THE RELATIONSHIP OF HERITAGE TREES IN URBAN HEAT ISLAND MITIGATION EFFECT AT TAIPING, PERAK, MALAYSIA

Nor Suhaida Yusof[1], Nur Huzeima Mohd Hussain[2], Noradila Rusli[3]

[1]Centre of Postgraduate Studies, Faculty of Architecture, and Surveying, Universiti Teknologi MARA, Seri Iskandar Campus, Seri Iskandar, 32610, Perak, Malaysia.

[2]Department of Landscape Architecture, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Seri Iskandar Campus, Seri Iskandar, 32610, Perak, Malaysia.

[3]Center of Study for Surveying Science and Geomatic, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Arau Campus, Arau, 02600, Perlis, Malaysia

[1]norsuhaidayusof90@gmail.com
[2]nurhu154@perak.uitm.edu.my
[3]noradilarusli@perlis.uitm,edu,my

Received: 22 December 2017
Accepted: 1 February 2018

ABSTRACT

Every tree species provide different cooling effect depending on their tree characteristics. Evergreen species such as heritage trees are significant in reducing the surface temperature. The aim of this paper is to determine the relationship of heritage trees in mitigating urban heat island at Taiping Old Town. The research had been conducted through Landsat 8 OLI and field data collection. This research integrated the Geographic Information System (GIS) and remote sensing in data processing and analysis. The results show the low significant relationship of tree characteristics and Land Surface Temperature (LST) with (R^2=0.17) which indicate that external factors may also influence the changes in temperature.

Keywords: Heritage Trees, Thermal comfort, Urban Heat Island (UHI), Tree Characteristics

INTRODUCTION

The eagerness of mankind to explore the living environments and create new settlements transformed for human needs has resulted in the establishing of the villages, towns and cities to meet the requirements of mankind regarding society, economy, culture and comfort (Shahidan, 2011). The new building structures and materials in the area of urbanisation have led to the undesirable changes in the natural ecosystem and landscape of the environment. As a result, the heat was reflected by the urban surfaces that will increase the temperature compared to the surrounding area. This phenomenon is known as Urban Heat Island (UHI) which will reduce human comfort and also could increase energy consumption in the buildings (Hashim, Ahmad, & Abdullah, 2007). The strategies in mitigation of the UHI have become an important issue in terms of energy saving and thermal comfort of human and environment (Akbari, Pomerantz, & Taha, 2001; Kong et al., 2016). One of the adaptive strategies that had been addressed by many researchers is to increase the amount of vegetation cover in the urban area (Dewan & Yamaguchi, 2009; Shahidan, 2011; Kong et al.,2016).

In tropical cities, the strategies of urban greening design could give the effect of providing shade and coolness to the outdoor environment (Tan & Ng, 2014; Abreu-harbich, Chebel, & Matzarakis, 2015; Lin, & Tsai, 2017). The results revealed that the effect of larger temperatures in the urbanised area as compared to surrounding areas with relatively have a larger amount of vegetation (Hashim et al., 2007). The previous studies revealed that the spatial variability of urban Land Surface Temperature (LST) depended on the land use and land cover on the urban surface types, which are the vegetated area covered by trees, grass, scrub and parks consistently have a cooler temperature than the surface area covered by stone, concrete and buildings. Thus, the contribution of vegetation cover is important in reducing heat in the city. Removal and replacement of vegetation cover by various built-up structures influence the impact to the environment which cause environmental pollution, climate change and breakdown of ecological cycles.

To minimise these adverse environmental effects, the problems need to be identified and proper implementation of urban planning systems need to be taken in terms of sustainable solutions (Senanayake, Welivitiya,

& Nadeeka, 2013)which use low albedo materials leading to high heat absorption in urban centres. In addition, removal of vegetation cover and emissions of waste heat from various sources contribute to the accumulation of heat energy, leading to formation of urban heat islands (UHIs. Thus, the impact of urban tree design and tree species on the enhancement of outdoor thermal comfort to the environment has been investigated (Tan & Ng, 2014). The strategic placement of trees and green infrastructure can reduce the UHI and air temperature between 2ºC and 8ºC (Doick & Hutchings, 2013). This is because the cooling effect of vegetation is different between tree species which involve numerous factors on tree characteristics and urban design (Abreu- Harbich et al., 2015; Chen & Yu, 2016). For example, the cooling effect is mainly determined by the canopy spread, leaf size and arrangement, tree height, bole height, solar radiation and the leaves properties (Leuzinger, Vogt, & Ko, 2010; Abreu-harbich et al., 2015; Kong et al., 2016; Lin et al., 2017).

Heritage trees have environmental implication which provide numerous benefits for the environment as well as for human health (Sreetheran, Adnan, & Azuar, 2011). Urban Heritage trees are considered to be the canopy layer of vegetation whereby the tree features of heritage trees comprise old trees (nearly and over 100 years), big (height, crowd spread and diameter breast height (DBH)), high density coverage and evergreen (Jim, 2005). The findings from Abreu-harbich et al., (2015) on vegetation parameters on their thermal control strategies, the tree species which are dominant on the plagiotropic trunk and branching structure, tall, has large coverage and small leaves that are a bipinnate type and linear shape that provide cooling effects.

Therefore, the aim of the study is to define the relationship of heritage trees in mitigating urban heat island at Taiping Old Town. The relationship between Land Surface Temperature (LST) and heritage trees thermal comfort parameter will be investigated to determine the internal and external factors of heritage trees toward mitigation of UHI.

UNDERSTANDING THE HERITAGE TREES AND URBAN HEAT ISLAND (UHI)

Heritage Trees

In urban warming mitigation, vegetation can be considered as one of the effective measures for both macro and micro-level in creating “oasis effect” to the environment in reducing the temperature (Akbari et al., 2001). This paper will discuss the role of heritage trees in reducing the UHI phenomenon in tropical cities. There have been several literature reviews on the importance of preserving heritage trees because of their special characteristics to the environment and social impact. The natural and cultural characteristics of heritage trees are dominant in urban cultural landscape and society which required the protection policy (Wan Ali, Hassan, & Hassan, 2016). The heritage tree is known as an ancient, beautiful, old, historic, exotic, landmark and veteran trees (Jim, 2004; Wan Ali et al., 2016). As defined by Jim (2005), the heritage tree are old trees (nearly and over 100 years), large size on their crown spread and diameter of breast height. Some of the special characteristics of heritage tree include being able to survive for decades to centuries, having a big structure and able to survive urban stress.

Urban Heritage trees are considered to be the canopy layer of vegetation. The different vegetation layers are differentiated by the height of trees which include emergent layer (usually on highland), canopy layer (lowland trees), understory layer, shrub layer and ground layer (see Table 1). Heritage trees play the appropriate ecological-landscaping roles in urban areas. Heritage trees have high resource values and can make significant contributions to the society and environment. The benefits include improvement of energy consumption to the building, air and water quality, cooling effect, and ultraviolet radiation reduction (Jim, 2004; Jim, 2006).

Table 1: Vegetation Parameter of Thermal Control Based on Layer of Vegetation

Layer of Vegetation	Vegetation parameters				
	Crown Geometry	Height	Trunk Geometry	Permeability	Leaves
1. Emergent Layer (usually on highland)	/	/	/	/	/
2. Canopy Layer (lowland Trees)	/	/	/	/	/
3. Understory Layer		/			
4. Shrub Layer					
5. Ground Cover					/

Urban Heat Island (UHI) Effect

Urban Heat Island (UHI) can be defined as the rise of temperature in any man-made area causing these areas to be significantly warmer than the surrounding countryside especially at night (MetOffice, 2012). According to the Dictionary of Landscape Architecture and Construction (Shahidan, 2011), the definition of urbanisation is the process of covering the significant portion of the land area with impervious pavements and concreted buildings. The negative impact of UHI not only relates to the urban area and environment but also affects human health and their associated ecosystems. In fact, UHI has been indirectly related to climate change because of its contribution to the level of Carbon Dioxide (CO_2) that led to the greenhouse effect and global warming.

In UHI phenomenon for the urban environment, two types of UHI categories have been simplified by Roth, (2002) and Shahidan, (2011) namely, air temperature UHI and surface temperature UHI. Usually the air temperature UHI is found beneath the air layer and the air layer is beneath the roof layer. On the other hand, the surface temperature UHI is found in the urban horizontal surface such as ground surface, rooftop, vegetation and bare soil (Shahidan, 2011). For the data collection of air temperature: UHI required the in-situ measurement from the fixed station and mobile traverse to monitor the air temperature trend (Lin & Tsai, 2017). On the other hand, the satellite images from remote sensing thermal data are used in measuring the surface temperature UHI by generating the LST distribution value (Hashim et al., 2007).

UHI Studies

The interest in UHI studies has rose among researchers to improve the surface temperature impact on energy balance in the urban and rural landscape (Rogan, Ziemer, & Ratick, 2015). Asaeda and Vu (1996) had studied the pavement materials like concrete and asphalt, known as emitting additional heat energy from 150Wm² to 200Wm² respectively, which significantly affected the land surface temperature on the ground. The temperature is often higher, warmer, more or less humid, shadier, and has reflected more sunlight than the climate of the surrounding land areas. According to Goggins (2009), stated that from U.S Census Bureau, the densely settled census blocks for the urban area with a population that is at least 2,500 people. Typically the urban area contains many man-made surfaces and structures such as buildings and roadways known to have much higher capacities of heat storage than natural and vegetated surfaces. The formations of UHI are strongly dependent on urban surface types. The study had revealed that the areas covered by vegetation such as trees, grass, shrubs and parks are cooler than the surface covered by concrete, stone and building (Rogan et al., 2015). Therefore, the landscape planning and urban cover play an important role in mitigating the UHI to create good thermal comfort to the environment. Table 2 shows the summary of UHI research based on the vegetation and the impact of tree species on the cooling effect of the environment. The study also shows that the land surface covered by the man-made features replaced the vegetated area could increase the surrounding temperature. On the other hand, the tree species which are dominant in the vegetation parameters for cooling effect could decrease the surface temperature in the urban area.

Table 2: Summary of UHI studies

Data	Thermal results	Location	References
Physiologically Equivalent Temperature (PET)	When average crown diameter is shorter than 1.5m, PET was higher than 40ºC and SVF larger than 0.411	Chiayi Park, Taiwan	Lin & Tsai, 2017
Landsat TM	Urban Landscape influences surface thermal urban variation (STUV)	Guangzhou, China	Chen & Yu, 2016

Terrestrial Laser Scanner (TLS)	Small-leaved species tend to have a more effective cooling effect.	Nanjing, China	Kong et al., 2016
ENVI-met Simulation	Contribution of trees in mitigating human heat stress compared to grassland by 2.7 K	Freiburg, Germany	Lee et al., 2016a mid-size city in Southwest Germany. It is characterised by residential buildings and street canyons with asphalt surfaces, grasslands and broad-leaved trees. The ENVI-met model was validated against human-biometeorological measurements and demonstrated good performance when simulating the urban thermal environment in terms of air temperature (Ta
Physiologically Equivalent Temperature (PET)	The species C. Pluvious F. can reduce PET 12ºC and 16ºC for individual and 12.5ºC and 14.5ºC for cluster	Campinas, Brazil	Abreu-harbich et al., 2015
Landsat 5 Thematic Mapper (TM)	By 39% tree lost due to urban development, the LST increase 2.6ºC	Worcester, Boylston	Rogan et al., 2015
ENVI-met model	Lower SVF (0.2-0.3), cooler temperature	Sham Shui Poi, Hongkong	Tan & Ng, 2014
Remote sensed thermal camera (varioCAm ,Infratec, Dresden)	Small-leaved size lead to cooler temperature	Basel, Switzerland	Leuzinger et al., 2010
Landsat ETM+	LST increase 5.94ºC when the stone and concrete replaced vegetated area	Indianapolis, IN	Weng et al, 2000

UHI Studies in Malaysia

Malaysia has a tropical climate which has the uniform temperature of high humidity, plentiful rainfall and light winds. Malaysian coordinates at 2º30' North latitude and 112º30' East Longitude and is part of South -East of Asia on the equator. The hot humid climate in Malaysia leads to a very hot summer during the drought and heavy rainfall during the North-East monsoon season (MMD, 2010). In Malaysia, the research on urban climate had been studied since 1972 until the present. The first study on urban climate in Malaysia was investigated by Sham in 1972 and 1973 when he used to study the urban microclimate in Kuala Lumpur using the temperature traverse method. In the study, it was found that the temperatures were higher in urban areas compared to the temperature in rural areas around the city and UHI intensity had increased during the night than during daytime. Then, the research from Jahi (1974) found that the UHI intensity existed in Kuala Lumpur between 2ºC to 3ºC (Shahidan, 2011).

Table 3 shows the UHI studies in Malaysia were carried out by researchers in other cities in Malaysia. The study stated the UHI intensity had increased in the urban area than the rural area up to 4 ºC -6° C. Furthermore, the increasing urban temperature influenced the air pollution and energy demand which then affected the environment and human life.

Table 3: UHI Studies in Malaysia

Location Study Area	UHI Studies	References
Kuala Lumpur	4 ºC to 5.5 ºC UHI intensity	Ilham S.M. Elsayed, 2005
Selangor	Heat greater than 24ºC at the land covered by building	Ahmad & Hashim, 2007
Kuala Lumpur	4 ºC -6° C of UHI intensity influencing air pollution and energy demand	Elsayed, 2012
Muar	UHI intensity 4 ºC during the day and 3.2 ºC during night time.	Rajagopalan, Lim, & Jamei, 2014
Putrajaya	UHI intensity 2.6 ºC	Shahidan, 2011
Iskandar Malaysia	1% vegetated area increase, 0.09 ºC LST decrease	Suherman et al., 2016

A Study of Taiping

The town of Taiping is well-known as having the highest humidity index in Peninsular Malaysia and is in the limelight for being recognised as a historical heritage town. The climate in Taiping can be categorised as a tropical rainforest climate in a hot-humid climate (Ali et al., 2016). The average annual rainfall between the Peninsular and Taiping is different as the average rainfall in Taiping is about 3000mm while the average rainfall for the Peninsular is about 2000 mm to 2500 mm. The range of temperature in Taiping is 24 ºC to 34ºC and the warmest months at Taiping are between the months of March until October with an average temperature of 31ºC (Climatedata.org). Figure 1 below shows the average temperature at Taiping old town city in the year 2016 which shows that it reached a high temperature in the middle of the year.

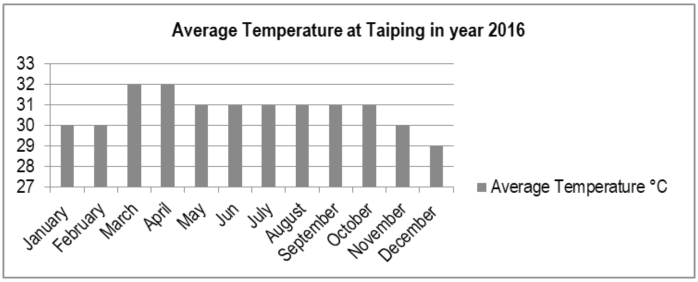

Figure 1: The Average Temperature in Taiping for Year 2016

(Sources: Climatedata.org)

Traditionally, the data of temperature is collected at the meteorological stations to analyse the formation of UHI. However, since the 1960s, remote sensing technology provides extensively primary information use in calculating the Land Surface Temperature (LST) for UHI analysis. In this research, the remote sensed data from Landsat 8 OLI is used to determine the UHI existence at Taiping. LST retrieved from the Landsat satellite images from the thermal infrared band is widely used in the urban thermal environment studies (Suherman et al., 2016).

DATA AND METHOD

Generating Land Surface Temperature (LST) from Remote Sensed Data

The data used for LST generation were obtained from Landsat 8 OLI (30/3/2016) which was downloaded from USGS website. The Landsat image was chosen based on limited cloud cover and during summer in order to generate stronger warming effect of UHI (Rogan et al., 2013). The thermal band in Landsat 8 OLI at band 10 (10.60 µm -11.19 µm) and band 11 (11.50 µm -12.51 µm) with the spatial resolution 30m (Department of interior U.S. Geological Survey (USGS), 2016). The Landsat 8 OLI also was georectified into WGS 84 coordinate system. The LST was generated by ERDAS Imaging software using the formula where all the information of Landsat 8 OLI was downloaded together with the images in (.txt) file. The equation (1) (Department of interior U.S. Geological Survey (USGS), 2016) shows the formula of LST to generate the LST distribution from Landsat 8 OLI.

$$\text{Ts} = \frac{K_2}{In\left(\frac{K_1}{L\lambda}+1\right)} = (1)$$

Where: T = The brightness temperature in Kelvin (k)
$L\lambda$ = TOA spectral radiance
K_1 = Constant thermal band
K_2 = Constant thermal band

Field Data Collection

The study area were divided into three zones that include A, B, and C (see figure 2) and were selected based on the temperature variation of LST distribution map which was generated from Landsat 8 OLI image. The study area was also selected based on the location of heritage trees which mostly covered the streets in Taiping old town. The data were collected in May 2017 (18 May 2017-22 May 2017) and September 2017 (22 September 2017- 25 September 2017) because of the range of the warmest months at Taiping. There are three species of heritage trees which are Samanea Saman, Pterocarpus Indicus and Swietenia Macropylla where were covered at the study area. The tree characteristics, such as crown diameter (m), tree height (m), diameter breast height (m), tree species, and coordinates of the trees were measured. The tree heights were measured using clinometer which measured the vertical angle and horizontal distance. The vertical angle was measured from the base of the tree until the tip of the tree and the diameter of breast height was taken using tape from 1.4 m from the ground (Ali et al., 2016). The crown diameter was measured using tape from the north-south axis and east-west axis and calculated using arithmetical mean (Lin & Tsai, 2017). The coordinates of each heritage tree is also taken using GPS Garmin. All the spatial and attribute data of heritage trees characteristics were analysed in Geographic Information System (GIS) using ArcGIS software.

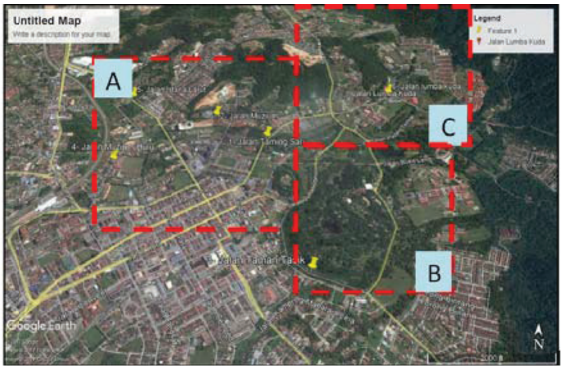

Figure 2: Measurement Sites of Study Area

RESULTS AND FINDINGS

The results of the study are shown in figure 3 that include the LST distribution, heritage trees and features of study areas. From the result below, it shows that the average temperature at Taiping old town was 29°C. The map also included the heritage trees spatial data along with the features of buildings, roads and water bodies. From the temperature variation, it shows the high temperature at the hard surface where the surface was covered with the concrete buildings. The temperature at the park was cooler than around the building with the temperature around 24°C -27°C as compared to when the heritage trees were planted around the building with the temperature around 31°C-34°C.

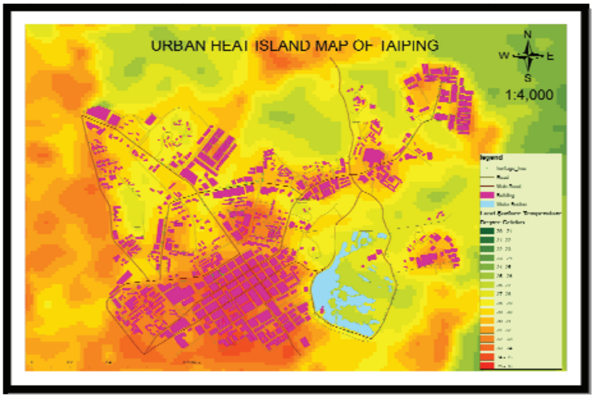

Figure 3: Urban Heat Island Map of Taiping

The Relationship Between Crown Diameter, Diameter Breast Height (DBH) and Tree Height

The database of heritage trees consist 206 trees which were surveyed in the study area. According to the database, the average crown diameter is 21.19m. Meanwhile, average of tree height is 19.36m and the average of DBH is 1.21 m. The interpretation from the map in figure 2 shows that the species of Samanea Saman were planted along the streets at Garden Lake and the majority of the tree species of Pterocarpus Indicus were planted along the streets near the compact buildings along with the tree species Swietenia Macropylla.

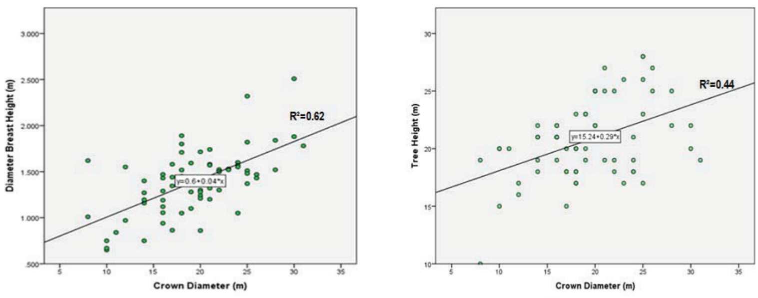

Figure 4: The Relationship Between Crown Diameter Versus DBH (a) and Crown Diameter Versus Tree Height

Figure 4 shows the relationship between crown diameters, DBH and tree height of heritage trees in the study area. From the results, it shows in figure 4(a); the given regression coefficient (R^2=0.62) which demonstrated a high correlation between the crown diameter and DBH of heritage trees in the study area. Figure 4(b) shows the relationship between the crown diameter and tree height which the regression coefficient is (R^2=0.44) that indicated the medium relationship between crown diameter and tree height. The conclusions from the results of figure 3 shows the positive linear relationship for both DBH and tree height with crown diameter.

Relationship Between Crown Diameter and Land Surface Temperature (LST)

Figure 5 shows the relationship between crown diameter and LST in the study area. The regression coefficient (R^2=0.17) shows the small relationship between the crown diameter of heritage trees and LST in the study area.

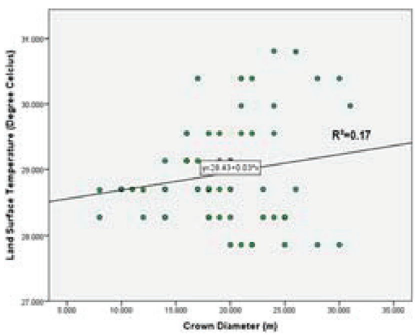

Figure 5: The Relationship Between LST and Crown Diameter

This result indicates the heritage trees which are dominant in the vegetation parameter, for thermal comfort to the environment, are able to slightly contribute to the reduction of temperature. This is because the modification and ground surface give the high significant in influencing the temperature variation (Shahidan, 2011). Furthermore, in order to improve cooler temperature to meet the thermal comfort is not easily controlled by tree characteristics (Lin & Tsai, 2017). They were influenced by various external factors in changes of temperature around the heritage trees which made it difficult to provide a cooling effect to the environment.

CONCLUSION

This paper aims to study the relationship of the heritage trees in mitigating Urban Heat Island (UHI). Based on the literature review, vegetation species play a significant role in reducing the land surface temperature (LST) as well as mitigating the formation of urban heat island (UHI). Furthermore, the heritage trees are dominant in the vegetation parameters on thermal cooling effect based on their tree characteristics. The features of the heritage trees that have large structures, large density coverage and can excel in urban stress can contribute to the cooling effect to the urban area. However, the heritage trees give the minimum significant on giving the cooling effect to the environment because the temperature is mostly influenced by urban design and ground surface. The external factors that include the water bodies, concrete surfaces, streets and buildings contribute to the increase in temperature and give the impact on the trees in reducing the surface temperature in the urban area.

ACKNOWLEDGEMENT

This paper is based on an ongoing research. The authors would like to express their sincere appreciation to Universiti Teknologi Mara (UiTM) for providing the material support and to all subjects who volunteered to participate in this study.

REFERENCES

Abreu-harbich, L. V. De, Chebel, L., & Matzarakis, A. (2015). Effect of tree planting design and tree species on human thermal comfort in the tropics. Landscape and Urban Planning, 138, 99–109.

Ahmad, S., & Hashim, N. M. (2007). Effects of Soil Moisture on Urban Heat Island Occurrences: Case of Selangor, *Malaysia. Humanity & Social Sciences Journal, 2*(2), 132–138.

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Solar Energy, 70(3), 295–310.

Chen, Y., & Yu, S. (2016). Impacts of urban landscape patterns on urban thermal variations in Guangzhou, China. International Journal of Applied Earth Observation and Geoinformation, 54, 65–71.

Department of interior U.S. Geological Survey (USGS). (2016). Landsat 8 (L8) Data Users Handbook. America (2nd ed., Vol. 2). Sioux Falls, South Dakota, U.S: EROS, LSDS-1574.

Dewan, A. M., & Yamaguchi, Y. (2009). Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. Applied Geography, 29(3), 390–401.

Doick, K., & Hutchings, T. (2013). Air temperature regulation by urban trees and green infrastructure. Forestry Commission, (February), 1–10. Retrieved from http://www.forestry.gov.uk/pdf/FCRN012.pdf/$FILE/FCRN012.pdf.

Elsayed, I. S. M. (2012). Mitigation of the Urban Heat Island of the City of Kuala Lumpur, Malaysia. Middle-East Journal of Scientific Research, 11(11), 1602–1613.

Goggins, G. (2009). Impacts of city size and vegetation coverage on the urban heat island using Landsat satellite imagery. Retrieved from http://proquest.umi.com/pqdweb?did=1707360601&Fmt=7&clientId=18803&RQT=309&VName=PQD.

Hashim, N., Ahmad, A., & Abdullah, M. (2007). Mapping urban heat island phenomenon: Remote sensing approach, 25–30.

Ilham S.M. Elsayed. (2005). A Study on the Urban Heat Island of the city of Kuala Lumpur, Malaysia.

Jim, C. Y. (2004). Spatial differentiation and landscape-ecological assessment of heritage trees in urban Guangzhou (China), 69, 51–68.

Jim, C. Y. (2005). Outstanding remnants of nature in compact cities : patterns and preservation of heritage trees in Guangzhou city (China), 36, 371–385.

Jim, C. Y. (2006). Valuation of Heritage Trees in Compact City, 53–80.

Kong, F., Yan, W., Zheng, G., Yin, H., Cavan, G., & Zhan, W. (2016). Agricultural and Forest Meteorology Retrieval of three-dimensional tree canopy and shade using terrestrial laser scanning (TLS) data to analyze the cooling effect of vegetation. Agricultural and Forest Meteorology, 217, 22–34.

Lee, H., Mayer, H., & Chen, L. (2016). Contribution of trees and grasslands to the mitigation of human heat stress in a residential district of Freiburg, Southwest Germany. Landscape and Urban Planning, 148(January), 37–50.

Leuzinger, S., Vogt, R., & Ko, C. (2010). Tree surface temperature in an urban environment, 150, 56–62.

Lin, Y., & Tsai, K. (2017). Screening of Tree Species for Improving Outdoor Human Thermal Comfort in a Taiwanese City. Sustainability.

Met Office. (2012). Urban Heat Islands (UHIs). Retrieved from http://www.urbanheatislands.com/

MMD (2010). Malaysia Meteorological Department, Meteorological databases, Malaysia.163.

Rajagopalan, P., Lim, K. C., & Jamei, E. (2014). Urban heat island and wind flow characteristics of a tropical city. Solar Energy, 107, 159–170.

Rogan, J., Ziemer, M., Martin, D., Ratick, S., Cuba, N., & DeLauer, V. (2013). The impact of tree cover loss on land surface temperature: A case study of central Massachusetts using Landsat Thematic Mapper thermal data. Applied Geography, 45(March), 49–57.

Rogan, J., Ziemer, M., & Ratick, S. (2015). The impact of tree cover loss on land surface temperature : A case study of central Massachusetts using Landsat Thematic ... Applied Geography, 45(March), 49–57.

Roth, M. (2002). Effects of cities on local climates. Proceedings of Workshop of IGES/APN Mega-City Project, 2002(January 2002), 1–13

Senanayake, I. P., Welivitiya, W. D. D. P., & Nadeeka, P. M. (2013). Remote sensing based analysis of urban heat islands with vegetation cover in Colombo city, Sri Lanka using Landsat-7 ETM+ data. Urban Climate, 5, 19–35.

Shahidan, M. F. (2011). The Potential Optimum Cooling Effect of Vegetation with Ground Surface Physical Properties Modification in Mitigating the Urban Heat Island Effect in Malaysia.

Sham, S. (1972). Monthly and seasonal rainfall at Tangling Hospital, Kuala Lumpur (1879-1964): An analysis using normal. Nusantara, 1, 93-99

Sham, S. (1973). The urban heat island: Its concepts and application to Kuala Lumpur. Sains Malaysiana, 2(1), 53-64.

Sreetheran, M., Adnan, M., & Azuar, A. K. K. (2011). Street Tree Inventory and Tree Risk Assessment of Selected Major Roads in Kuala Lumpur , Malaysia Street Tree Inventory and Tree Risk Assessment of Selected Major Roads in Kuala Lumpur , Malaysia, (September 2011).

Abreu-harbich, L. V. De, Chebel, L., & Matzarakis, A. (2015). Effect of tree planting design and tree species on human thermal comfort in the tropics. Landscape and Urban Planning, 138, 99–109.

Ahmad, S., & Hashim, N. M. (2007). Effects of Soil Moisture on Urban Heat Island Occurrences: Case of Selangor, Malaysia. Humanity & Social Sciences Journal, 2(2), 132–138.

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. Solar Energy, 70(3), 295–310.

Chen, Y., & Yu, S. (2016). Impacts of urban landscape patterns on urban thermal variations in Guangzhou, China. International Journal of Applied Earth Observation and Geoinformation, 54, 65–71.

Department of interior U.S. Geological Survey (USGS). (2016). Landsat 8 (L8) Data Users Handbook. America (2nd ed., Vol. 2). Sioux Falls, South Dakota, U.S: EROS, LSDS-1574.

Dewan, A. M., & Yamaguchi, Y. (2009). Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. Applied Geography, 29(3), 390–401.

Doick, K., & Hutchings, T. (2013). Air temperature regulation by urban trees and green infrastructure. Forestry Commission, (February), 1–10. Retrieved from http://www.forestry.gov.uk/pdf/FCRN012.pdf/$FILE/FCRN012.pdf

Elsayed, I. S. M. (2012). Mitigation of the Urban Heat Island of the City of Kuala Lumpur, Malaysia. Middle-East Journal of Scientific Research, 11(11), 1602–1613.

Goggins, G. (2009). Impacts of city size and vegetation coverage on the urban heat island using Landsat satellite imagery. Retrieved from http://proquest.umi.com/pqdweb?did=1707360601&Fmt=7&clientId=18803&RQT=309&VName=PQD

Hashim, N., Ahmad, A., & Abdullah, M. (2007). Mapping urban heat island phenomenon : Remote sensing approach, 25–30.

Ilham S.M. Elsayed. (2005). A Study on the Urban Heat Island of the city of Kuala Lumpur, Malaysia.

Jim, C. Y. (2004). Spatial differentiation and landscape-ecological assessment of heritage trees in urban Guangzhou (China), 69, 51–68.

Jim, C. Y. (2005). Outstanding remnants of nature in compact cities: patterns and preservation of heritage trees in Guangzhou city (China), 36, 371–385.

Jim, C. Y. (2006). Valuation of Heritage Trees in Compact City, 53–80.

Kong, F., Yan, W., Zheng, G., Yin, H., Cavan, G., & Zhan, W. (2016). Agricultural and Forest Meteorology Retrieval of three-dimensional tree canopy and shade using terrestrial laser scanning (TLS) data to analyze the cooling effect of vegetation. Agricultural and Forest Meteorology, 217, 22–34.

Lee, H., Mayer, H., & Chen, L. (2016). Contribution of trees and grasslands to the mitigation of human heat stress in a residential district of Freiburg, Southwest Germany. Landscape and Urban Planning, 148(January), 37–50.

Leuzinger, S., Vogt, R., & Ko, C. (2010). Tree surface temperature in an urban environment, 150, 56–62.

Lin, Y., & Tsai, K. (2017). Screening of Tree Species for Improving Outdoor Human Thermal Comfort in a Taiwanese City. Sustainability.

MetOffice. (2012). Urban Heat Islands (UHIs). Retrieved from http://www.urbanheatislands.com/

MMD (2010). Malaysia Meteorological Department, Meteorological databases, Malaysia.163.

Rajagopalan, P., Lim, K. C., & Jamei, E. (2014). Urban heat island and wind flow characteristics of a tropical city. Solar Energy, 107, 159–170.

Rogan, J., Ziemer, M., Martin, D., Ratick, S., Cuba, N., & DeLauer, V. (2013). The impact of tree cover loss on land surface temperature: A case study of central Massachusetts using Landsat Thematic Mapper thermal data. Applied Geography, 45(March), 49–57.

Rogan, J., Ziemer, M., & Ratick, S. (2015). The impact of tree cover loss on land surface temperature : A case study of central Massachusetts using Landsat Thematic ... Applied Geography, 45(March), 49–57.

Roth, M. (2002). Effects of cities on local climates. Proceedings of Workshop of IGES/APN Mega-City Project, 2002(January 2002), 1–13.

Senanayake, I. P., Welivitiya, W. D. D. P., & Nadeeka, P. M. (2013). Remote sensing based analysis of urban heat islands with vegetation cover in Colombo city, Sri Lanka using Landsat-7 ETM+ data. Urban Climate, 5, 19–35.

Shahidan, M. F. (2011). The Potential Optimum Cooling Effect of Vegetation with Ground Surface Physical Properties Modification in Mitigating the Urban Heat Island Effect in Malaysia.

Sham, S. (1972). Monthly and seasonal rainfall at Tangling Hospital, Kuala Lumpur (1879-1964): An analysis using normal. Nusantara, 1, 93-99

Sham, S. (1973). The urban heat island: Its concepts and application to Kuala Lumpur. Sains Malaysiana, 2(1), 53-64.

Sreetheran, M., Adnan, M., & Azuar, A. K. K. (2011). Street Tree Inventory and Tree Risk Assessment of Selected Major Roads in Kuala Lumpur , Malaysia Street Tree Inventory and Tree Risk Assessment of Selected Major Roads in Kuala Lumpur , Malaysia, (September 2011).

Suherman, A., Rahman, M. Z. A., Busu, I., Akil, A. M., Ho, C. S., Salim, M. R., … Tifwa, H. Y. (2016). Exploring the role of green and blue infrastructure in reducing temperature in Iskandar Malaysia using remote sensing approach.

Tan, Z., & Ng, E. (2014). Influence of Greenery in Cooling the Urban Atmosphere and Surfaces in Compact Old Residential Building Blocks: A Building Morphology Approach, (December 2014), 1–8.

Wan Ali, A., Hassan, N., & Hassan, K. (2016). The Morphology of Heritage Trees in Colonial Town : Taiping Lake. Procedia - Social and Behavioral Sciences, 222, 621–630.

Weng, Q. (2000). Environmental impacts of land use and land cover change in the zhujiang delta, china. Tesis.