# Delineating the heat islands in Digos City: A factor in urban development

**[1]Adelaine Marie V. Dullin, [1]Lowella G. Dumaguit, [1]Daylyn G. Yting, [1]Melanie M. Pecision***
[1]Teacher Education Department, UM Digos, Philippines
**Corresponding author:* mpecision@gmail.com

## ABSTRACT

The development of urbanization in Digos City is at its peak. This rapid transformation of urban areas leads to the study of urban heat island formation in the city. In detecting this UHI, images obtained from the remote sensors were used to determine heat islands in Digos City. To identify the land cover of this UHI, the Landsat Enhanced Thematic Mapper is used. Upon this process, four major types of land cover were determined: Urban, Agriculture, Vegetation, and Barren areas that were utilized to highlight the heat island prevalent areas. UHI was evident and can be detected by fractional vegetation cover. This vegetation cover was derived by computing the NDVI from the images. The analysis of the difference of heat island areas between 2001 and 2007 was computed by subtraction method and verified by ground-truthing. With these processes, it is evident that there is heat island formation in Digos City.

***Keywords***: *Urbanization; Heat Island; Remote sensors; Landsat Enhanced Thematic Mapper; NDVI*

## INTRODUCTION

Rapid urbanization has an important influence on different angles on the roles of life and research especially in determining the patterns of development and quantifying its impacts are what captures the experts' attention (Kumar, 2012). The surface temperature is distinguished as one of the important factors in the urban surface environment. The increase of temperature in some urban areas in comparison to the neighboring suburban and rural places is known as heat island phenomenon (Landsberg, 1981).

The increase of buildings and roads and the decrease of greener areas have been the causes of the increase of temperature. This occurrence has been the reason of the microclimate in urban areas to be hotter than the neighboring places. Some of the microclimate's effects are the increase in energy consumption due to the need of cooling the areas and in return will lead to the higher emission of greenhouse gases. Economic and health of the inhabitants, as well as the concern in the national and environmental authorities, will also be affected by this phenomenon (Lall, 2014).

Urban heat island (uhi) studies have been traditionally conducted in isolated locations within situ measurement of air temperature (Chudnovsky, 2004). It is also well-known that the satellite-based images make it possible to study Urban Heat Is-land (UHI) both remotely and on the continental or global scale (Streutker, 2002). Land surface temperature derived from Landsat images which are being rectified by GIS software have been extensively used for Urban Heat Island (UHI) studies (Weng, 2003).

The objectives of this paper are to determine the heat islands in Digos City, to guide future researchers especially those who want to study urban system and climate change to enable integrated urban planning mitigation. This study can also be a great help to encourage planning authorities to build infrastructure with the right ratio to a greener area in a certain location so that increase in temperature will be minimized.

## METHOD

This study was a descriptive research with spatial data analysis and ground truthing. According to Knupfer (1996), descriptive research refers to the observation and description of the subject without influencing it. This includes the observation of bio-geophysical parameter of the Earth that provides great potential for urban land cover construction materials and the composition and structure of urban cano-pies, for improving the understanding of the urban surface energy budgets, and ob-serving the urban heat island effect (Zoran, 2011). This study also involves spatial data analysis which is a body of methods and techniques for analyzing ‘events' at a variety of spatial scales, the results of which depend upon the spatial arrangement of the ‘events' (Longley, 2005). This research is also an observational study without interaction to the surroundings for the data gathering in remote sensing method is verified through actual observation and getting the actual temperature of the areas being detected as heat islands.

The subject for the research study is the City of Digos, (Fig. 1) a second-class City and the capital of Davao del Sur (6° 44' 59" north, 125° 21' 26" east). It has an area of 287.10 km2 (110.85 sq. Mi), a density of 520/km2 (1,400/sq. Mi), and a population of 149,891 as of the census in 2010. The 1995 urbanized area covers about 917.18 hectares. The residential, commercial, and industrial areas increase while the memorial park allocation decreased by 22.08%. The residential, commercial, industrial, and institutional developments are concentrated in the city proper.


*Figure 1. Digos City (Google Map)*

Table 1. *Landsat Images and Sources*

| Sensor Type | Path/Row | Acquisition Date | Source |
|---|---|---|---|
| Landsat7 ETM+ | 112/55 | May 22, 2001 | USGS |
| Landsat7 ETM+ | 112/55 | April 5, 2007 | USGS |

Two landsat images from 2001 and 2007 (table 1) will be used as the data for the land cover pattern, NDVI map, detection, and measurement of the heat islands in Digos City. These pre-processed images will be downloaded from the USGS earth explorer website and are subject for rectification. The ARCGIS 10.2.2 software will process the satellite images, and classification method will be applied. Images of the study area will have a rectangular area of interest so that non-urban and agricultural/vegetative area will be included. With this, the variation can be seen vividly.

Using the bands of the pre-processed images from the USGS earth explorer website, the land use/cover pattern will be mapped. At the classification stage, supervised classification will be applied to the two images. This is done by creating polygons in certain areas with the help of google earth as training samples for introducing ideal classes in the images separately. Maximum classification method of ARCGIS 20.2.2 software will be used to create a closer correspondence in the maps produced. Mostly five classes are being considered in the study area such as the build-up area, barren land, agricultural areas, water and vegetation so that a comparison and variation of land cover can easily be determined. Post classification can also be performed to improve the accuracy of the classification since some surfaces are heterogeneous and had a complex combination of features such as with urban built-up which is composed of buildings, roads, grass, and soil.

The normalized difference vegetation index (NDVI) is a measurement of the amount and vigor of vegetation at the surface. To create an NDVI map, the LandSat images of 2001 and 2007 will be used. After unzipping the images, bands 4 and 5 will be used for the mapping. Digos boundary will be inserted and will be used for clipping the map. Then the model builder will be made wherein the formula (equation 1) will be used to calculate and create the NDVI map. The index is defined by equation (Kumar, 2012)

$$\mathrm{Ndv\,i} = \frac{\mathrm{nir} - \mathrm{r}}{\mathrm{nir} + \mathrm{r}}$$

Equation 1. NDVI formula

Where:
NDVI = normalized difference vegetation index
NIR = near-infrared spectral band
r = red spectral band

To identify the heat islands in Digos City, thermal map will be created using the bands 4, 3 and 2 from 2001 and 2007 images. Digos boundary will then be used for clipping the Digos area then 3 training samples for heat islands, vegetation and no data are created by drawing polygons on specific areas and will be saved as signature files maximum classification method will be used to process the heat island maps for each year. The removal of vegetation and no data will be followed for the heat islands computation then the reclassification method through spatial analyst will be used to change the maps from raster to polygon. Heat island area computation will be done through ARCG IS software, and then subtraction method will be used to identify if there is an increase of heat island formation between 2001 and 2007. For measuring heat islands in the barangay level, the heat island map will be used then the barangay boundaries of Digos City will be attached to the map. The use of spatial join in the ARCGIS will then be performed to get the areas per barangay. Ground truthing will be conducted after heat island determination in Digos City to measure surface and air temperature around the area. This observation will also help to determine what type of land use is the heat island as well as the surface materials and its horizontal and vertical spaces. This will be done by selecting 40 sample points of heat islands and 40 non-heat islands. The instrument to be used in this observation will be thermometers to identify the present temperature of the area and also GPD (global positioning system) mobile phones to determine its estimated location as well as the classification accuracy.

For the analysis, the subtraction method will be used. The land surface temperature from the 2001 map will be subtracted to the 2007 map to determine the difference. The two maps will also be compared to determine if the urban heat islands have increased after more than five years.

## RESULTS AND DISCUSSIONS

*Land Use/Cover Map Pattern of Digos City in 2001 and 2007*

Analysis of land cover pattern and its changes require a substantial amount of data from the earth's surface. Remote sensing tools provide sufficient amount of data from which updated amount of land use/land cover information can be extract-ed, analyzed, and simulated effectively. In making the Land Use/ Land Cover Pattern of Digos City, more than 10 samples/training sites were selected for each class so that there will be a high level of classification accuracy. With the high accuracy level, the classification became coarse since there were many training samples and the Land Use/Land Cover Map needs more or less five classes so the merging of the training samples related to its nearest classification was done until six classes were made. However, according to Digos city demography, there are 9 land use classification as of 2010. Still, the final classification turned only into four classes since the area covered by the clouds were considered to be no data. The water bodies are not visible in the satellite images that the data provider gave. Water bodies like rivers in the studied area were covered by vegetation that later made it as part of its classification. Forest/forest categories and grassland were fused into vegetation class, and quarry was included in barren class as areas without plants. Tourism classes shared its areas to the other classes and made it as its part. After producing the complete land use/land cover maps for the two years, the total area coverage of the four classes was determined using reclassification method and converting the raster data set of each area into polygon for the calculation. Using this information, the calculation of each class was being made to identify if there is a difference between the two maps being studied.

Table 2. Land Use Areas

| **Land use/cover** | **Area (ha)** | |
|---|---|---|
| | **2001** | **2007** |
| Vegetation | 7653.28 | 11843.87 |
| Agriculture | 6926.50 | 6529.84 |
| Urban | 1469.68 | 3334.68 |
| Barren | 7667.22 | 4411.31 |
| No Data | 4696.06 | 2485 |
| Total | 28,412.74 | 28,604.70 |

Upon comparing the land use/land cover areas, the results are shown in Table 4. Vegetation areas have increased possibly because of the Barren areas in the year 2001 that might have been planted, causing its decrease and increase in the vegetation. Agriculture areas have slowly decreased since urbanization at present is rapidly increasing. Urban growth has its corresponding increase by land area based on the computation in Table 4. The increase in urban built-up cover directly affects heat island formation (Pereira, 2004), which is the main objective of this research. In particular, the increase in urban built-up and the decrease of the agricultural and greener areas surrounding these urbanized places might be the reason for its sudden formation. Classifying these classes and determining the increase and decrease of each class areas can be an indicator in identifying heat island areas in Digos City.

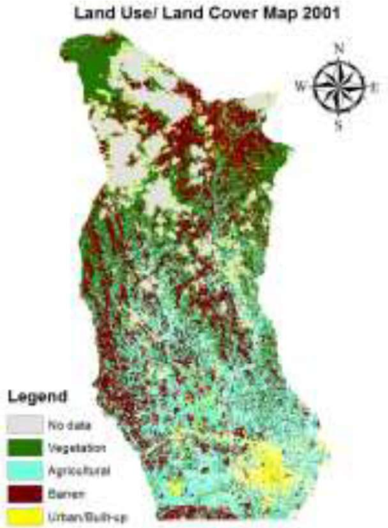


*Figure 2. Land Use/ Land Cover Map 2001*

**Derivation of NDVI Map**

The amount and nature of vegetation cover depicted by the vegetative fraction, and for urban areas which are commonly covered by partial vegetation, surface thermal properties can greatly affect the measurement of temperature through the thermal process of conduction, convection, and radiation. The normalized difference vegetation index (NDVI) is a remote sensing method that allows one to view and identifies greenness of vegetation (relative biomass) and can be a tool to determine initial green-up of the vegetation.

in this study, Landsat data and NDVI was used to compare NDVI values in 2001 and 2007. NDVI will produce a 3-channel color image of near infrared (NIR). Nir indicates vegetation as light red since healthy vegetation reflects infrared light. Clouds were colored white, while urban areas are green. Vegetation will usually appear darker red as per the map shows figure 3 and 4. Typically, darker red indicates healthier vegetation and based on the NDVI map, the study area appears to have a dominantly color yellow that indicates moderate vegetation and color green which considered to be a low vegetation. In line with the corresponding NDVI value, Digos City has a moderate to low vegetation which means areas with low vegetation has a chance to have a higher temperature that will lead to heat island formation. Based on the map result, the areas that considered as a low vegetation are urbanized places specifically with building infrastructures. The map shows that areas where there is rise in temperature are urbanized areas that emit long wave radiation and fail to reflect or transmit it back (Crothers, 2015).


*Figure 3. NDVI Map 2001*

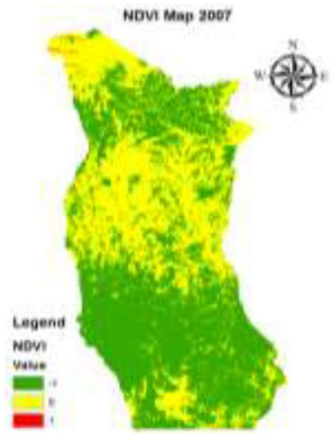


*Figure 4. NDVI Map 2007*

*Heat island Dimension of Digos City*

Using the created thermal maps with the aid: the Landsat imagery, the heat island formation for the year 2001 and 2007 (Figure 5 and 6) were usually found in urban and barren areas. This is based on the land cover/land use classification pattern made previously. If the heat island map is placed above the land cover/use map, it can easily be seen that heat island formation is dominant in the urbanized and barren areas. In 2001, heat island measures approximately 545.79 has. And 2007 measurement is .684.34 has. With these data analyses, there is a change in dimension, and it is increasing. This was being determined by subtraction method in which the heat island area of 2007 was being subtracted by the area of 2001. The result was an increase of 138.55 has. Which means that the heat island area in 2007 had increased. With this result, it was being observed that the change of heat island dimension is being affected by the increase in urbanization and the decrease in the agricultural areas (Table 3). By simply looking and comparing the two maps, we can easily say that heat island dimension decreases. However, if we look it thoroughly (Figure 7 and 8), we can infer that heat islands in 2001 is in a sporadic state (Fig. 6) which means that it was scattered into the entire city yet in a small and thin layer compared to 2007 that clustered in a certain area (Figure 8). With this concept, ARCGIS was used to compute the approximate heat island areas in both years, and it was found out that there is an increase of 138.55 has. In heat is-land formation.

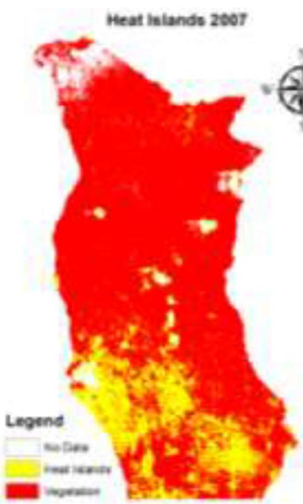


Figure 5. *Heat island Map 2001*

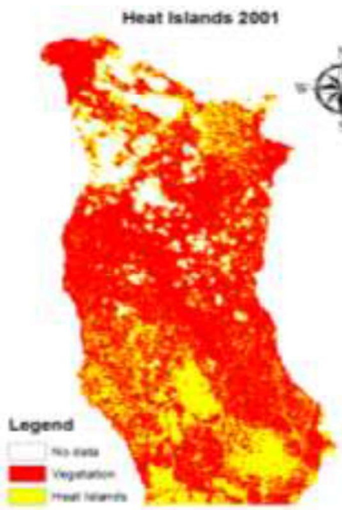


Figure 6. *Heat Island Map 2009*

In identifying these areas, the heat island maps were placed above the land use/cover map to determine its classification and it was found out that heat island areas are mostly urban built-up, barren and some agricultural areas (Fig. 10 and 11).


*Figure 7. Heat Island Areas in 2001*


*Figure 8. Heat Island Areas in 2007*


*Figure 9. Heat Islands in 2001*

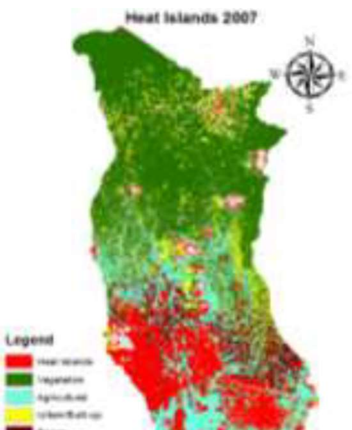


*Figure 10. Heat Islands in 2007*

*Heat Island Verification*

Using Descriptive Statistics, the heat and non-heat island sample areas were being computed and recorded to verify if both samples have equal temperatures. It was found out that Heat island temperature samples were not equivalent to the non-heat island temperature samples. With this result, the data was considered not normally distributed, and for the test which has not a normal distribution of samples, a non-parametric test was being used.

Table 4. S*ummary Statistics*

| Variable | Obs. | Obs. With Missing Data | Obs. Without Missing Data | Min | Max | $\bar{x}$ | SD |
|---|---|---|---|---|---|---|---|
| Temp \| N | 40 | 0 | 40 | 29.00 | 34.00 | 31.58 | 1.38 |
| Temp \| Y | 40 | 0 | 40 | 33.00 | 44.00 | 37.88 | 2.58 |

Upon the result of the computation, it was being found out that the temperatures from both locations were significantly different. With this, the verification of what makes it different was by ground-truthing.

Since heat island detection is through remote sensing, ground-truthing was being performed to calibrate the data being sensed by the satellite imagery. Through observation of the 40 sample points of heat island location, it was being found out that the maximum temperature, which was 41 degrees Celsius, were from areas that were highly urbanized, such as commercial and industrialized places. Other places which are heat islands were from residential, quarries, dryers, and some rice fields. There were also heat island formation in places within banana plantations, especially the offices, but it has a lower temperature than commercial, industrial, and some residential areas. For areas in the map which were chosen as non-heat island samples, it was being found out that this area was mostly covered with vegetation such as banana plantations, mangoes, trees, and other crops, causing its low temperature.

*Heat Island in the Barangay Level*

In determining the extent of Heat island formation in the barangay level, Digos barangay boundary has been used from the Phil GIS. With Spatial Join from the

ArcGIS software, the area of Heat Islands was being found out. Table 5 shows the result of the barangays that have the increase and decrease heat island formation.

Table 5. *Heat Island Formation per Barangay*

| Barangay | 2001 (ha.) | 2007 (ha.) | Difference | Percentage |
|---|---|---|---|---|
| Aplaya | 23.34463 | 33.68915 | 10.34452 | 44% |
| Balabag | 7.278973 | 33.60747 | 26.328492 | 362% |
| Binaton | 2.79742 | 0.451346 | -2.3460745 | -84% |
| Cogon | 24.19906 | 1.065034 | -23.13403 | -96% |
| Colorado | 28.31867 | 34.68249 | 6.3638224 | 22% |
| Dawis | 23.74758 | 33.75218 | 10.0046 | 42% |
| Dulangan | 29.79171 | 35.19495 | 5.4032417 | 18% |
| Goma | 8.501263 | 34.63928 | 26.13802 | 307% |
| Igpit | 6.855179 | 4.356175 | -2.4990039 | -36% |
| Kapatagan | 21.88452 | 1.403489 | -20.481028 | -94% |
| Kiagot | 24.42801 | 33.44962 | 9.0216113 | 37% |
| Lungag | 7.319766 | 33.25089 | 25.931119 | 354% |
| Mahayahay | 7.900869 | 33.14976 | 25.248886 | 320% |
| Matti | 28.98291 | 34.8847 | 5.9017852 | 20% |
| Ruparan | 25.76561 | 33.86936 | 8.1037508 | 31% |
| San Agustin | 27.40459 | 33.24965 | 5.8450646 | 21% |
| San Jose | 24.68022 | 33.25867 | 8.5784538 | 35% |
| San Miguel | 25.40494 | 34.41174 | 9.0067908 | 35% |
| San Roque | 30.3905 | 33.0684 | 2.677905 | 9% |
| Sinawilan | 23.97125 | 0.811509 | -23.159744 | -97% |
| Soong | 0.811635 | 0.070891 | -0.7407445 | -91% |
| Tiguman | 28.54585 | 35.15401 | 6.6081577 | 23% |
| Tres de Mayo | 23.66742 | 33.55101 | 9.8835926 | 42% |
| Zone I | 23.26794 | 33.17879 | 9.9108417 | 43% |
| Zone II | 23.26152 | 33.07535 | 9.813834 | 42% |
| Zone III | 23.2609 | 33.0675 | 9.8065991 | 42% |
| **Total** | 525.79293 | 684.34340 | 158.5605 | 13.54% |

With this result, it was found out that the Heat island dimension has increased mostly in the barangay levels, located near or within the city proper. The increase in heat island formation mostly took place in 11 rural barangays and nine urban barangays. The decrease of agricultural areas and agro-industrial development highly affect the heat island formation for the rural barangays. Also, the expansion of urbanized areas is one reason for the said formation (Table 6).

Table 6. Barangays with Increased Heat Island Formation

| Barangay | 2001 | 2007 | Difference | % | Brgy. Class. |
|---|---|---|---|---|---|
| Balabag | 7.278973 | 33.60747 | 26.328492 | 362% | Rural |
| Colorado | 28.31867 | 34.68249 | 6.3638224 | 22% | Rural |
| Dulangan | 29.79171 | 19495 | 5.4032417 | 18% | Rural |
| Goma | 8.501263 | 34.63928 | 26.13802 | 307% | Rural |
| Lungag | 7.319766 | 33.25089 | 25.931119 | 354% | Rural |
| Mahayahay | 7.900869 | 33.14976 | 25.248886 | 320% | Rural |
| Matti | 28.98291 | 34.8847 | 5.9017852 | 20% | Rural |
| Ruparan | 25.76561 | 33.86936 | 8.1037508 | 31% | Rural |
| San Agustin | 27.40459 | 33.24965 | 5.8450646 | 21% | Rural |
| San Roque | 30.3905 | 33.0684 | 2.677905 | 9% | Rural |
| Tiguman | 28.54585 | 35.15401 | 6.6081577 | 23% | Rural |
| Aplaya | 23.34463 | 33.68915 | 10.34452 | 44% | Urban |
| Dawis | 23.74758 | 33.75218 | 10.0046 | 42% | Urban |
| Kiagot | 24.42801 | 33.44962 | 9.0216113 | 37% | Urban |
| San Jose | 24.68022 | 33.25867 | 8.5784538 | 35% | Urban |
| San Miguel | 25.40494 | 34.41174 | 9.0067908 | 35% | Urban |
| Tres de Mayo | 23.66742 | 33.55101 | 9.8835926 | 42% | Urban |
| Zone I | 23.26794 | 33.17879 | 9.9108417 | 43% | Urban |
| Zone II | 23.26152 | 33.07535 | 9.813834 | 42% | Urban |
| Zone III | 23.2609 | 33.0675 | 9.8065991 | 42% | Urban |

The decrease of heat island formation in some barangays (Table 7) indicates the increased vegetation. These barangays are mostly located in natural park areas such as Binaton, Kapatagan, and Soong, where preservation, planting of trees, and increased crops were dominant. For Barangay Igpit, the increase of banana plantation is the factor for decreasing heat island formation.

Heat islands are dominant in urbanized and barren areas in the entire Digos City, particularly in industrial, commercial, and residential areas that reflect warmer temperature in its surrounding places. Urban development, solar radiation, and anthropogenic heat source contribute to heat island formation. The reduction of soil and vegetation, which are replaced by non-transpiring and non-evaporating surfaces like metal, asphalt, and concrete infrastructure, impacts increasing the temperature in the atmosphere. Expanding parking areas made up of pavement materials like asphalt and concrete also adds to the heat island formation.

Table 7. Barangays with Decreased Heat Island Formation

| Barangay | 2001 | 2007 | Difference | Percentage | Brgy. Classification |
|---|---|---|---|---|---|
| Binaton | 2.79742 | 0.451346 | -2.3460745 | -84% | Rural |
| Cogon | 24.19906 | 1.065034 | -23.13403 | -96% | Urban |
| Sinawilan | 23.97125 | 0.811509 | -23.159744 | -97% | Rural |
| Soong | 0.811635 | 0.070891 | -0.7407445 | -91% | Rural |
| Igpit | 6.855179 | 4.356175 | -2.4990039 | -36% | Rural |
| Kapatagan | 21.88452 | 1.403489 | -20.481028 | -94% | Rural |

## CONCLUSION AND RECOMMENDATIONS

The major land cover/use classified by this study are Urban, Vegetation, Agricultural and Barren areas. Heat Islands are prevalent in the urbanized, barren, and some agricultural areas in Digos City. The expansion of urban areas, decreased agriculture, and agro-industrial development in Digos City are the major contributors to the continuing formation of heat islands. Barangays that are near the city proper have an increased heat island formation. The increase of vegetation in a few barangays has helped the decrease of heat island formation.

Atmospheric correction should be applied to improve the land cover/use process and heat island detection. There should be an improvement in the quality of Landsat imagery used in the research study. The GIS software must be tailored-fit for raster analysis.

## REFERENCES

Chudnovsky, A. D. (2004). Diurnal Thermal Behavior of Selected Urban Objects Using Remote Sensing Measurement. Energy and Buildings 36, 1063-1074.

Crothers2, P.-M. R. (2015). "The Theory of Heat Radiation" Revisited. Department of Radiology, The Ohio State University, 120.

Knupfer, N. N. (1996). Descriptive Research Methodologies. Handbook of Research for Educational Communications and Technology, 1196-1212.

Kumar, S. K. (2012). Estimation of Land Surface Temperature to Study Urban Heat Island Effect Using Landsat ETM+ Image. International Journal of Engineering Science and Technology, 773.

Lall, A. (2014). Scoping Study for Policy Initiatives to Minimize Urban Heat Islands. New Delhi: Shakti Energy Foundation.

Landsberg, H. (1981). The Urban Climate Vol.285. Md., USA: Academic Press.

Longley, P. G. (2005). Geographic Information Systems and Science. Second Edition. John Wiley.

Pereira, R. A. (2004). Characterizing the Spatial Pattern Changes of Urban Heat Islands in Metro Manila Using Remote Sensing Techniques. PHILIPPINE ENGINEERING JOURNAL, 20.

Streutker, D. (2002). Satellite-measured Growth of the Urban Heat Island of Houston, Texas. International Journal of Remote Sensing 23, 2595-2608.

Weng, Q. 2. (2003). Fractal Analysis of Satellite-detected Urban Heat Island Effect. Photogrammetric Engineering and Remote Sensing, 555-556.

Zoran, M. (2011). Sattelite Observation of Urban Heat Island Effect. 1.