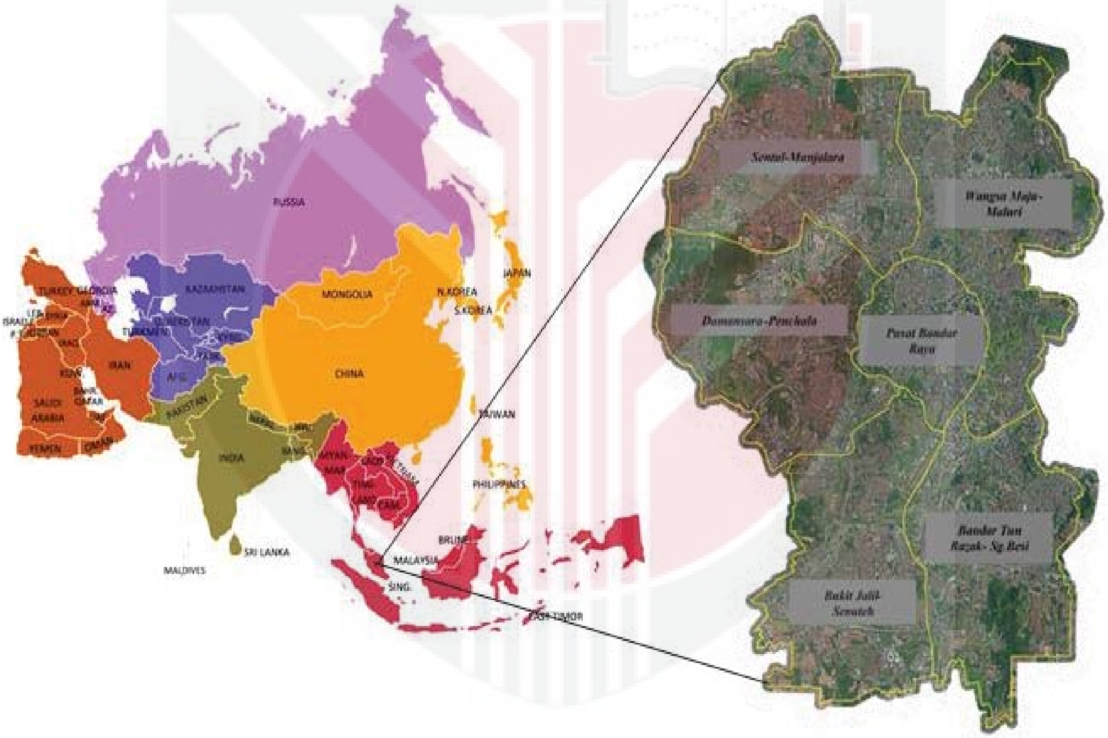

Figure 1.1 : Kuala Lumpur Location on the Central West of Peninsular Malaysia with Acreage of 243 km² (Source: Kuala Lumpur Structure Plan, 2004)

1.1.2 Urban green space change and increase in land surface temperature

UGS areas act as a natural cooling eco-system through evapotranspiration, which reduces both air and land surface temperatures (LST) (Buyadi, Wan Mohd, & Misni, 2014) but was soon degraded through rapid development activity. Uncontrolled development can affect the LULC in urban areas, where the green space is aggressively transformed into impervious surface areas through the construction of buildings and roads that impact the surface energy balance (Alavipanah, Wegmann, Qureshi, Weng, & Koellner, 2015). Consequently, these impervious surface materials which absorb more energy has resulted in a higher LST gradient (Ilayaraja, Reza, Kumar, Paul, & Chowdary, 2016). In other words, LST can be described as how hot the 'skin' of the earth is to touch at a particular location. It is also determined by the energy changes between the land surface and the surrounding atmosphere (Voogt and Oke, 2003).

Moreover, the escalation of what is termed as an urban heat island (UHI) is also associated with the saturation of the LST gradient and depends on the type of land use (Ullah, Tahir, Akbar, Hassan, Dewan, Khan, & Khan, 2019). Urban areas will normally show a higher LST value than in rural areas, which leads to the formation of a UHI event. However, the presence of UGS in urban areas has been proven to help lower the LST value thorough its shade and evapotranspiration process (Jafari, Soltanifard, Aliabadi, & Karachi, 2017) Therefore, information on the changes of UGS and its impact on LST needs to be examined, by understanding both the past and ongoing conditions of land use, indirectly providing an early response to mitigate UHI effects.

1.1.3 The use of spatial technologies

Geographic Information Systems (GIS) are powerful computer-based systems which enable the storing of vast amounts of data for data processing, analysing spatial databases and organising information according to the user's needs (Abd Aziz and Rasidi, 2012). Generally, the UGS changes analysis and LST extraction are carried out by integrating the GIS system with satellite Remote Sensing (RS) data. Both systems are cost-effective and can enhance information through its high spatial resolution imagery and free access available data. It is effectively used for monitoring and understanding the changing pattern of urban areas development and helps to quantify the LST gradient, as these advance technologies storing a thousand of world temporal imagery data and be able to analyse large-scale areas with detailed spatial information.

1.2 Research Problems

The issues regarding the degradation of UGS in this study will be discussed, covering the changes over a six-year period and how this scenario has potentially contributed to the variation of LST gradient in the city of KL. Monitoring the many UGS areas within the city is important to collect and map, in which could enable city planners to understand the temporal event of UGS loss in and around KL as well as improving the data information. Besides that, there are limited studies that have comprehensively used advanced technologies for mapping in determining the predicting UGS patterns and effect on LST gradients, particularly in the context of Malaysia. Most empirical studies investigated current situation rather than for future prediction (Hua and Ping, 2018; Buyadi et al., 2013; Isa, Wan Mohd, & Salleh, 2013). This is because research using RS in tropical urban areas like KL is challenging in obtaining clear and cloud-free data, thus increasing the effort to monitor UGS and LST change analysis. Moreover, the highly heterogeneous form of the land and colour will lead to the spectral similarity among land use types and effect the prediction outcomes. Therefore, this current study is designed to extend the body of knowledge in this field in term of the approach and method to alleviate the LST gradient through the prediction of the UGS pattern for future city planning development in KL.

Even though most local councils including the KLCH make use of GIS to track land-use changes and as a support device for controlling development, most existing databases are obsolete and outdated (Mohd Yusof, 2012a). Thus, utilising RS imagery data has great potential to aid city planners to extract, update and detect LULC changes, particularly UGS by applying appropriate protocols via the GIS platform (Noorollahi, 2005). The wide-ranging output generated from multiple temporal RS could improve the reliability of the data in addition to developing high performance in interpreting the real visualises scenarios.

1.2.1 Cities are Getting Crammed

Humanity historically has managed to change nature's landscape. Likewise, the unrestricted movement of the population from rural areas to cities has led to the transformation of land use activities (Awang Besar, Fauzi, Ghazali, Hazim, & Ghani, 2014). Urbanisation is an extreme factor that manifests the population concentrated in urban areas, thereby changing the land cover. In 2016, 54.5% of the world's population resided in city areas this includes Tokyo, Delhi and Hong Kong. Globally, there were 31 megacities has more than 10 million inhabitants, of which 15 of these cities are located in Asia and Africa (UN, 2019).

Urbanisation has exerted increasing tension and pressure in most cities, causing the shrinkage of UGS across Asia, North and South America and Africa (Abebe and Megento, 2016), often generated and driven by the demand for new housing and modern infrastructure (Kabisch, Strohbach, Haase, & Kronenberg, 2016). The changes in land use activity from natural vegetation to impervious surface areas has a profound influence caused by the urbanisation phenomenon. The 'green' surface areas are converted into 'black' areas having a hard surface, covered in concrete and asphalt, and no space left for the 'green' to survive (Jiang & Tian, 2010). Therefore, this causes changes in structure, form and the city's size as mentioned by (M. Nor, Corstanje, Harris, & Brewer, 2017). In their study, they stated that one of the factors that contribute to the changes in the city's form is due to the poor policy structure and ineffective implementation of urban monitoring management. The uncoordinated master plan also lacks information for future strategies, has discriminated the green space planning structure.

As a developing country, Malaysia, especially KL, has similar experiences regarding rapid urbanisation. This phenomenon contributes to economic development in the country as well as improving the well-being of its citizens (Isa, Wan Mohd, & Salleh, 2017). However, unfortunately, the new development and injection of the population into KL has been uncontrolled and has ultimately altered the city's natural resources (Elsayed, 2012). Currently, KL comprises a population of 1.8 million and is projected to increase to 2.2 million by 2020 (KLCH, 2012). As such, the UGS in KL is being sacrificed to supply land for new developments to meet the growing population. The consequential outcome of this process has broadened the juridical boundary limits; thus expanding the city's hinterlands (Mohammadian, Tavakoli, and Khani, 2017). More megastructures have been developed and built to meet the pressure of the global economy, for instance, Kenanga Wholesale City and St Regis One KL (Kozlowski, Norsidah, & Suhardi, 2015) that have used the green space areas purposely for commercial development.

According to Mohd Noor, Abdullah, and Manzahari (2013), two factors have contributed to the pattern of this change of UGS in KL between 1990 and 2010 related to urban sprawl development pattern and the increment of built-up areas. The growth of KL resulted in a horizontal form where the development started and continued to spread to suburban areas that had more land. This potentially dissolved the left-over UGS across the KL boundary. On the other hand, Kanniah (2017) mentioned that one of the largest parks in KL, Kepong Metropolitan Park, has been partially cleared to allow for affordable housing development to cater for the city's increasing population. This is occurring as green space is always claimed to be a liability and non-profit sector in planning development.

1.2.2 City's Heat: When KL Green is Not Equal to Green

Green areas in a city form the foundation of nature's productivity in the urban structure and play a vital role in the health of a city. Somehow, even looking at the greenery areas will make you feel better. That is how green areas contribute to the city's urban fabric and attracts people to live in these areas (Mansor and Said, 2008). These green assets are also valuable to enhance the aesthetics of a city; a catalyst for health improvement, generating social interactions and balancing the environment (KLCH, 2004). However, the UGS is increasingly being invaded by skyscraper development and continues to be destroyed to meet the interests of some individuals and organisations (Waldner, 2009). Furthermore, UGS mainly becomes a potential site or an area to be developed (Chiesura, 2004) and becomes a major source of economic investment (Lichtenberg, 2011). The only 'left-over space' in an urban setting presents the opportunity for extending the urban boundary, generated by an increasing population and the intensity of the development. This presents a number of issues and challenges, especially for urban planners, to provide or plan for comfortable housing, public facilities and better infrastructure.

According to Mwirigi, Ikiugu, Kinoshita, and Tashiro (2012), in most developing countries, UGS has declined due to rapid urban expansion as much of the space has used to accommodate residential, commercial and industrial development activities. The continued and uncontrolled development trend will affect the fragmentation and disturbance of urban dwellers via floods, air and noise pollution, social and health issues (Kim, Lee, & Sung, 2016; Mansor and Harun, 2014). The views of some authors have also posted that as urban areas have expanded, the earth surface slowly fraction (Riffat, Powell & Aydin, 2016). Jafari et al. (2017) suggested that urban development should aim to be more self-sufficient in utilising resources rather than depleting resources drawn from areas outside the city. Within this context, it can be further argued that UGS should not be viewed as merely the 'left-over' or 'residual' spaces that have not yet been developed, but it should appreciate as spaces which function to give a life-support system to the city health environment.

In the city of KL, a tremendous change in land use activity had occurred since 1974 when the city was declared a Federal Territory Administrative area and the coverage expanded to 243 km^2 from its established area set in 1860 that was 0.65 km^2 (refer to Figure 1.2).

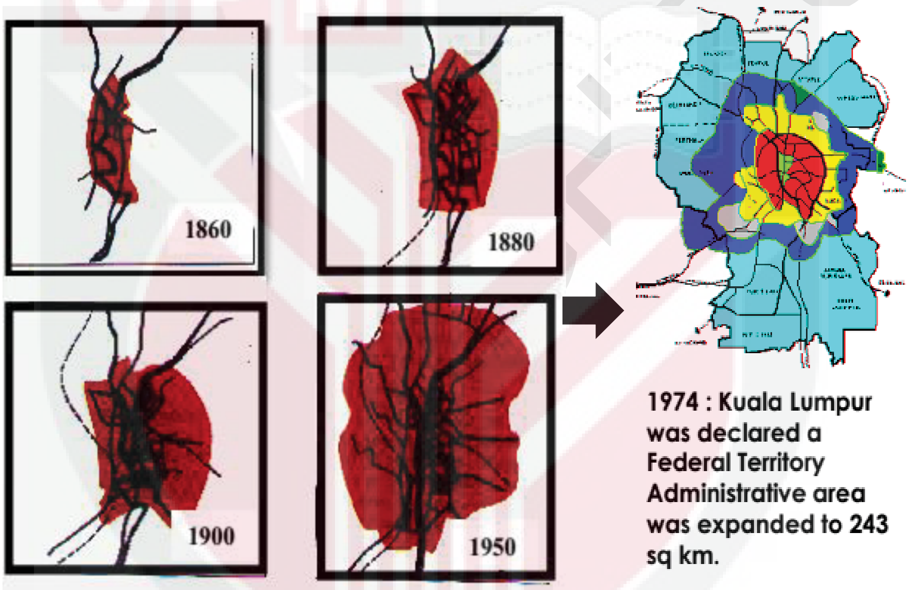

Figure 1.2 : Kuala Lumpur Development Changes Pattern
(Source: Kuala Lumpur Structure Plan 2000, 1984)

Since this period, more development began to levitate especially in the city's central zone from migration activity (Awang Besar et al., 2014). Uncontrolled development driven by high population density reduced most of the UGS in the city. According to previous research conducted in 2017, it statistically shows the green space coverage in KL has increased by 4%, from 6,215 ha in 2014 to 7,310 ha in 2016 due to the implementation of the "Greening KL Programme" under the Malaysia Economic Point Project (Kanniah and Chin, 2017) However, if looking at the green cover percentage in a particular forested area in KL, it was reduced by 9% from its gazetted zone (Kanniah, 2017). Yakob, Yusof & Hamdan (2012) reported that UGS in the KL city has mostly been converted to residential areas to achieve sustainable urban housing development.

Notably, throughout this period, the disappearance of UGS started to gain increasing attention from local residents protesting in the media; newspaper articles reported on current controversies, for instance, issues at Taman Bukit Kiara and Bukit Gasing (Berita Harian, 2017; Tan, 2015). Taman Bukit Kiara is one of the gazetted green areas that should have been preserved under the Kuala Lumpur Structure Plan 2020 strategies (KLCH, 2002). However, it has been converted into mix-use development with a six-lane road construction project connecting the Penchala Expressway to KL. The Harian Metro (2017) reported that local residents in Taman Tun Dr Ismail had submitted 500 petitions to KLCH to demonstrate their protest towards the loss of green spaces. Bukit Kiara, Bukit Gasing which is the only green lung left in KL, has been partially signified for development. Tan (2015) highlighted that the issues regarding slopes and the harm caused through the road surface near Bukit Gasing had been impacted by hilly bungalow development projects. The preservation of these green areas has been ignored as designated under the future master plan. The acquisitiveness of development not only rescinds the natural resource in the city but also damages recreational facilities. Yahya (2018) also highlighted the issue related to the football field in Bandar Tun Razak that will be converted to accommodate an affordable housing scheme project. The issues raised by urban dwellers is not only to protect the green space in these areas but raising concerns regarding the city's environment and awareness to consequential health issues.

Many researchers in various field and concern studied the increasing temperature of the KL scenario. It was the first touchdown by Sham. S. in the early 1970s. Then he has expanded the studies in 1972, 1973,1976,1985,1987 and 1991. He uses traverse technique to study the variance of KL intensity temperature and found that normally Kuala Lumpur city centre stated the higher temperature rather than its outer ring because of the human activities and dense concrete buildings. Siti Zakiah (2004) anticipated and explored more on Sham studies. She has improved the awareness on the improvement of outdoor living environment such increase the use of natural elements as a cooling effect for humidity. She has proved that the temperature taken at vegetated areas has reduced up to 10%-14% humidity and create a more comfortable place for people to stay longer rather than built-up areas.

Therefore, it demonstrates that the replacement UGS functionality in the city area has led to significant changes in local climate conditions. According to Elsayed (2012), six factors contribute to the cause of variable temperature distribution in KL, namely, the urban fabric, nature of the city structure, artificial heat production, evapotranspiration, unique property of the urban environment and human activities. Elsayed intended to raise awareness and to strategise, which necessitates land management and plant cover increment. His study reveals that KL is covered mostly by dark coloured surfaces like roofs, roads, parking and absorbs more heat during the day, radiating it at night. The city of KL should also incorporate the planning of trees to reduce the city's body of heat.

In another study, Isa et al. (2017) proposed a way to mitigate and help KL to reduce the amount of uncontrolled heat of the LST, by combatting the UHI. Their study showed that the distribution of KL's vegetation areas was partially less than half of the entire area of KL. Figure 1.3 illustrates the concentration of the green cover located on the outskirts of the city of 12.7% while built-up areas represent the remainder. The study found that the area covered by dense vegetation and matured trees tend to have a lower temperature than other places such as Kampung Baru and Bukit Damansara which are mostly covered by human-made features, of 36.2 ºC and 33 ºC, respectively.

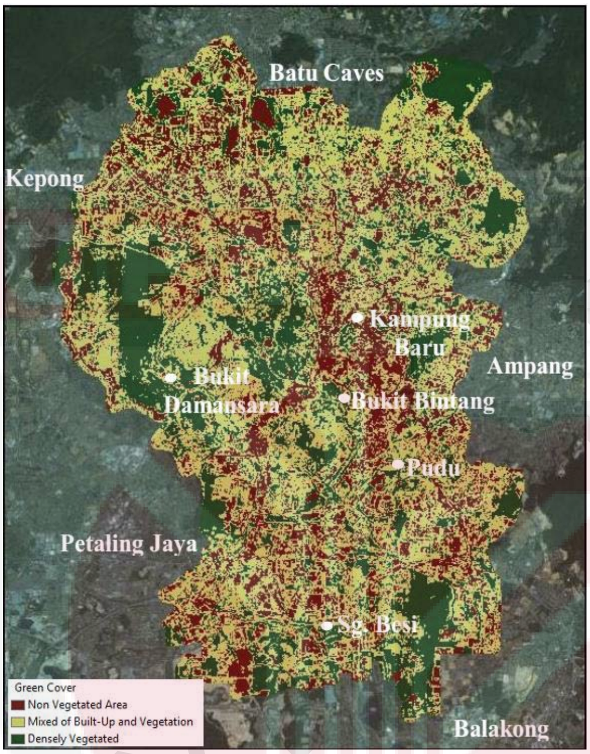

Figure 1.3 : Green Areas Distribution in Kuala Lumpur (Source: Isa et.al, 2017)

Furthermore, the increasing LST in KL has a strong relationship with the intensity of the built-up area's activity (Buyadi et al., 2013; Elsayed, 2012). The range of temperatures between the densely built-up areas with green areas of the same region can vary between 4 ºC and 6 ºC (The Star, 2015). This variation in temperature can lead to human discomfort and increase the consumption of cooling and associated costs. Thus, within the context of this argument, it is important to prevent and plan for the best form of cooling to mitigate the urban heat effect in KL by increasing the density of green space in the city. Moreover, there is a need for urban planners to have a systematic tool that integrates the body of knowledge regarding this issue that can be translated into an advanced technology solution. As such, it will offer alternatives for planners to manage, control and increase the presence of UGS in KL and indirectly help the city to reduce its heat body.

1.2.3 The Needs of Mapping Technology in UGS Planning and Urban Climatic Analysis

GIS has been applied in many fields and practices, including detecting land use transformation and heat temperature distribution. The technology is also used for managing, controlling and mapping the phenomenon and has been effectively used by planners to plan the city land resources. In the context of planning for UGS in KL, Mohd Yusof (2012b) suggested that urban planners require reliable and up-to-date database using GIS and high-resolution imagery to obtain transparent information and produce a systematic inventory of green spaces. Isa et al. (2017) recommended that KL city needs a new form of urban climatic analysis to translate the series of meteorological data into a simple form and understandable by planners and policymakers. The analysis should generate an advanced language that could project the variable temperature distribution in the city that correlates with the issue of UGS loss in gaining a more comprehensive understanding of the city's environment.

In KL, GIS has been used for more than ten years in the KLCH technical department, mainly in land use database development and for land parcel updating. However, in monitoring land use and variance of urban temperature which involves the aspects needed for analysis, they are not capable of assessing this data given the minimum storage at present to update the spatial database and instead is contingent on manual inventory records. Thus many local scholars and GIS experts help the local authority to form a view on the current phenomenon both on land-use changes and heat temperature distribution (Awang Besar et al., 2014; Buyadi et al., 2013; Ahmad, Hashim, & Jani, 2009). For example, a study by Mohd Noor et al. (2013) successfully developed GIS-based techniques for mapping green space distribution in KL using three series of RS images 1990, 2001 and 2009. The high-resolution aerial imagery was used to detect and acquire green space changes that covered ten years. The findings suggested that the city's UGS ratio has decreased due to the pressure of urban development, particularly for housing and infrastructure developments.

On the other hand, many scholars have attempted to develop real visualised scenarios on LST gradients in KL using various techniques, methods and by merging various software applications to obtain a reasonable output (Mohd Noor et al., 2013; Nurul Iman, Asmala, & Burhanuddin, 2014; Wang, Aktas, Stocker, Carruthers, Hunt, & Epshtein, 2019). However, it was an exceptionally long process, requiring high capacity and processing hardware, repeating procedures and multiple calculations, thus were prone to many mistakes. Therefore, it is crucial to introduce a new automated model that could simplify the process of analysing land changes, the extraction of the LST pattern and predict the scenarios using a single processing platform. Additionally, it could help to attract more researchers to expand the knowledge in this domain, particularly in prediction analysis that correlates between the subject of UGS and LST. Thus, this study recognises this issue as a point of departure to be explored further.

1.2.4 Research Gap

This study has identified several gaps from reviewing the research in this field. The first gap is in relation to the mapping, monitoring, and analyse of LULC changes, including UGS, and the applied classification and segmentation process. While various algorithms and methods can be used to produce a spatial land use classification and segmentation output, for instance, maximum likelihood classification (MLC), Quad Tree-based (QT) and Support Vector Machine (SVM) (Hsu, Chang, & Lin, 2010), the selection of a suitable classification algorithm depends on the data input, computer capacity, algorithm chosen and scale of the area (Kaur & Kaur, 2014). Most literature has used MLC and QT classifier with little consideration on processing time and performance in using appropriate hardware (Nurul Amirah Isa, Mohd, et al., 2017; Kanniah & Chin Siong, 2017; Taati, Sarmadian, Mousavi, Pour, & Shahir, 2015). Interestingly, SVM was proven to be the best algorithm that can perform accurately in land classification given its ability to handle the complexity of features and best assessment for separating the features into classes with maximum margin (Ullah et al., 2019a). However, at this stage, there are limited studies, particularly in the context of KL that use the SVM algorithm in the operational classification process. Therefore, given the consideration of hardware readiness and efficiency in producing accurate results, this study will adopt the SVM algorithm as the main generator for KL's land classification assessment.

Secondly, in the context of planning for UGS and environmental issues in KL, Mohd Yusof (2012b) suggested that urban planners need a highly valid and up-to-date database using a GIS supporting high-resolution imagery to obtain transparent information and to produce a systematic inventory of UGS. Furthermore, Isa et al. (2017) recommended that the city of KL needs a new urban climatic analysis that could translate the series of meteorological data into a simple form, able to be understood by urban planners and policymakers. The analysis should generate an advanced language that could project and predict the variance temperature distribution in the city that correlates with the issue of UGS loss for more sustainable planning in the future. Most previous studies focused on the past, and current scenarios such as UGS changes within particular periods, heat temperature for particular years and were limited in integrating these two issues in predicting the events in the future (Isa et al., 2017; Kanniah, 2015; Buyadi et al., 2014; Y. Kwak, 2016; Elsayed, 2012; H. Chang & T. Chen, 2015; W. Takeuchi & Hashim, 2015). Therefore, by considering the limitations of previous studies, the integration between the UGS issue and climatic conditions are investigated in the current study. Accordingly, it is anticipated that this study will contribute to the design of KL's City UGS in the future more effectively, by learning from the experiences of past environmental conditions aided by the use of advanced technologies. This study is expected to fill the gap in previous studies, particularly on the prediction of UGS change patterns and the effects on the LST gradient in KL city. To aid in gaining a better understanding of this process, Figure 1.4 presents a comprehensive diagram of the research gap.

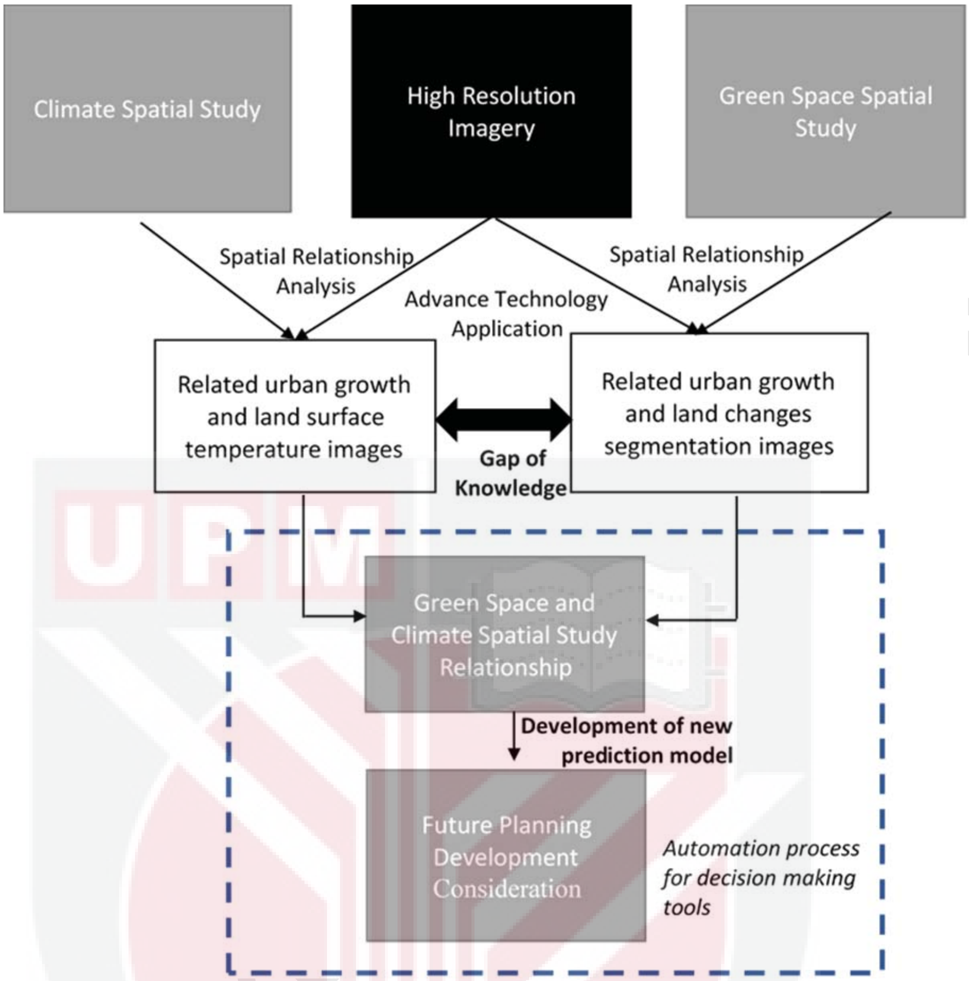

Figure 1.4 : Research Gap (Source: Author's Construct, 2018)

By reflecting and responding to the statements, discussions and research gap above, three main research questions are posited:

i. What is the spatial-temporal evolution of UGS over the past six years, and how much UGS loss is evident within the boundary of KL city?
ii. What are the changing patterns of LST for the past six years, and how do UGS changes contribute to the variance of the LST within the boundary of KL city?
iii. What is the main predictor used to predict UGS changes and its effect on the LST pattern for KL city, and the optimal spatial model technique that can be developed to analyse this scenario?

1.3 The aims and main research objective

This study aims to monitor the UGS changes and LST pattern in KL for the past six years and to develop an automated prediction model of this scenario for the year 2025 via temporal and spatial variation, using high-resolution aerial imagery data supported by the use of advanced technology mapping. In gaining a more in-depth understanding of the issues, the following research objectives are formulated:

i. To map the spatial-temporal evolution of UGS over the past six years and to examine the UGS loss within the boundary of KL city.
ii. To assess the pattern of LST change for the past six years and investigating the correlation between UGS changes and the effect on the LST within the boundary of KL city.
iii. To develop an automated spatial prediction model that used urban indices predictor in analysing the scenario of UGS changes and their effect on the LST pattern in KL city.

1.4 Research Significance

It is anticipated that the findings of this study will provide relevant information into land planning management which could enhance the existing practice as and stimulate a valuable discussion among city planners in KL. In preparation of receiving further pressure from the continual urbanisation process in the city, these findings could be used as a guide and reference towards the basic understanding of how urban planners could effectively plan and identify which UGS should be conserved and help in mitigating the heat temperature scenario for a further six years. The useful source of information from high-resolution aerial imagery could also help to provide transparent decision-making during the evaluation of the development plan on which potential green space should be preserved and which sites need to be green.

Similarly, the development of a novel spatial model technique could be used as a planning tool for local authorities to plan for UGS developments supported by a more comprehensive strategy. The model could also be expanded and used by other government departments and private agencies related to green space initiatives and practices. Generally, the main contributions of this study include the proposed methodology that combines multiple algorithms, tools and techniques to estimate future LST patterns according to UGS changes in KL city. This could be used as an analysis tool for urban planners and for landscape planning in developing the city with less UHI unsettling effects.

Moreover, given the emphasis of this study, it was decided that the research should concentrate on the UGS within the boundary of KL since the city was developed in the Klang Valley urban area and other parts of this region have also been affected by the loss of UGS. Likewise, the matured database and useful information for aerial imagery, land parcels, land use and meteorological data were also available for the KL area. This was accessed through the formal collaboration and permission with KLCH and the Malaysian Meteorological Department (MMD). Next, the UGS changes and LST pattern are analysed over a six-year period, referring to the KLCH's Strategic Plan, which adopted 5-10 years as a mature period for assessing city developments and achievements. Also, the RS data with clear images and with less cloud cover for KL were available within this timeframe and could be accessed via the USGS website at no charge.

Even though, the spatial patterns of urban thermal conditions have been studied by many scholars. comprehensive understanding of UGS that effects LST in a temporal change in a humid tropical area like KL is limited. Moreover, most published research has focused on a smaller area, for instance, Bukit Bintang, Kampong Bharu (Abd Aziz & Rasidi, 2012) or other strategic development zones in this city. Therefore, the outcome of this study can be used as one of the considered references for urban planners and landscape architects to manage KL's green spaces that could help the city towards mitigating the UHI effects in the future. Additionally, this study is also considered as providing new findings in the field of urban planning, which will contribute to future development in this area. This is because, most previous studies have focused on current scenarios such as UGS changes within particular periods, heat temperature for particular years and have failed to integrate these two issues in projection planning in future developments (Wang, Aktas, Stocker, Carruthers, Hunt, & Malki-Epshtein, 2019; Kanniah, 2017; Buyadi et al., 2013, Hashim et al., 2007). Thus, the output of this study could contribute to designing cities of the future with learnings from past experiences and by applying advanced technologies of the present era.

In conclusion, the main significance of this study and findings will help in developing a solution in UGS spatial analysis development that could reflect the influence of future heat distribution in KL urban environmental settings. Besides that, the new integration model that combines both UGS and LST into one comprehensive new prediction model could assist urban planners, decision-makers, and any related urban-climate field professionals and researchers to understand, analyse, monitor and manage UGS development to alleviate the LST gradient in a city.

In a global context, the output generated from this prediction analysis were believes could help Malaysia pledged in Paris Agreement, 2015 to reduce the country's carbon emission intensity by 45% by 2030 (KL LCSBP 2030). As capital city of Malaysia, KL presents huge potentials to implement Nationality Determined Contribution (NDCs) particularly on the global effort to mitigate climate change effects through various initiatives, planned and action to conserve green areas. The analysis presented in this study could makes an equitable contribution towards global effort to stabilise heat gradient through identification of future preservation area of UGS in the city.

1.5 Scope of The Study

This research utilised RS data to map, monitor and detect UGS changes and LST pattern distribution in KL City, Malaysia. In this study, the period between 2014 and 2019 was considered to analyse these two parameters given first, the availability of the 'Landsat' image for KL used in carrying out the LST analysis and second, the rapid construction period that occurred between these years; barer land and earthwork could be detected on green space areas, particularly regarding affordable housing developments activity (KLCH, 2018). Two types of imagery used to carry out the analysis related to the years 2014, 2016 and 2019, which are orthophotography and Landsat images. The orthophotography data were used to classify and extract the UGS areas, given its capability to provide details on captured land objects. Besides that, the orthophotography image used was geometrically corrected based on KL projections which are in the Geocentric Datum of Malaysia 2000 (GDM 2000), thus ensuring that the land object(s) could be segmented precisely within the boundary area. In the classification analysis, Support Vector Machines (SVM) was chosen as the classification algorithm given its capability in providing high accuracy thus increasing the percentage of the object(s) segmented compared to other methods (Li and Shao, 2014; Taati, Sarmadian, Mousavi, Pour, & Shahir, 2015). However, in the segmentation and classification analysis, this study did not capture the vertical UGS area due to the various green orientation attached to the buildings. In KL, the vertical green areas are not only provided on rooftops but also between floors and at the edge of buildings; thus, this scenario required a three-dimensional view analysis based on micro-scale analysis.

Furthermore, in this study, the temperature distribution was analysed based on the land surface form and not on the atmospheric form because it was unable to obtain the data from meteorological stations inside the city, thus providing limited access to validate the model. Moreover, heat islands could be more accurate to predict based on the land surface form because it is widespread throughout the days as the constant heat energy being observed from the sun (United States Environmental Protection Agency [EPA], 2012). In contrast, the atmospheric temperature was influenced by heat flux since it depends on the weather for certain periods. Here, hot spells can be weak during or at late morning and throughout the day and become more pronounced after sunset due to slow release of heat from urban activity. Therefore, given this fact, and for justification purposes, the temperature for KL was analysed based on the land surface form at a city level which excludes other atmospheric factors such as humidity. The LST data was retrieved from Landsat 8 Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS) Collection 1 Level-1 data from the United States Geological Survey (USGS) website. Landsat 8 is the latest Landsat series and launched on 11th February 2013 by National Aeronautics and Space Administration (NASA). The KL data was only available and captured from 2014 onwards; this study used this year as the starting point for the analysis stage. According to Li and Jiang (2018), Landsat 8 is suitable for LST analysis as it provides two thermal infrared sensors (TIRS) with moderate resolution from 100 metres for thermal mapping and capturing estimated soil moisture.

1.6 Organisation of The Study

The current thesis is organised into six chapters with the summary of the research design illustrated in Table 1.1 below, along with the strategy to extract the materials needed in developing this academic paper. Chapter 1 has presented an overview of UGS changes and the impact towards LST in KL with a particular focus on describing the research aims, research questions and objectives. Chapter 2 presents and discusses the literature review and the development of the theoretical framework. The chapter begins by defining the benefits and definition of UGS, exploring land changes factors as well as the LST theory and fundamental elements with reference to previously published research. The chapter continues by reviewing the use of RS and GIS applications for measuring UGS and LST, respectively. several techniques and methods used for land classification, climatic mapping and the prediction model that applies the CA-Markov model are also discussed.

Chapter 3 analyses the first objective of this study, as presented in Chapter 1, which is mapping the spatial-temporal evolution of UGS over the past six years and to examine the UGS loss within the boundary of KL city. In this chapter, the spatial technique used, and parameters used in the experiments via the ArcGIS platform are presented. This is followed by Chapter 4 that discusses the findings related to the second objective, which is to assess the pattern of LST change for the past six years and investigating the correlation between UGS changes and the effect on the LST within the boundary of KL city. Chapter 5 discusses the development of an automated prediction model of UGS changes and its effect on the LST pattern in 2025. Chapters 3-5 are structured in the following sequence: Introduction, research methodology, results and discussion, and conclusion and recommendation. Finally, Chapter 6 summarises all findings, along with recommendations and suggestions for future research.

Table 1.1 : Summary of research design

Research Aim	To monitor the UGS changes and LST pattern in KL for the past six years and to develop an automated prediction model of this scenario for the year 2025 via temporal and spatial variation, using high-resolution aerial imagery data supported by the use of advanced technology mapping.				
Problem Statement Summary	The issues described in this study are discussed regarding the degradation of UGS, and changes over six years and how this scenario can potentially contribute to the variation of the LST gradient in KL city. Monitoring the many UGSs within the entire city of KL is important to enhance present information which may enable city planners and other related urban-climatic fields to understand the loss of UGS in KL city, updating the spatial view and data. Besides that, limited studies have used advanced technologies for mapping in determining the prediction of UGS patterns and its effect on LST pattern particularly in KL city, Malaysia				
Main RQ	What is the spatial-temporal evolution of UGS that has been loss for the past six years and the impact on LST pattern in developing this prediction scenario for KL city?				
RQ CONSTRUCT	**CONSTRUCT DESCRIPTION**	**ACTIVATING INQUIRY APPROACH (Sub-RQ/RO)**	**STRATEGY OF INQUIRY**	**TECHNIQUES OF ANALYSIS**	**TARGETTED OUTPUTS**
Who	UGS	**Sub-RQ1:** What is the spatial-temporal evolution of UGS over the past six years within the boundary of KL city? **Sub-RO1:** To map the spatial-temporal evolution of UGS over the past six years within the boundary of KL city	Literature, documentation related to KL - UGS historically and existent spatial database, KL development plans, Landsat imagery source, GIS application,	Remote sensing and GIS spatial analysis through segmentation and classification techniques.	Spatial map of UGS classification for 2014, 2016, and 2019.

Table 1.1. Continued:

		Sub-RQ2: How much UGS loss is evident within the boundary of KL city **Sub-RO2:** To examine the UGS loss within the boundary of KL city	Literature, documentation related to KL - UGS historical and existent spatial database, KL development plans, Landsat imagery source, ArcGIS application, MS Excel.	Remote sensing and GIS spatial analysis through segmentation and classification techniques.	Spatial map of UGS changes for six years and statistics of gain and loss.
What	LST	**Sub-RQ3:** What are the changing patterns of LST for the past six years within the boundary of KL city? **Sub-RO3:** To assess the pattern of LST change for the past six years within the boundary of KL city.	Literature, Landsat imagery source, ArcGIS application, MS Excel.	Remote sensing and GIS spatial analysis through LST equation and algorithm (map algebra).	Spatial map of LST changing pattern for 2014, 2016, and 2019, statistics of LST differential changes.
		Sub-RQ4: How do UGS changes contribute to the variance of the LST within the boundary of KL city? **Sub-RO4:** Investigating the correlation between UGS changes and the effect on the LST within the boundary of KL city	Literature, Landsat imagery source, ArcGIS application,	Remote sensing and GIS spatial analysis through spatial autocorrelation analysis.	Spatial autocorrelation map of LST and UGS.

Table 1.1. Continued:

How	Prediction Scenario	**Sub-RQ5:** What is the main predictor used to predict UGS changes and its effect on the LST pattern for KL city? **Sub-RO5:** To used urban indices predictor in analysing the scenario of UGS changes and their effect on the LST pattern in KL city.	Literature, KL development plans, Landsat imagery source, the Model builder in ArcGIS application, QGIS application through Molusce plugin.	Remote sensing and GIS spatial analysis through ANN-CA Model.	Calculation using combination of urban indices parameter to predict UGS changes and LST pattern for the next six years (2025), and automate the analysis using model builder in ArcGIS.
		Sub-RQ6: What is the optimal spatial model technique that can be developed to analyse this scenario? **Sub-RO6:** To develop an automated spatial prediction model that used urban indices predictor in analysing the scenario of UGS changes and their effect on the LST pattern in KL city.	Literature, KL development plans, Landsat imagery source, the Model builder in ArcGIS application, QGIS application through Molusce plugin.	Remote sensing and GIS spatial analysis through ANN-CA Model.	Spatial map of UGS prediction and LST prediction for the next six years (2025), automated processing for all analysis development.

(Source: Adapted from Ibrahim, 2011)

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