Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 7, Issue, 12, pp.24820-24825, December, 2015

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

MEASUREMENT OF LAND SURFACE TEMPERATURE AND ITS RELATION TO VEGETATION COVER: A CASE STUDY OF KOLKATA MUNICIPAL CORPORATION

[1*]Rajib Sarkar and [2]Lakshmi Sivaramakrishnan

[1]Senior Research Fellow, Department of Geography, The University of Burdwan, Burdwan
[2] Professor & HOD, Department of Geography, Jadavpur University

ARTICLE INFO

Article History:
Received 20th September, 2015
Received in revised form
18th October, 2015
Accepted 15th November, 2015
Published online 30th December, 2015

Key words:
Urbanisation,
Land use and land cover change Land surface temperature,
Emissivity, NDVI.

ABSTRACT

Urbanisation is a global phenomenon that leads to rapid change in land use and land cover. This change significantly alters surface material from pervious to impervious concretized material. Changes in surface material introduce hike in surface temperature. Biological resources such as vegetation not only act as a sink to CO_2 but also help to reduce surface temperature by providing shades to surface materials. To understand such relation a study has been conducted on land surface temperature of Kolkata based on landsat satellite data. In this study, land surface temperature is measured from thermal image of using landsat Thematic Mapper satellite sensor. To calculate land surface temperature a method developed by Artis and Carnahan is adopted. The surface temperature shows that temperature is higher in north Kolkata in comparison to south Kolkata. In the process to calculate surface temperature, normalised temperature vegetation index (NDVI) has also been calculated using Near Infrared band and red band of the same satellite. The NDVI shows a negative relationship with surface temperature.

Citation: Rajib Sarkar and Lakshmi Sivaramakrishnan, 2015. "Measurement of land surface temperature and its relation to vegetation cover: a case study of Kolkata municipal corporation", *International Journal of Current Research,* 7, (12), 24820-24825.

INTRODUCTION

Rapid population growth and maximum utilization of natural resource leads to sharp change in land use and land cover pattern in urban areas. Now urbanisation has become a global phenomenon (UN Report, 2007). Most of the people have started to live in urban areas than its rural counterpart. This has lead to heavy pressure on biophysical settings of urban environment. Urbanisation results transformation of natural landscape that alters thermal, radiative, roughness and moisture properties of the surface and atmosphere above (Hung *et al*. 2006). For this reason many ecological problems have surfaced (Yeh and Li, 1999; Xiao *et al*, 2006; Deng *et al*, 2009). Of these problems, Urban Heat Island (UHI) is placed on top where temperature in urban areas remains elevated than surrounding rural areas (Voogt and Oke, 2003). Surface in urban areas are made of artificial material like bricks, concrete, asphalt etc. All these material have high thermal inertia (Arrau and Pena, 2010), greater thermal conductivity and higher solar radiation absorption. Due to conversion from vegetated and porous surface to impervious and concrete surface, evaporation regime of urban areas has also altered. Temperature in urban areas also increases because of long wave radiative loss, reduced turbulent heat transfer for complicated geometry in urban fabric and anthropogenic heat emission in atmosphere (Arnfield, 2003; Dousset and Gourmelon, 2003; Pu *et al.* 2006; Stathopoulou and Cartalis, 2007). Land surface temperature is the most important indicator in understanding nature and characteristics of Urban Heat Island (UHI). Rao (1972) initiated the use of thermal infra red data to study urban area and thereafter research continues on the application of thermal data and its derived product of land surface temperature. Different satellites have been used at different scale to measure surface temperature. Ground based measurement of surface temperature is very much complex for wide area. Satellite based land surface temperature estimation has helped to cover both spatial and temporal disadvantages of ground based point values (Zhao-Lian Li *et al*. 2013). Land Surface Temperature (LST) of any particular place is directly linked with existing land use and land cover (LULC). With the change in land use and land cover pattern surface temperature distribution also changes. Relation between Land Surface Temperature (LST) and Land use Land cover has attracted attention of myriad researchers along the globe (Chen *et al*., 2006; Xiao and Weng, 2007; Thi Van and Xuan Bao, 2010). Different approaches and methods have been used to understand this relation in different spatial and temporal context.

Corresponding author: Rajib Sarkar,
Department of Geography, The University of Burdwan.

In this paper, aim has been set to measure Land Surface Temperature (LST) from satellite imagery based thermal data and its relationship with vegetation cover. Vegetation cover will be represented by Normalised Differential Vegetation Index (NDVI). NDVI is a widely used vegetation index across the World to represent growth, stress and abundance of vegetation.

Study Area: Kolkata Municipal Corporation (KMC) is the spatial unit under investigation. Kolkata is located on the eastern bank of Hooghly-Bhagirathi River. KMC encompasses an area of 187.33 sq km with 141 wards and 15 boroughs (Census, 2011). In this study, borough will be smallest unit enquire. The area is delineated with $22^0$30' to $22^0$37' North and 88^0 18' to 88^0 23' East. Kolkata is the state capital of West Bengal, megacity and a prime focal point of urbanization in eastern India. This city is also termed as 'City of Joy' for its aesthetic beauty and cultural richness. With three hundred years of enriched colonial legacy, this city has attracted masses around the country and across to reside here.

MATERIALS AND METHODS

For quantitative measurement of Land Surface Temperature (LST), Landsat Thematic Mapper (TM) 5 image (Path 44/Row 138) of dated 8^{th} November, 2011 was used. Landsat TM has seven spectral bands. Among them bands from 1-5 and 7 have spatial resolution of 30 meter. Thermal infra red band is represented by band no 6 and has a spatial resolution of 120 meter. The data were acquired from United States of Geological Survey site. In this study, spectral band 3(0.63-0.69), band 4 (0.75-0.90) and band 6 (thermal infra red) were used.

Data Pre-Processing: Landsat TM, Level 1 processed data were used for the study. Level 1 processed data covers geometric correction. This correction process includes both digital elevation models and ground control points to achieve a product that is free from distortions related to the Earth (e.g. curvature, rotation), satellite (e.g. attitude deviations from nominal), and sensor (e.g. view angel effects)

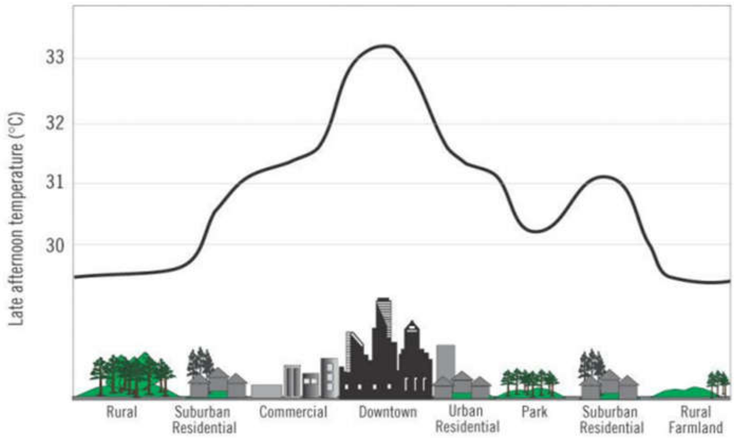


Figure 1. A sketch of an Urban Heat Island profile. Source: Arrau and Pena, 2010

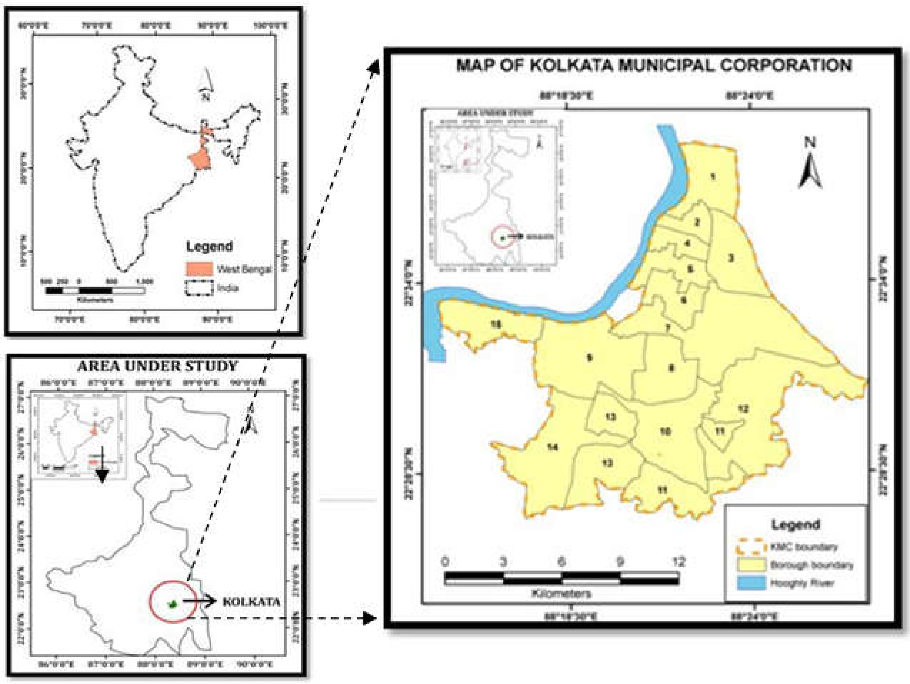


Figure 2. Location map of the study area

(Farina A, 2012). This data is also orthorectified (Landsat Project Science Office, 2001). Images were rectified based on Universal Transverse Marcator (UTM) projection system with zone no 45 and World Geodatic Survey (WGS, 1984) datum. Nearest Neighbor algorithm has been used to resample red, NIR and TIR band to uniform resolution of 30 meter. Images covers <1% of cloud and are fairly clear for further processing. For atmospheric correction, Top of Atmosphere (TOA) atmospheric correction was used for its simplicity and easiness to use.

Calculation of At Sensor Radiance and Planetary Reflectance

Calculation of at sensor radiance (Lλ) is the fundamental step for any form of measurement based on remote sensing data. In this study also at sensor radiance is calculated for band no 3 (red), band no 4 (NIR) and band no 6 (TIR) of landsat data. Radiance calibration is an important step to make radiometric correction of the images. At sensor radiance (Lλ) is calculated based on the following formula

$$L\lambda = \left(\frac{\text{LMAX}\lambda - \text{LMIN}\lambda}{\text{QCALMAX} - \text{QCALMIN}}\right) * (\text{QCAL-QCALMIN}) + \text{LMIN}\lambda \quad (1)$$

Where,

Lλ = Spectral radiance at sensor's aperture in watts/meter²*ster*µm

LMAXλ = the spectral radiance that is scaled to QCALMAX in watts/meter²*ster*µm

LMINλ = the spectral radiance that is scaled to QCALMIN in watts/meter²*ster*µm

QCALMAX = Minimum quantized calibrated pixel value corresponding to LMAXλ [DN]

QCALMIX = Minimum quantized calibrated pixel value corresponding to LMINλ [DN]

QCAL = Quantized calibrated pixel value [DN].

Spectral radiance of bands red and near infra red (NIR) are further analysed to convert exoatmospheric top of atmosphere reflectance (TOA). Top of atmosphere reflectance is also called in band planetary albedo and it helps to reduce inter-band spectral variability and also contains variation arising from different data acquisition data and time (Chander *et al*., 2009).TOA reflectance of band 3 and 4 is calculated with the following formula.

$$\rho\lambda = \frac{\pi \,.\, L\lambda \,.\, d^2}{ESUN\lambda \,.\, \cos\Theta} \quad (2)$$

where,

ρλ = Planetary TOA reflectance [unitless]
π = Mathematical constant equal to 3.141159 [unitless]
Lλ = Spectral radiance at sensor's aperture in watts/meter² ster µm
d = Earth-Sun distance in astronomical units
$ESUN\lambda$ = Mean solar exoatmospheric solar irradiance in watts/meter² ster µm
Ө = Solar Zenith angle [degrees]

NDVI calculation

Normalized Differential Vegetation Index is an important index to determine health of vegetation. NDVI is also used to measure spatial extension of vegetation cover. NDVI was first developed by Rouse *et al*. in 1974. NDVI is extensively used in different literatures to identify health of vegetation. NDVI is calculated based on reflectance values of red channel and near infra red channel (Tam *et al*., 2010).

$$\text{NDVI} = \rho NIR - \rho Red \;/\; \rho NIR + \rho Red \quad (3)$$

NDVI = Normalised differential Vegetation Index
ρNIR = Reflectance of Near Infra Red band
ρRed = Reflectance of Red band.

Derivation of Land Surface Temperature (LST)

Deriving surface temperature from thermal data requires a lot of conversion of data. Staring from conversion of digital number to radiance temperature by using the Planck's radiance function

$$B_\lambda(T) = \frac{C_1}{\lambda^5 (e^{\frac{C_2}{\lambda T}} - 1)} \quad (4)$$

Where,
C_1 = 1.19104356*10^{-16} W m^2 and C_2 =1.43876869* 10^{-2} m K

Considering absence of atmospheric effects, temperature (T) of a ground object can be theoretically determined by inverting the Planck's function

$$T = \frac{C_2}{\lambda \text{In}[\frac{C_1}{\lambda^5 B_\lambda(T)} + 1]}$$

(5)

This equation can be rewritten as

$$T = \frac{C_2 / \lambda}{\text{In}[\frac{C_1}{\lambda^5} \frac{1}{B_\lambda(T)} + 1]} \quad (6)$$

Now, let's consider $K_1 = C_1 / \lambda^5$ and $K_2 = C_2 / \lambda$ and satellite measured radiant intensity $B_\lambda(T) = L_\lambda$, then the above mentioned equation is formed into an equation like one usually used in calculating brightness temperature from Landsat TM image (Landsat Project Science Office, 2001)

$$\text{TB} = \frac{K2}{\text{In}\left(\frac{K1}{L\lambda} + 1\right)} \quad (7)$$

Where,

TB = Surface brightness temperature in Kelvin
$K2$ = Calibrated constant 2 [K]
$K1$ = Calibrated constant 1 [K]
Lλ = Spectral radiance at sensor's aperture in watts/ meter²ster µm
In = Natural Logaritham.

Here K_1 and K_2 is the coefficient determined by effective wavelength of the satellite sensor (Ghulam, 2010). Surface brightness temperature derived from equation no 7 refers to a black body object which absorb and radiate full of its energy. Buy in nature no objects behave like a black body. So for this reason correction of land surface emissivity (LSE) become very much necessary. Emissivity is usually defined as a ratio which compares the spectral radiant emittance of a surface to that of a blackbody at the same temperature (Artis and Carnahan, 1982). LSE is an important parameter when deriving LSTs as the emissivity of a surface will influence the amount of thermal radiation that it emits.

LSE is determined by several factors including the chemical composition, roughness and moisture content of a surface. The emissivity of a surface can have values between 0 and 1, however, for most objects spectral emissivity is very close to 1 (Stathopoulou *et al*., 2007). There are two methods of calculating emissivity. One is based on land use and land cover based and another one is NDVI based method. In this study NDVI based emissivity calculation has been carried out.

A. NDVI < 0.2

Pixels with NDVI values lower than 0.2 are considered as man-made materials or man-made materials with sparse vegetation. Emissivity (ε) values are obtained from the reflectivity values in the red channel,

B. NDVI > 0.5

Pixels with NDVI values higher than 0.5 are considered as fully vegetated. These pixels are assigned a typical emissivity value of 0.98 for vegetation.

C. 0.2 ≤ NDVI ≤ 0.5

Pixels with NDVI values greater than or equal to 0.2 or less than or equal to 0.5 are considered to be a mixture of man-made materials and vegetation. In this case, the emissivity of a surface is expressed as:

$$\varepsilon = 0.004P_v + 0.986 \quad (8)$$

Vegetation proportion (P_v) has been calculated based on the following equation prepared by (Carlson & Ripley, 1997):

$$P_v = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2 \quad (9)$$

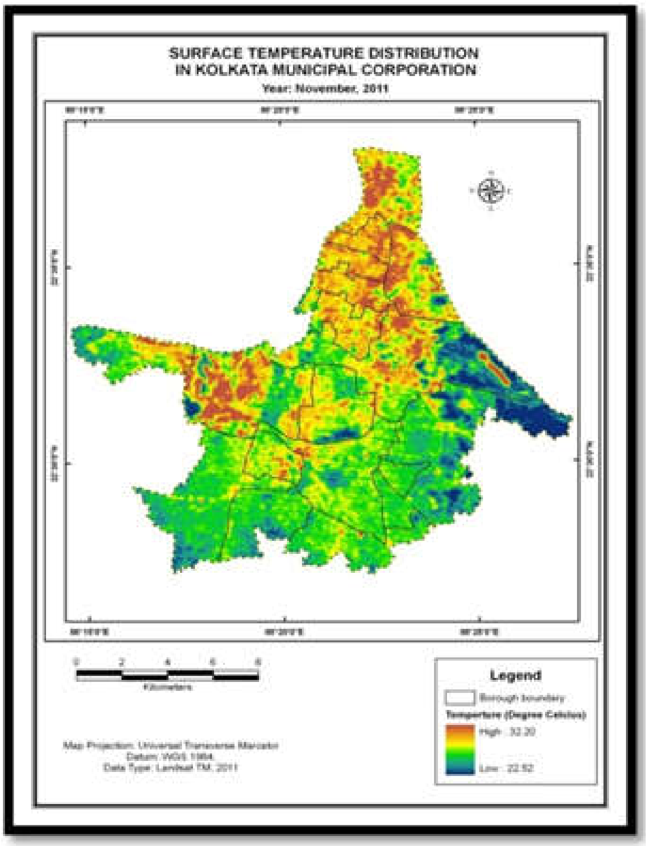
Where,

P_v = Vegetation proportion;
$NDVI$ = Normalised differential vegetation index;
$NDVI_{max}$ = Maximum value of NDVI;
$NDVI_{min}$ = Minimum value of NDVI.

Analysis and Result

Analysis of Land Surface Temperature

Land surface temperature distribution in Kolkata shows a predominance of north Kolkata over southern region. Highest temperature is recorded for the area is 32.20 °C and lowest temperature is 22.52 °C. Using Arc GIS 9.3 Zonal statistics function, borough wise mean temperature has been calculated. It shows that boroughs of south eastern and southern Kolkata (borough no 8,9 and 11-15) represent lower mean value of surface temperature. Apart from the general temperature gradiant from north to south, some pockets are there where surface temperature is much lower. This is mainly because of presence of vegetation in those areas. In analyzing temperature distribution, it can be easily said that the area where vegetation concentration is low surface temperature remains high.



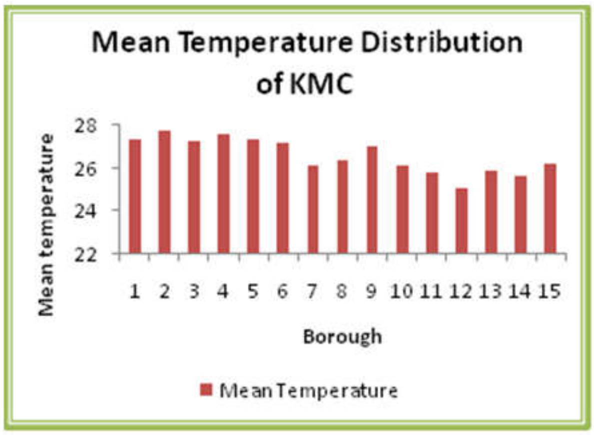


Figure 3. Spatial distribution of surface temperature and borough wise mean temperature

Analysis of Vegetation Abundance through NDVI

Vegetation concentration in Kolkata is marked by presence of Central Business Districts (CBD). Red taint is spread out across NDVI image of Kolkata except for a few patches. NDVI value range for Kolkata is from 0.590 to -0.322. NDVI index is higher towards eastern part of Kolkata. In this area is NDVI values are higher due to perennial agricultural practice. In central Kolkata NDVI value is higher near Maidan. NDVI value is also higher near Rabindra Sarobar and over Tallygonge Golf Club. Apart from that NDVI values spikes towards south which is away from main city centre. Borough wise mean NDVI data also tells the same story of spatial distribution of vegetation where northern boroughs lacks much vegetation and southern borough are well off in vegetation.

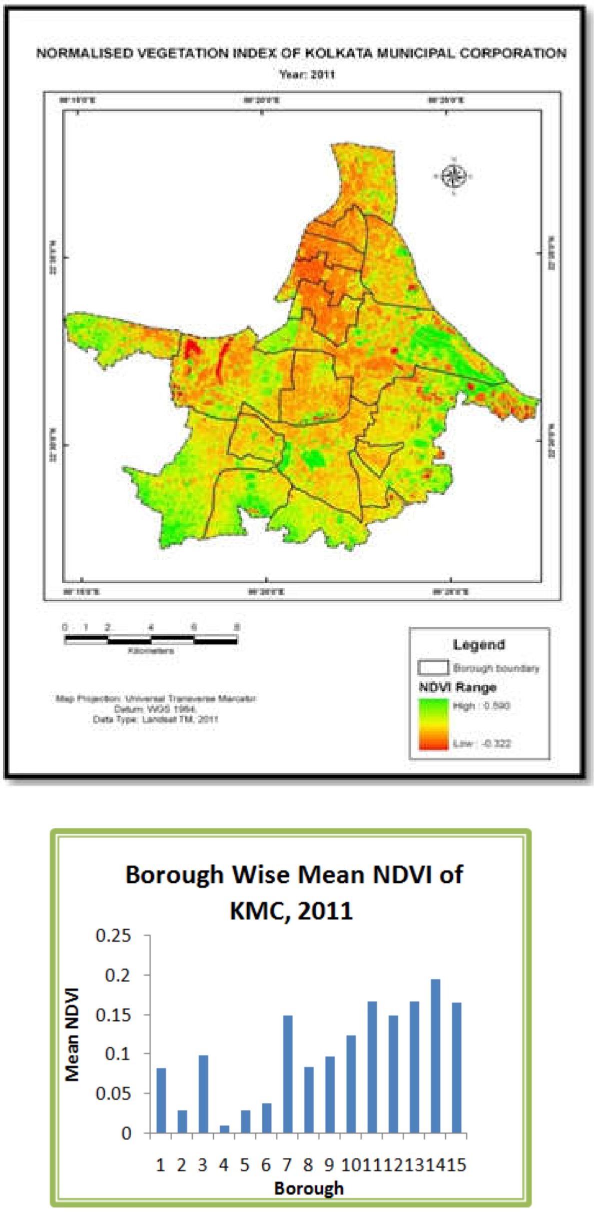


Figure 4. Spatial concentration of NDVI and borough wise mean NDVI distribution in Kolkata

Relationship between LST and NDVI

Based on borough wise mean Normalised Differential Vegetation Index (NDVI) and Land Surface Temperature (LST) a correlation analysis is performed. For the analysis NDVI represents the independent variable and LST is treated as dependent variable. Pearson's Product Moment correlation between two variables gives a high negative value of -0.87 which clearly states the influence of vegetation upon temperature distribution in the study area.

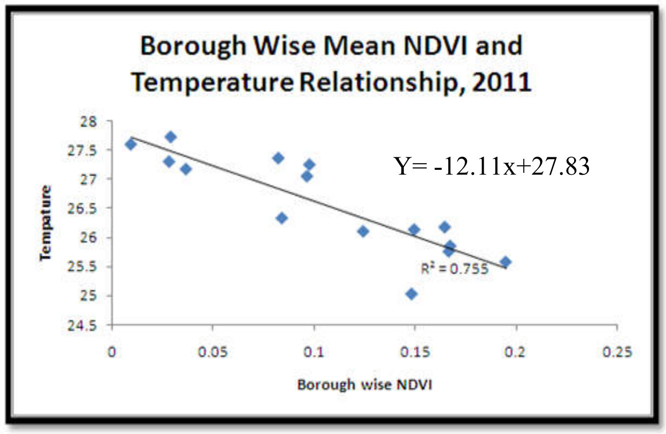


Figure 5. Bivariate relationship between NDVI nad LST in Kolkata

A regression line is also established between mean NDVI and LST scatter plot. Linear regression line also strongly expresses the negative relationship between NDVI and LST values with coefficient of determination (R^2) value of 0.755. This negative expression also illustrates the fact that in boroughs where the vegetation is abundant temperature remains low and vice versa.

Conclusion

The major goal of the study has been to quantify intensity of land surface temperature from satellite imagery and to understand nature of relationship between surface temperature with existing vegetation cover. Form the study it is found that thermal infra red band can be efficiently used to measure land surface temperature in any particular area. Normalised Differential Vegetation Index is calculated from the imagery data and its relationship with Land Surface Temperature has been observed. The relationship reaffirms the role of vegetation on temperature control in urban area.

Acknowledgement

We also acknowledge USGS for their support for providing Landsat data free of cost. This paper is past of Ph.D research work with fellowship from University Grant Commission (UGC). So special thanks goes to them.

REFERENCES

Artis, D., and Carnahan, W. 1982. Survey of emissivity variability in thermography of urban areas. *Remote Sensing of Environment,* Vol. 12, pp. 313-329.

Arnfield, A. J. 2003. Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. *International Journal of Climatology*, 1-26.

Arrau, C. a. (n.d.). The Urban Heat Island (UHI) Effect. Retrieved 10 20, 2010, from http://www.urbanheatislands.com

Census Report. 2011. Kolkata: The Registre General of India.

Chander, G., Markham, B., and Helder, D. 2009. Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. *Remote Sensing of Environment* , 893–903.

Chen, Y., Wang, J. and Li, X. 2002. A study on urban thermal field in summer based on satellite remote sensing. *Remote Sensing of Land & Resources*, 55-59.

Dash, P., Gottsche, F. M., Olesen, F. S. and Fischer, H. 2002. Land surface temperature and emissivity estimation from Land surface temperature and emissivity estimation from. *International Journal of Remote Sensing*, 2563–2594.

Dousset, B., and Gourmelon, F. 2003. Satellite multi–sensor data analysis of urban surface temperatures and landcover. *ISPRS Journal of Photogrammetry and Remote Sensing*, 43-54.

Farina, A. 2012. Exploring the relationship between land surface temperature and vegetation abundance for urban heat island mitigation in Seville, Spain. Lund, Solvagatan, Sweden.

Hung, T., Uchihama, D., Ochi, S. and Yasuoka, Y. 2006. Assessment with satellite data of the urban heat island effects in Asian mega cities. *International Journal of Applied Earth Observation and Geoinformation*, 34-48.

Li, Z.-L., Wu, H., Wang, N., Qiu, S., Sobrino, J. A., & Wan, Z. e. 2013. Review article: Land surface emissivity retrieval from satellite data. Retrieved from http://dx.doi.org/10.1080/01431161.2012.716540

Office, L. P. (n.d.). Landsat 7 Science Data User's Handbook . Retrieved 9 15, 2010, from http://Landsathandbook.gsfc.nasa.gov/handbook/handbook_htmls/chapter11/chapter11.html

Pu, R., Gong, P., Michishita, R. and Sasagawa, T. 2006. Assessment of multi–resolution and multi–sensor data for urban surface temperature retrieval. *Remote Sensing of Environment*, 211-225.

Stathopoulou, M. and Cartalis, C. 2007. Daytime urban heat islands from Landsat ETM + and Corine land cover data: an application to major cities in Greece. Solar Energy , 358-368.

Tam, K., Lim, H., MatJafri, M., & and Abdullah, K. (2010). Landsat data to evaluate urban expansion and determine land use/land cover change in Penang Island, Malaysia. *Environmental Earth Sciences*, 1509-1521.

Thi Van, T. and Xuan Bao, H. 2010. Study of the impact of urban development on surface temperature using remote sensing in Ho Chi Minh City, northern Vietnam. *Geographical Research,* 86-96.

UN. 2007. World Urbanization Prospects: The 2007 Revision Population Database. Retrieved 11 7, 2010, from http://esa.un.org/unup

Voogt, J. A. and Oke, T. R. 2003. Thermal remote sensing of urban climates. *Remote Sensing of Environment*, 370-384.

Xiao, H., and Weng, Q. 2007. The impact of land use and land cover changes on land surface temperature in a karst area of China. *Journal of Environmental Management*, 245-257.

Xiao, J. Y., Shen, Y. J., Ge, J. F., Tateishi, R., Tang, C. Y., Liang, Y. Q., *et al*. 2006. Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. *Landscape and Urban Planning*, 69–80.

Yeh, A. G. and Li, X. 1999. Economic development and agricultural land loss in the Pearl River Delta, China. *Habitat International,* 373–390.

****