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# VISUALIZING URBAN HEAT ISLAND THROUGH GIS AND REMOTE SENSING: CASE OF THE SOUTH-WEST PENINSULAR OF MALAYSIA

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## ABSTRACT

*Urbanization has changed the natural land uses and land covers into more manmade land uses. The resultant excessive heat generated by these areas, also known as heat island phenomenon gave negative effects to the dwellers. Urban heat island phenomenon not only reduced the human comfort, but it also affect the urban's energy consumption for cooling purposes. The general aim of this research is to examine spatial and temporal variation of UHI in the southwest Peninsular Malaysia. Based on remote sensing data i.e. infrared MODIS sensor of the area, land surface temperature (LST) was retrieved and utilized to pattern urban heat island (UHI). The monthly composite MODIS data were divided into four seasonal periods. About 162 locations of urban and rural known pixels within the area of the southwest Peninsular Malaysia were selected through systematic sampling to develop GIS contour map using Arc-GIS and Image-J software. Apart of that, a field study was done to demarcate monthly variation of ambient temperature within Klang Langat Valley. In general, there is a significant difference between urban and rural surface temperatures. As a suggestion to the urban planner, the existence of green spaces is not only important as an ecological-social landscape, but it is also vital to the urban microclimate stability. This study also suggests that the MODIS-LST data retrieved from the University of Tokyo is the most viable information to monitor urban heat island pattern in Malaysia.*

**KEYWORDS**: *Urbanization, energy consumption, temperatures, microclimate*

## INTRODUCTION

Urbanization lead to land use changes that take place from green areas or agricultural estates to become built up areas. These changes not only altered hydrologic components such as surface runoff, but it also influence thermal properties of the ground surface that cause higher energy budget as well as changing the surrounding atmospheric condition. Due to urbanization processes, the urban micro climate ecosystem will also be affected indirectly. Most of the problem in urban areas is the increase of surface temperatures due to alteration and conversion of vegetated areas. These changes affect the absorption of solar radiation, surface temperature, evaporation rates, storage of heat, wind turbulence and can drastically alter the conditions of the near surface atmosphere over the urban core.

Many human activities are concentrated in cities within the South-West Peninsular of Malaysia. There is also very rapid increase in the population of the area. Consequently, natural vegetation has been replaced with high rise buildings and road constructions and materials that are largely impermeable. A footprint of South West Peninsular of Malaysia have been converted into newly urban areas and always associated with the early stage of urbanization and has changed many natural land use types to more manmade land uses. The resultant heat generated in the urban areas posses threat to human life. This issue has brought some negative effects including deterioration the living environment, increase in energy consumption for cooling purposes and decrease in human comfort (Shaharuddin & Noorazuan 2007).

Thus, the general aim of this article is to examine spatial and temporal variation of surface temperature and the intensity of urban heat island in South-West Peninsular of Malaysia. This article will also highlights any significant difference in surface temperature between urban and rural areas within the South-West Peninsular of Malaysia from 2004 to 2010 time period. This study uses current research technique (i.e remote sensing) and therefore is expected to make significant contribution with regard to policies that may help reduce surface temperatures in the area and thus creating better environment for the inhabitants.

## ANTHROPOGENIC IMPACT ON URBAN HEAT ISLAND

By 2025, it is estimated that more than 80% of global population will be living in cities (United Nations 2003). Thus, urban related problems such as environmental pollution, energy crisis and overcrowded population will be worsening through time. Apart from this, excessive anthropogenic heat produced by the urban dwellers will also create an adverse effect to human and its environment. The rapid expansion of urban areas and overcrowded urban population not only reduced the urban public health, but it also affected the energy consumption as well as utilisation of fossil fuel (WHO 2005). Since 1900, the global surface air temperature has increased approximately $0.5^{o}C$. This increase has been mainly connected with anthropogenic heat and human activities (Rybak 2009).

Anthropogenic heat is heat generated by human activities such as fuel combustion, water heating and also air conditioning for cooling. Many research on the anthropogenic heat highlighted the difference in values of anthropogenic heat between small towns and large cities. The differences sometimes can reach between 50 to 100 $W\ m^{-2}$ (Landsberg 1981). The more sources of human activities will generate more heat, this means that the total human population will also affects anthropogenic heat through human metabolism. According to Rizwan et al. 2008, since this heat is entirely controlled by human activity, it is possible for man to heavily affect the local climate.

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The impact of anthropogenic activities on the global climate system is also due to the emissions of greenhouse gases that trap energy from the sun, creating a higher air temperature globally. Land use changes especially deforestation release large amounts of certain greenhouse gases into the atmosphere (Ayodeji 2009). So, people who live and work in urban areas utilize more energy for cooling (fans, air conditioning etc) and to create a better human comfort situation. The rapid increase of energy demand made the earth produce more pollutants and wastes such as the heat from combustion (Asakereh et al. 2010). That is why many researchers nowadays focus their research on energy crisis and management (Asakereh et al. 2010). In a global view, carbon dioxide concentration in the atmosphere also could affect climate change.

Green or vegetation covers help a lot in improving to urban environment, such as preserving water and soil, controlling temperature and humidity of air and preventing pollution (Geological Survey 2003). The environment in rural areas is normally cooler than the urban areas because of evapotranspiration from the vegetation areas. Trees and vegetation can reduce surface temperature by means of evapotranspiration through the convention of vaporized water to the atmosphere (Gartland 2008). Thus, reforestation or greening initiatives at a global scale not only make the globe healthier, but also create a better environment to the dwellers.

A surface area which has closed isotherms indicates that it is relatively warm and commonly associated with areas of human disturbance such as towns and cities and warmer than the surrounding rural areas is called urban heat island (UHI) (Figure 1). When the term urban heat island is used, usually it refers to the relative's warm air temperature near the ground (canopy layer). However, UHI form is the air temperature due to a difference in cooling between urban and rural areas. There are three different kinds of urban heat island, i.e. 1) Boundary Layer Heat Island that can be measured by direct or remote sensing measurement 2) Canopy Layer Heat Island measure by the direct measurement or field observation and 3) Surface Heat Island measure by the thermal remote sensing measurement (Oke 1987).

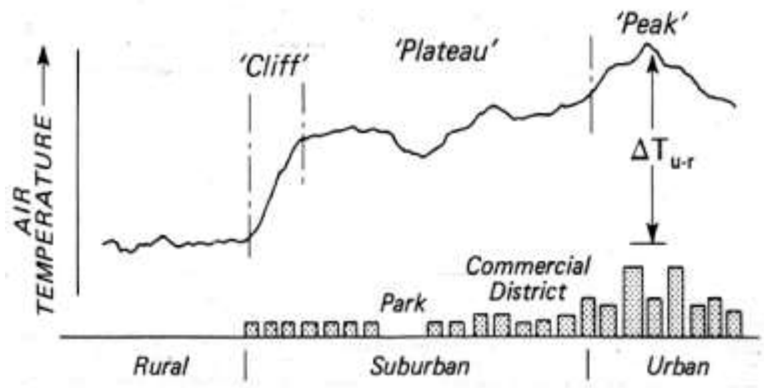



**Figure 1. General cross section of UHI (Oke 1987)**

Urban heat island in major cities is a common phenomenon in the world, including the Asia region. Urban heat island effect is defined as a high temperature in urbanized area as compared to the surrounding areas with relatively large amount of vegetation. Most cities show a large heat island effect registering between 5 to 11 Celcius warmer than surrounding rural areas (Foley et al. 2005; Rizwan et al. 2008). Since 1818 many researchers (Cicek and Turgoklu 2005; Changnon, 2001; Shaharuddin 2003) have investigated the excessive urban heat in many parts of the world. The general consensus has been that urbanization leads to the degradation of environmental quality and also affects ecosystem health (Douglas and Parry 1983; UN 2001). Previous studies of Santamouris et al. (2001) found that the exact extent of the UHI depends on time and space as a function of meteorological, locational and urban characteristics.

The UHI causal-effect relationship is not one to one connection. This means that there are several causes that can influenced UHI generation, and there are also a bunch of effects that than can be produced by the UHI. Many factors that influenced urban heat island could broadly be categorized as controllable and uncontrollable factors (Rizwan et al 2008). The controllable factor which is related to human activity especially urbanization could affect UHI through their urban design or landscapes such as building and green parks. The uncontrollable factors could further be categorized such as air speed and cloud cover, and cyclic effect variables such as solar radiations. Based on the literature review, there are various sources of heat that could affect serious consequences both human health and the environment. Many urban heat studies have been done in Malaysia since 1970s. However, application of thermal remote sensing in urban heat studies is still lacking.

## METHOD AND STUDY AREA

This research is based on a scientific-quantitative or positivistic approach in which a proper scientific method has been developed to analyze and determine the land surface temperature. The basic of this method is the utilization of MODIS's Thermal Infrared bands through a given time and space within the South-West Peninsular of Malaysia. The processed (geo-corrected) MODIS satellite imageries supplied by MODIS Lab, University of Tokyo is done through a normal procedure as shown in Figure 4 (Wataru et al 2012). The processed MODIS data (2004 to 2010) were used to analyze surface temperatures and urban heat island effect. Laboratory experimental works such as image processing and spatial analysis include the use of GIS/ RS software's i.e. Image J and Arc-view 3.2. In order to gain the spatial view and temperature distribution of the urban heat island, 162 ground station points were chosen based on a grid sampling (10 km x 10 km) (see Figure 2 & 3).

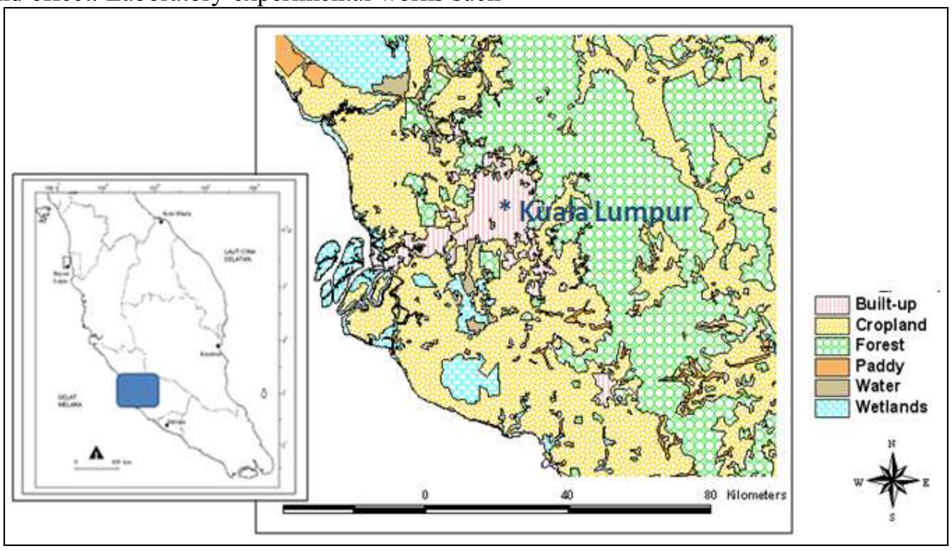



**Fig 2. The study are: Southwestern of Peninsular Malaysia**

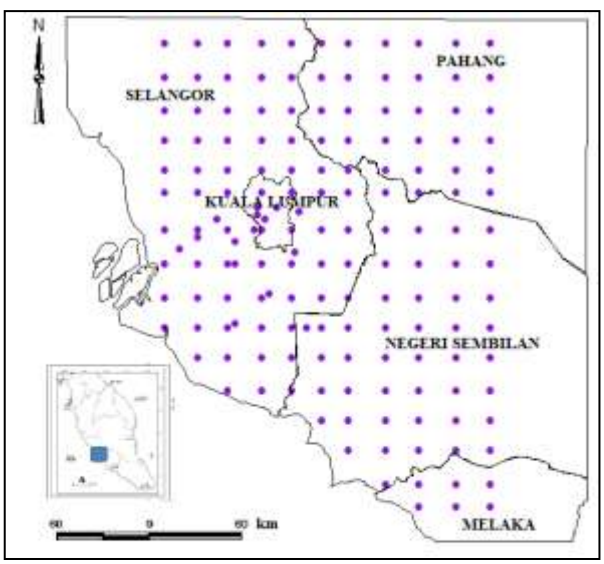



**Fig 3. 162 ground station points selected based on 10km x10km grid sampling**

The raw image is imported into Image-J with some alterations, firstly to reformat the image to Unsigned 16 data and to quantify the pixels involved as well as to sycronise the data into Little Endian byte order. About 162 points/locations involved is registered as X-Y GIS Longitude latitude coordinate in Dbase-IV file using Arc-View software in order to visualize UHI based on different periods. From that amount, about 72 points representing as urban centers whereas 90 points is considered rural areas.

Inversed Distance Weighted (IDW) method is selected to develop isotherm line for the UHI in Spatial-Analyst Arc-View. Inverse Distance Weighted (IDW) is an interpolation method to visualize a spatial pattern based on a given and known points. The closer a point to the center of the cell being estimated, the more influence, or weight, it has in the averaging process (Arc-GIS 2009). The isotherm line developed by Arc-View is interpolated into polygon or areal manually in order to visualize area involved in UHI as well as to quantify the affected area.

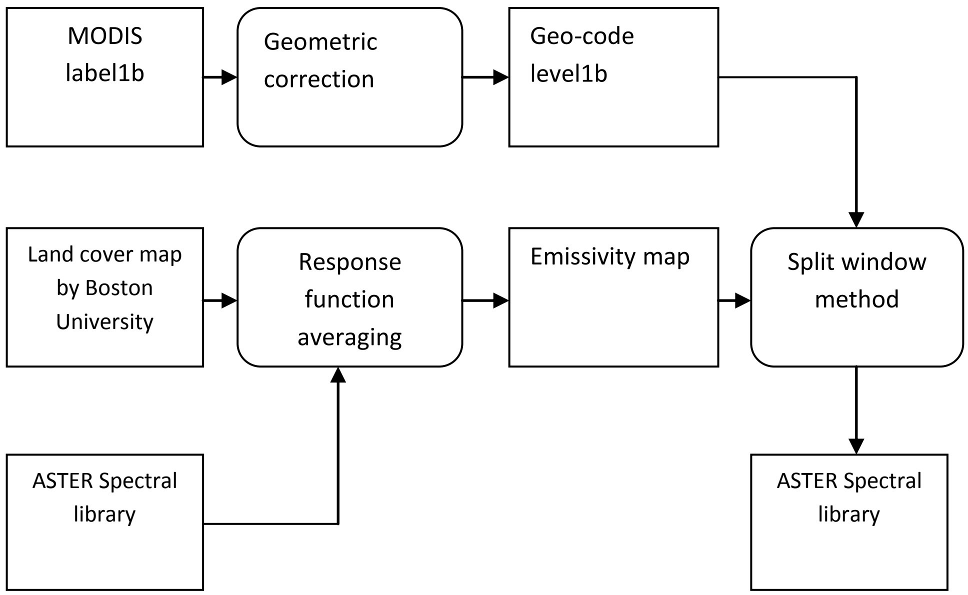



**Figure 4. A normal procedure used to produced a processed MODIS data by University of Tokyo**

## RESULT AND DISCUSSION

Table 1 shows the daytime temperature differences between urban and rural stations (2004 to 2010). In general, the urban areas experienced greater heat than the rural (the temperature differences is 3° Kelvin). Within 2004-2010, the difference in temperature is slightly similar. There is no extreme value of temperature in that period occurred. The same trend of differences occurred in the night time, with smaller magnitude (Table 2). Within 2004-2010, the difference in temperature is slightly similar, except for 2008-2009 the variation is in 2° Kelvin.

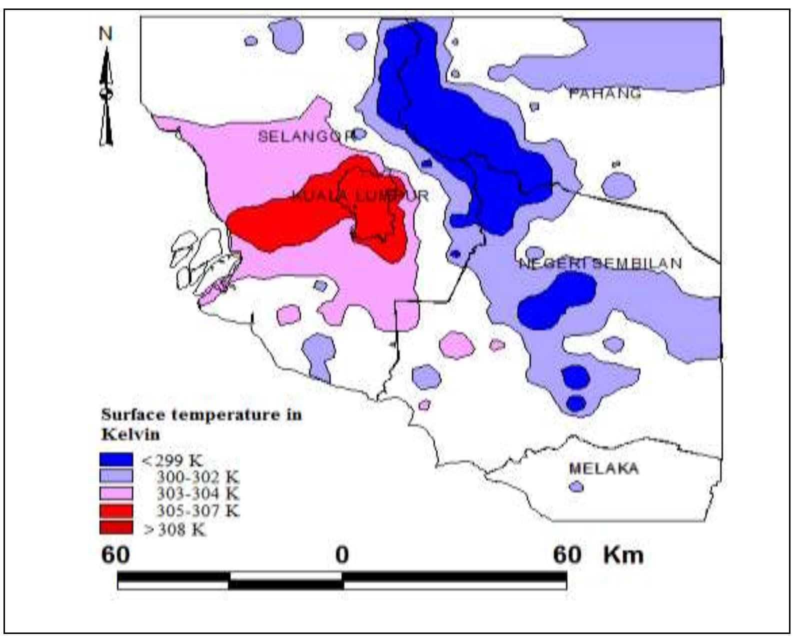
**Table 1 Average yearly (day time) urban and rural surface temperature (2004-2010)**

| Year | Urban Temperature (in ° Kelvin) | Rural Temperature (in ° Kelvin) | Temperature Differences (Average UHI) (in ° Kelvin) |
|---|---|---|---|
| 2004 | 304 | 301 | 3 |
| 2005 | 304 | 300 | 4 |
| 2006 | 303 | 300 | 3 |
| 2007 | 304 | 301 | 3 |
| 2008 | 304 | 301 | 3 |
| 2009 | 303 | 300 | 3 |
| 2010 | 305 | 302 | 3 |
| Average | 304 | 301 | 3 |

**Table 2 Average yearly (night time) urban and rural surface temperature (2004-2010)**

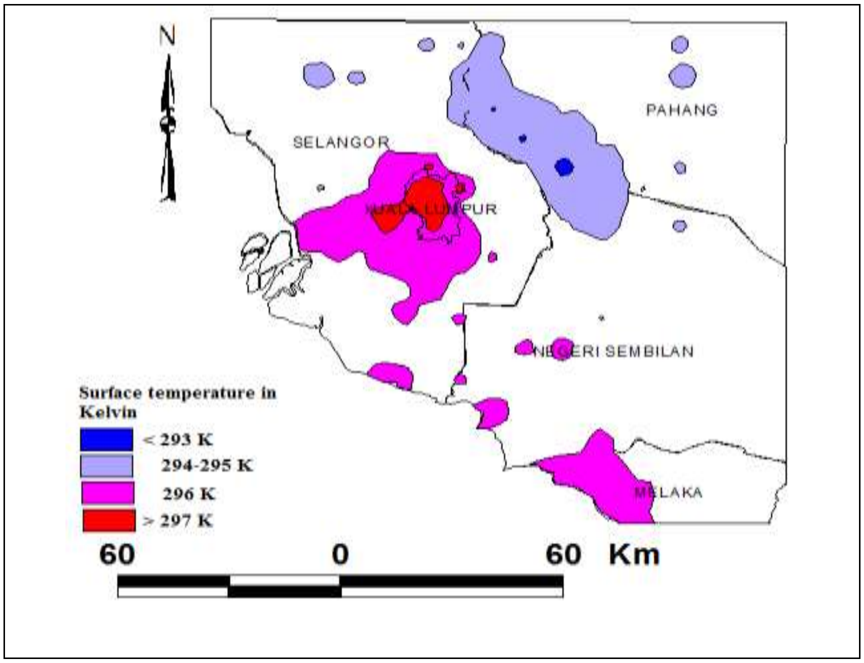
| Year | Urban Temperature (in ° Kelvin) | Rural Temperature (in ° Kelvin) | Temperature differences (average UHI) (in ° Kelvin) |
|---|---|---|---|
| 2004 | 295 | 294 | 1 |
| 2005 | 296 | 295 | 1 |
| 2006 | 297 | 296 | 1 |
| 2007 | 296 | 295 | 1 |
| 2008 | 296 | 294 | 2 |
| 2009 | 294 | 292 | 2 |
| 2010 | 297 | 296 | 1 |
| Average | 296 | 295 | 1 |

An effort also has been done to quantify areas which are above 300 ° K (27°C) for each period. The 300 ° K (27°C) is considered as temperature benchmark for human comfortability in tropic region based on the ASHRAE standard (ASHRAE 1993). In general, the average surface temperature between day time and night time (Figure 5 and Figure 6) shows a significant variation in spatial pattern. The blue color area (less than 299 ° K) that is representing the green lung area of main range that lies from North to Southeast of the study area is considered as the cooler area comparatively. The highest intensity of heat area can be seen in the lowland of Klang-Langat Valley, both in night and day time. Based on the spatial analysis done in Arcview, the total area which is above 300° K (27°C) is approximately 10,059.3 km$^2$ occurred in the day time.




Note:Total area above 300 K (27°C) is approximately 10059.3 Km$^2$ (in day time)

**Figure 5 2D surface temperature visualization (Daytime)**




Note:Total area above 300° K (27°C) ) is approximately 0 Km² in Night time

**Figure 6. 2D surface temperature visualization (Night time)**

The statistical analysis was done by using the processed of MODIS data from 2004 to 2010. The pre-processing steps, i.e. data quality control stage include checking errors or outliers and normality test. Table 3 shows the similarity between the mean and 5% trimmed data, which mean that the error or outliers have been cleaned prior to the analysis (Field 2009). Eventhough the normality test (Table 4) shows the distribution is not normal ($p < 0.001$, dF = 6912) for both variables (urban and rural), its histogram pattern of the data still similar to the normal curve (Figure 7). Thus, this allows us to run the data through parametric test accordingly (Field 2009; Othman Talib 2012). The correlation analysis shows a strong relationship between urban and rural temperature ($r = 0.66$, $p<0.001$).

**Table 3 The mean and 5% trimmed mean data for urban and rural temperature**

| Mean temperature data (urban) | 5% trimmed mean data | Mean temperature data (rural) | 5% trimmed mean data |
|---|---|---|---|
| 302.13 | 302.22 | 301.87 | 301.56 |

**Table 4 Tests of Normality**

| | Kolmogrov-Smirnov test[a] | | |
|---|---|---|---|
| | **Statistic** | **Different** | **Significant** |
| Urban | .044 | 6912 | .000 |
| Rural | .053 | 6912 | .000 |

a. Lilliefors Significance Correction

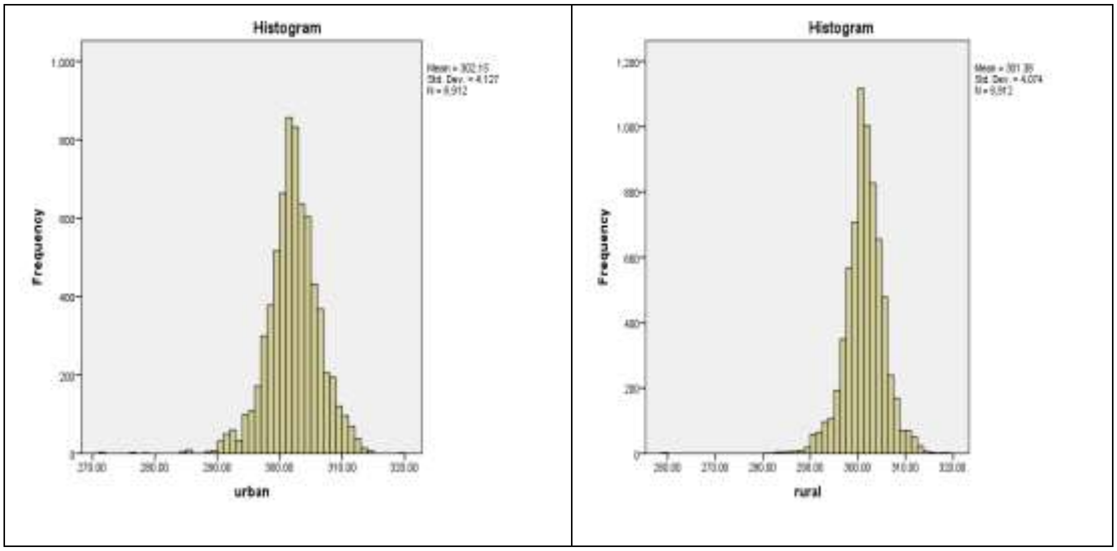



**Figure 7 Normal curve pattern for both data**

**Table 5 The correlation analysis (urban and rural stations)**

| Parametric Correlation | | | urban_temp | rural_temp |
|---|---|---|---|---|
| Pearson Corr | urban_temp | Correlation Coefficient | 1.000 | .665** |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 6912 | 6912 |

**. Correlation is significant at the 0.01 level (2-tailed).

Based on 162 points were selected per month, and for this study we have collected 75 months (from January 2004 until March 2010), therefore the total points (N) is approximately 6912 (Table 5). The correlation analysis between urban and rural station (Table 5) shows that a high correlation and significant values ($r=0.665$, $p<0.001$). The correlation analysis between day and night temperature (Table 8) also shows a high significant correlation value ($r=0.76$, $p<0.001$).

**Table 6 The mean and 5% trimmed mean data for Day and Night temperature**

| Mean temperature data (day) | 5% trimmed mean data | Mean temperature data (night) | 5% trimmed mean data |
|---|---|---|---|
| 301.77 | 301.71 | 278.88 | 278.90 |

**Table 7 Tests of Normality**

| | Kolmogorov-Smirnov[a] | | | | | Shapiro-Wilk |
|---|---|---|---|---|---|---|
| | Statistic | different | Significant | Statistic | different | Significant |
| Day temperature | .144 | 162 | .000 | .968 | 162 | .001 |
| Night temperature | .167 | 162 | .000 | .932 | 162 | .000 |

a) Lilliefors Significance Correction

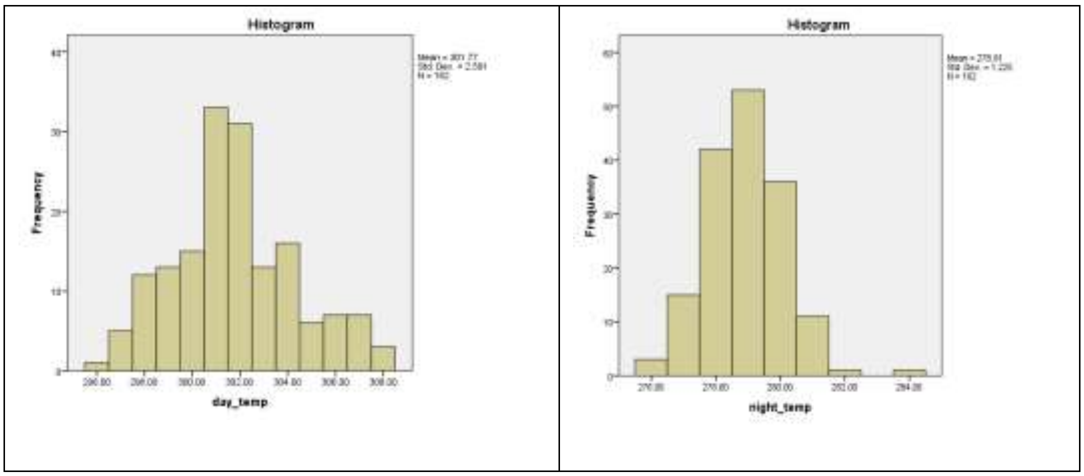



**Figure 8 Normal curve pattern for both data**

**Table 8 Correlation Analysis between Day and Night temperature**

| Parametric Correlation | | | day_ temperature | night_ temperature |
|---|---|---|---|---|
| Pearson Corr | day_ temperature | Correlation Coefficient | 1.000 | .762 |
| | | Sig. (2-tailed) | . | .000 |
| | | N | 162 | 162 |

**. Correlation is significant at the 0.01 level (2-tailed).

Urban centers have distinguish differences in ambient temperature with the rural stations within the study period. In general, urban centers experienced higher magnitude of land surface temperature from the rural station. This is true and can be related to a greater area of urbanised region, newly develop areas and also a significant contrast of urban landscapes such as imperviousness surfaces. This research outcome actually similar with some recent related studies, for example in Gartland (2008), Jauregui (1997), Kim and Baik (2004) and Hung et.al. (2005). Eventhough this study did not included land use land cover changes in the study area from 2004 to 2010, but other studies such as Shaharuddin et al. (2011) and Shaharuddin and Noorazuan (2007) showed the study area experienced and extensive urban land used changes within that period (2004-2010).

Another part of the study showed that the higher magnitude of surface temperature occurred especially in the day time. In general, urban landscapes especially the impervious surfaces absorbed excessive heat at the mid time or afternoon. These extra heat generated by the solar radiation has caused urban objects such as roof tops, roof pavements, concrete surfaces producing long wave radiation, and these radiation captured by the MODIS sensor. That is why most of the day time temperature will be the higher in the urban centers. Study done by Shaharuddin and

Noorazuan (2007) also has revealed the higher magnitude of surface temperature in the day time in Klang Valley region in 2005 by using band 6 of Landsat TM imageries. However, it is believed that heat energy supplied within day time through sunlight has increased the night ambient temperature. This is based on the day-night correlation analysis result (Table 8).

## CONCLUSION

In general, the spatial analysis of surface temperature has shown a significant differences between urban and rural areas. The major hot spot area falls within the urban cornubation of Klang Valley. The conversion of the contour lineage (i.e. one degree variation) into areal (polygon in Arcview) has contributed a visual of the urban heat island within the study area. In contrast, the uplands of the Klang Valley (Northwest to Southeast orientation of the map) showed a scenario of 'cold island' due to natural landscape or forested area of the uplands. This study also suggests that the MODIS-LST data retrieved from the University of Tokyo is the most viable information to monitor urban heat island pattern in Malaysia.

## REFERENCES


1. *Asakereh, A, Akram, A, Rafiee, S & Marzban, A. 2010. Energy Consumption and Greenhouse Gases Emission form Canned Fish Production in Iran a Case Study: Khuzestan Province. Research Journal of Applied Sciences, Engineering and Technology,* **2**(5): 407-413
2. *Ayodeji, O. 2009. Urbanisation and the incidence of urban heat island implications for climate change and global warming. REAL CORP, 2009.*
3. *Changnon, S. A. 2001. Assessment of the quality of thunderstorm data at first-order stations. Journal of Applied Meteorology,* **40**(4): 783-794.
4. *Cicek, I. & Turkoglu, N. 2005. Urban effects on precipitation in Ankara. Atmósfera,* **18**(3): 173-187
5. *Douglas, V. I. & Parry, P. A. 1983. Effects of reward on delayed reaction time task performance of hyperactive children. Journal of Abnormal Child Psychology,* **11**(2): 313-326.
6. *Foley, J. A, DeFries, R, Asner, G. P, Barford, C, Bonan, G, Carpenter, S. R. & Snyder, P. K. 2005. Global consequences of land use. science,* **309**(5734): 570-574.
7. *Geological Servey. U.S. 2003. Landsat 7 Science Data. User Handbook.*
8. *Gartland, L. 2008. Heat Islands: Understanding and mitigating heat in urban areas. Earthcan. London.*
9. *Landsberg, H.E. 1981. The Urban Climate. International Geophysics Series Academic Press. Vol. 28.*
10. *Oke, T. R (ed). 1987. Boundary Layer Climates. Routledge, London : Methuen Co. 435 pp.*
11. *Shaharuddin, A. & Noorazuan, Md .Hashim. 2007. Effects of soil moisture on urban heat island occurrences: case of Selangor, Malaysia. Humanity & Social Sciences Journal,* **2** (2), 132-138.
12. *Rybak, O. O. 1996. Statistical structure of air surface temperature time series. Atmosfera,* **10** (2).
13. *Rizwan, A. M, Dennis, L. Y. & Liu, C. 2008. A review on the generation, determination and mitigation of Urban Heat Island. Journal of Environmental Sciences,* **20** (1): 120-128.
14. *Shaharuddin, A. 2003. Trends of urban climate in several urban areas in Malaysia: An analysis of urbanization impacts (in Malay). In the National Conference proceedings of Development Challenge, Environmental Dilemma, 12 to 13 September 2003, UKM Bangi. pp. 703 – 724.*
15. *Santamouris, M (ed.). James & James. 2001. The Canyon Effect. Energy and Climate in the Urban Built Environment, London.*
16. *WHO. 2005. Environmental health country profile. Philippines: World Health Organization. http://www.wpro.who.int/NR/rdonlyres/FA5CA 9AA-B230-4863-837D A0709ECAA514/0/philippines_ehcp_18Nov2004.pdf. Accessed April 7, 2008, p 16.*
17. *United Nations . Piracha, A. L. & Marcotullio, P. J. 2003. Urban ecosystem analysis: identifying tools and methods. United Nations University. Institude. of Advence Studies (UNU/IAS), Tokyo.*