Study of Landcover and Population Density Influences on Urban Heat Island in Tropical Cities by Using Remote Sensing and GIS: A Methodological Consideration

Humayun SARKAR, India

Keywords: Urban Heat Island, Landcover, Population Density, Tropical Areas.

SUMMARY

The urban heat island phenomenon is a warmest condition in the city area due to unexpected changing of landcover and population density. Nowadays it is the most growing environmental problems in urban areas especially in tropical cities. The study of urban heat island phenomena could be studied by using remote sensing and GIS, where as remote sensing for landcover and GIS database management system as for population density.

The methods would be used to represent the urban heat island with qualitatively, quantatively and comparison analysis. There are few methods which already been done, directly related with remote sensing like band combinations 644 of ETM+ for landcover and vegetation, comparison of two several dated ETM+ images for thermal analysis of landcover and vegetation, ASTER/TIR used with mathematically for vegetation and watery areas. Other new methodologies were used together with remote sensing and GIS for land cover / land used and urban growth pattern respectively, NDVI from ETM+ and elevation from DEM used for urban heat island. However it is obvious that population density could be presented with GIS and Database management system for development of UHIs together with remote sensing.

However through out discussion of this paper, reveals that urban heat island might exits over urban areas and thermal level vary gradually with in cities with a direct relationship to landcover and population density.

Study of Landover and Population Density Influences on Urban Heat Island in Tropical Cities by Using Remote Sensing and GIS: A Methodological Consideration.

Humayun SARKAR, India

1. INTRODUCTION

With the development of satellites and remote sensing since 1960s, the environmental science has undergone radical changes because advancement of quantities approach. However today most vital problem in urban area is is to increasing temperature. Scientists called these phenomena *Urban Heat Island*. Remote sensing and GIS could be studied it and extensions to developing country's cities are highly desirable because we face the greatest population concentration growth. It is quite often difficult to delimit the many contributors to the problem.

In 1987 the world population was five billion and it is estimated that this figure will have doubled by the middle of 21st century. The current world population growth rate (measured by deducting the current mortality rate from the birth rate) is 1.6%. Around the world four babies are born every second. The greatest increase in population is occurring in Asia, Africa and Latin America. In 1990 these three continents made up 84% of the world's population (Radford, 1994) and land surface become less which converted into buildings, roads etc. Heat island is considered as a part of drought that can take place regularly in a certain city and it is caused by landcover and population density.

Remote Sensing is related with the resolution and which helps to measure objects on our earth surface and it greatly demands to study about urban phenomena such as UHIs, which can be studied by remote sensing. According to Sutanto (1995) there are four type of resolution are as spatial, spectral, temporal and radiometric resolution. Sabins (1997) defines spatial resolutions is the ability to distinguish between two closely spaced objects on an images. He stated that spatial resolution is affected by the shape, size, arrangement and contrast ratio. Spectral resolution is defined as the sharpness about the long wavelength, which is used to record object more clearly (Sutanto, 1995). Temporal resolution of a sensor system refers to how often it records imagery of a particular area and radiometric resolution defines the sensitivity of a detector to differences strength as it records the radiant flux reflected or emitted from terrain or target of interest (Jensen, 1996).

Many of earlier studies investigated the issue of the relative warmth of cities by measuring the air temperature employing land based observation of stations other studies used scheduled measurements of temperature using temperature sensors mounted on car, along various routes (Kirono 1996, Yamashita 1996, Comrie 2000, Pinho and Manso 2000). This method can be both costly and time consuming. Recent studies indicate that satellite remote sensing is one of the promising technologies inherently studied for understanding the relationship between landcover change and changes in surface temperature (Bekele, 2002). The advantage of using

remote sensing data is contingent of the availability of high resolution, consistent and repetitive coverage measurements of earth surface conditions (Owen et al., 1998).

So the study of about the urban heat island phenomena over tropical environment could have been studying with the help of remote sensing and Geographical Information System (GIS), which is less time consuming as well as effective.

2. PROBLEMS

The main problems for increasing city's temperature are as given bellow:
-Population density is one of the major problems for increasing city's temperature. An increasing amount of population concentration (growth pressure) in tropical cities are maximum, as a result temperature is increasing automatically. Whatever temperature is emitted from human body is abnormal rather than normal for the case of tropical cities.

-Land cover, which is increasing rapidly in urban tropical areas, a big problem for increasing urban temperature. Generally these cities are made of concrete materials, for example buildings are made of bricks, glasses and metals.

On the other hand roads are made of asphalt, cement and stones, vegetation is cut down due to urbanization, open water land area is become less as a result heat is automatically rising and reflection and absorption abilities of several object is different as compare with the rural object one.

3. OBJECTIVES

The main objective of this paper is to demonstrate the landcover and population density influences to develop urban heat island phenomena over tropical cities.

4. HYPOTHESIS

The hypotheses of this research are as follow:
Landcover and population density greatly influence to urban heat island have a positive relationship with urban heat island.
The relationship among landcover, population density and urban temperature can be expressed with this formula:

$$T = f (Lc, Pd)$$

Where as, T = temperature, f = function Lc = landcover, Pd = population densit.

5. METHODOLOGY

5.1 Material and Tools

- Remote sensing imaginaries including thermal band
- Administrative map of given city (scale 1:10,0000- 25,0000)
- Population data of same city with same year.

6. NECESSARY TOOLS AND INSTRUMENT

- Computer 1 unit with necessary instruments
- Necessary Software
- GPS for coordinates and field check.
- Infra-red thermometer for measuring surface temperature of different object.

6.1 Research Procedure

6.1.1. Pre-processing

Remotely sensed data is not free from internal and external errors such as radiometric and geometric distortion. "Therefore, it is necessary to preprocess the remotely sensed data prior to actually analyzing (Teillet,1986 in Jensen 1996). So both process will be regard any kind of correction like *radiometric correction and geometric correction*

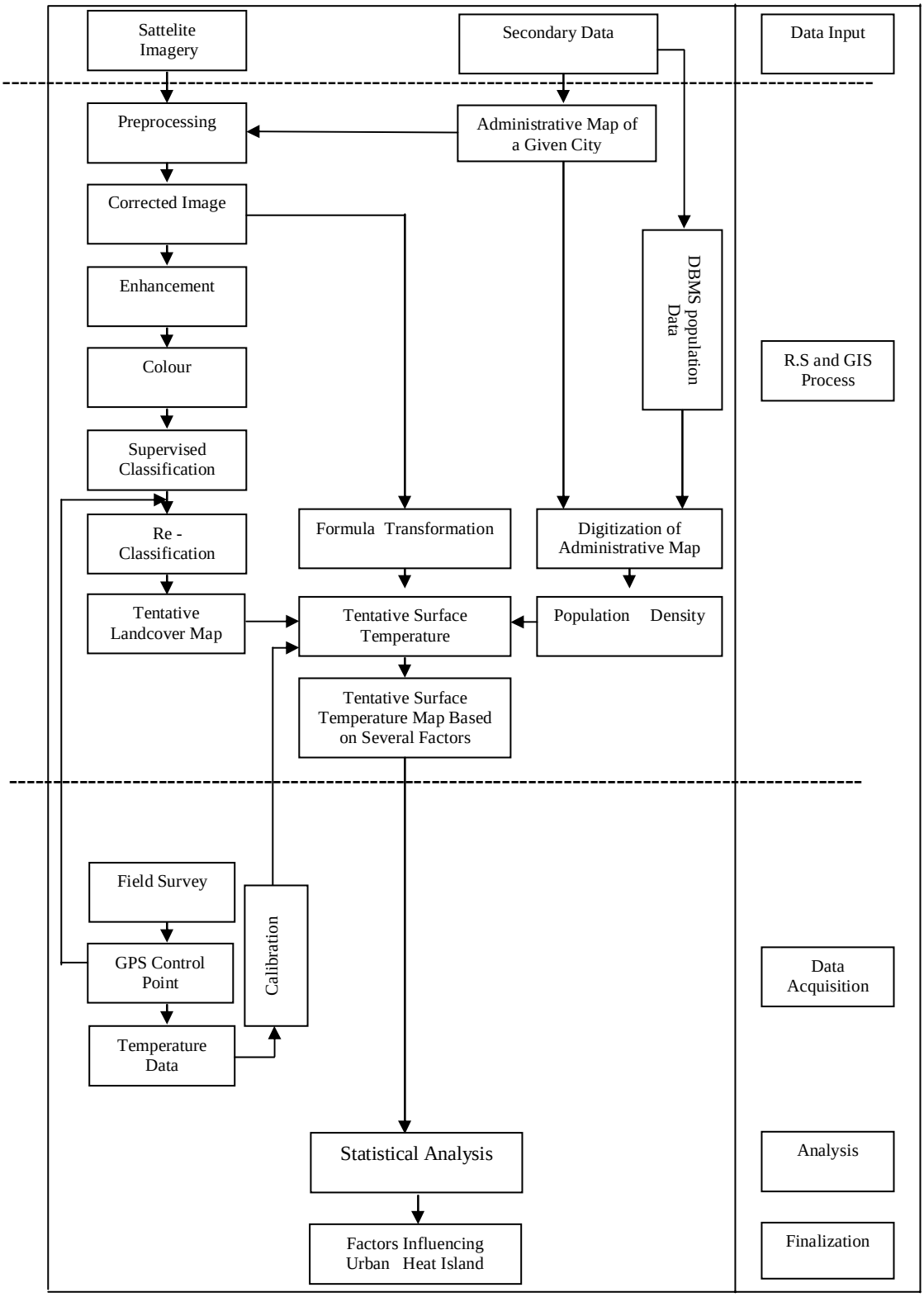

Figure. 1.The Flow Chart.

6.1.2 Image Enhancement

The goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between the features in the scene (Lillesand and Kiefer., 1994). Linear contrast enhancement, Nonlinear contrast enhancement.

6.1.3 Colour Composite

Colour composite is a process, where we used a combination of band and that combining band gives more information. However there are two types of composites

- True Colour Composite (TCC)
- False Colour Composite (FCC)

But for this FCC will be used because of benefit and several informations. FCC composite also two types

- Standard composite (432)
- Non standard composite (452, 453, 457)

6.1.4 Supervised Classification

Generally there are several methods for supervised classification. The most general methods are given bellow are as Parallelepiped, Minimum Distance, Maximum Likelihood. The maximum likelihood is more suitable for land cover and land use classification.

6.1.5 Reclassification

Reclassification for land cover is needed because of distortion and finally we will get the land cover map.

6.2 Tentative Surface Temperature Map

6.2.1 Formula for Temperature

The formula which will be used for this band 6, already been formulated by which is bellow:

- Conversion of Digital Number (Dn) to Radiance ($L\lambda$).
- Conversion of Radiation to Temperature.
- Conversion Radiance Temperature To Kinetic Temperature.
- Conversion of Temperature Kelvin to Celsius.

6.2.2 Urban Population Density

Population density is not more than an expression of the ratio between the number of population in a given area and the surface of the area (Yunus., 1978).

- Urban population density based on administrative areas.
- Urban population density based on morphological areas.
- Urban population density based on housing areas.

6.2.3 Tentative Surface Temperature Map Bsed on Several Factors

For the tentative surface temperature map, based on the several factors could be gained by Remote Sensing and GIS integration that is generalization. Generalization also two ways.

- Raster to vector conversion.
- Vector to raster conversion.

6.3 Field Survey

6.3.1 For the Field Survey the Following Activity Will be Done

At first administrative map a given city is divided into grid system. Then temperature samples are to be taken according to coordinate by GPS. It is assumed that with in one sample area temperature will be collected from several variables and then it will be averaged. The average temperature is considered as surface temperature of one sample.However the object's temperature will be measured by infrared thermometer according to satellite tracking time with in same time.

6.3.2 Calibration Method

The average surface temperature of each ground sample will be calibrated with satellite temperature of the same cordinate. The equation is

$$Y = aX$$

Where as,

Y = average surface temperature of all samples

X = average satellite temperature of all samples

a = function

So the function "a" value will be multiplied by satellite temperature of each sample on the satellite.

6.3.3 Statistical Analysis

Basically in this research used two types of statistical analysis will be considered for getting the final result. However the degree of confidence of this research consider as 85 – 95 % because of field survey.

6.3.4 Multivariate Regression Analysis

For the new model building regression analysis will be considered to establish the relationship among the variables. Due to the two independent variables like land cover and

population density, multivariate linear regression will be considered to find out the following relationships.

T = f (lc, pd)
Where as,
T = temperature
f = function
lc = land cover
pd = population density

So the confirmation of above relationship will be expressed the following formula which already mention by Sugiyono (2003).

$$Y = a + b_1 X_1 + b_2 X_2$$

Where as,
Y = the value of the dependent variable for the ith observation.
X1, X2 = the value of the independent for the ith observation.

However the land cover value will be determined from the composite band. But land cover will contain by the vegetation, buildings, roads, wetland and open space. So land cover value will be determined from the samples value of satellite image and the population density value will also be determined according to population density given city. For the above calculation the following process will be done.

So landcover, which contain n^{th} samples are taken on the basis pixel value. However as a condition of the regression analysis the above n^{th} observations of population density multiple by n^{th} value and it becomes n^{th} observations of landcover but this observation depend on ground samples. So the total observations of two independent variables is same and it is assumed that result will be quite effective and will be proved that these two factors have a great role for urban heat island development.

6.3.5 Hypothesis Test

Here consider two types hypothesis of test are as

Ho = there is no influence of land cover and population density on the urban heat island.
H1 = there is an influence of land cover and population density on the on the urban heat island.

T – TEST:
t - stats > t - table Ho is rejected
t - stats < t - table H_1 is accepted
with standard error $\alpha = 0.05$

The formula which will be used for two variables are given bellow:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2} - 2r\left(\frac{S_1}{\sqrt{n_1}}\right)\left(\frac{S_2}{\sqrt{n_2}}\right)}}$$

Where as, $\overline{X}_1$ = average sample1, $\overline{X}_2$ = average sample2, S1 = standard deviation of sample 1, *S2* = standard deviation of sample 2, S_1^2 = variance of sample 1 , S_2^2 = variance of sample 2, r = correlation between two samples

7. URBAN HEAT ISLAND INFLUENCING BY SEVERAL FACTORS:

7.1 Discussion

There have been little researches in this field, which discussed about urban heat island phenomena. Baumann (2001) used remote sensing as a tool for searching the urban heat island phenomena. He used Landsat ETM+ with combination of bands 644. Where as band 6 as thermal infrared and both band 4 as red for vegetation and land used pattern. The result of above research shows that the urban heat island might exist over the city, the thermal level vary considerably with in the city with a direct relationship to land use and vegetation coverage.

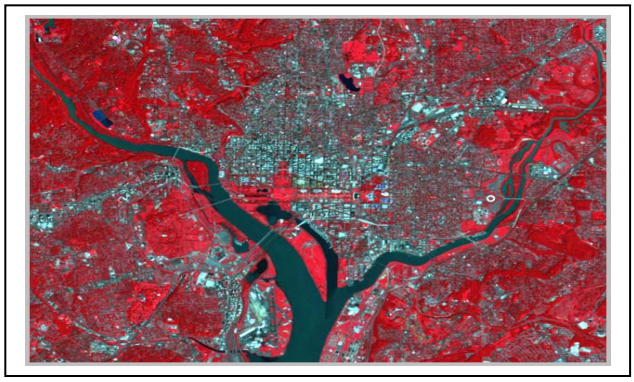

Figure.1. Urban Heat Island by Using Composite band (6 red, 4 green, 4 blue) Baumman (2001)

Bekele (2000) used landsat thermal infrared imagery (LandsatETM+) as for UHIs. He used mathematical calculation for above thermal imagery but his main ambition was to compare two images (1992 and 1999), the thermal response of the different landcover. His research proved that the thermal responses of different landforms indicate the vegetation in surface temperature of different surface forms. The downtown area shows relatively high temperature as compare to the vegetation and water surroundings areas.

Nakamura et al (2002) also used ASTER/TIR for the development of urban heat island. They used land cover like vegetation, watery area that plays important role for increasing the temperature. However they also used the mathematical calculation for their research. This

research shows that there is a great influence of vegetation and water areas for the development of urban heat island.

Weng (2001) established a new methodology for impact of surface temperature. He used remote sensing for landcover/land use and GIS based modeling employed for urban growth pattern. The result revealed that a notable and uneven urban growth raised surface radiant temperature in urbanized area. So the integration of remote sensing and GIS was founded to be effective in monitoring and analysis urban growth pattern and evaluating urbanization impact on surface temperature.

Serrano et al (2004) used to represent the urban heat island where elevation was obtained from digital elevation model (DEM), using a digital cartography of z-interpolated contour lines. And the vegetation cover distribution map was carried out using landsat ETM+. He used for vegetation cover NDVI. The result shows that the relationship between the spatial distribution vegetation and elevation help to develop urban heat island and the relationship is strong in both classes. A high percentage of the spatial variation of temperature is explained by means of elevation and NDVI.

The substantial amount of the variance of temperature rise in cities could be explained by a function of population growth. The growing cities showed the highest warming rates and square root of the population number as the most representative factors for the urban contribution to the temperature change (Mitchell, 1961). On the other hand Oke (1973) pointed that temperature is increase in city area. And he used the empirical relation to represent the urban rural temperature as concentration on population. It is quite often difficult to delimit the many contributors to the problem. However, one of the most noticeable and one that has proven to have an extremely strong correlation with the urban heat island phenomenon or urban surface temperatures is the population density of a major city (Lo and Faber, 1997 in Clemonds). However population data could be mapped by GIS (Paulsson, 1992) and integrated with remote sensing.

8. CONCLUSION

In conclusion we can draw underline that urban heat island is the most city's growing problem and it is the result from landcover changes and population growth. Remote sensing and GIS is to be used to investigate the UHIs phenomena to tackle such environmental problems in city area especially for tropical urban areas. It is also hoped that future remote sensing and GIS will be used widely for the above major problems in urban areas.

BIOGRAPHICAL NOTES

Humayun Sarkar, is the student of remote sensing in postgraduate in Gadjah Mada University under the scholarship from the government of Indonesia and recently involved for research urban heat island in tropical cities. He is doing his research in Yogyakarta City (Indonesia). He was passed his graduation in pure Geography followed by Economics and English and one year M.A. in geography in Aligarh Muslim University, India.

REFERENCES

Baumann, P.R., 2001. An Urban Heat Island Washington, D.C. Access from internet www . Oneonta.edu/ faculty / baumann / goosat2 / Urban_Heat_Island / Urban _Heat_Island . htm. Sept 2003.

Bekele,G., 2002. Assessing Urban Heat Island in Morgantown, WV Using Landsat Thermal Infrared Imagery. Access From internet http//:geo. wvu/geog655/spring2002/01/project.htm. Jan 2004.

Oke, T. R., 1973. City Size and the urban heat island. Atoms. Environ. 7,786-779.

Paulsson, B.,1992. Urban Applications of Satellite Remote Sensing and GIS analysis; Urban Management Discussion Paper UMP9; The world Bank; Washington, D.C.

Pinho, O.S. and Manso, Orgaz, M.D., 2000. The Urban Heat Island in a small city in costal Portugal. International Journal of biometeorology, vol.44, 198- 203.

Kirono, D.G.C., 1997. Variation of Nocturnal Surface Temperature Within SuburbanResidential Land use: A case study of suburban Fairfield, Western Sydney, Australia. The Indonesian Journal of Geography.28 (74) 45- 55.

Yamashita, 1996. Detail Structure of Heat Island Phenomena from Moving Observations from Electric Trans Cars in Metropolitan Tokyo. Atmospheric Environment, vol. 30,429-435.

Nakamura M, Hirano Y, O shiro, Yasuoka Y., 2002. Characterization of Urban Heat Radiation Flux Using Remote Sensing Imagery. Access from Internet htth // www. Remote sensing for urban geography. Jan 13, 2004.

Redford, S. H., 1994.Climate change, version 1.1r, Interactive Learning Production and Yorkshire Television.

Sabins, Jr.F.F, 1986, 1997. Remote Sensing : Principles and Interpretation, W. H. Freemanand Co, San Francisco.

Serrano V.S.M, Parts C.J.M, Saz M.A., 2004. Topography and vegetation cover influence on urban heat island of Zaragoza (Spain). Access from Internet htth // www. Remote sensing for urban geography. Jan 13, 2004.

Sutanto, 1997. Interpretability of Remote Sensing Image for Urban Features: Yogyakarta Example. The Indonesian Journal of Geography.29 (74): 65-93

Weng Q., 1999 A Remote Sensing – Gis Evaluation of Urban Expansion and Its Impact on Surface Temperature In The Zhujiang Delta, China. International Journal of Remote Sensing, 2001. vol.22.No.10, 1999-2014.

Redford, S. H., 1994.Climate change, version 1.1r, Interactive Learning Production and Yorkshire Television.

CONTACTS

Humayun Sarkar
Pakuahat, Malda (W.B)
PIN- 732138
INDIA.
Tel + 91 03511 266905

Humayun Sarkar
Pogung Baru D-34, Sleman
Yogyakarta
INDONESIA
Tel + 62 0274 562031
E: mail: humayun_sarkar@yahoo.com