MONITORING OF LAND SURFACE TEMPERATURE AND ANALYZING OF ENVIRONMENTAL PREDICTION ON ASANSOL AND DURGAPUR SUB-DIVISION, BURDWAN DISTRICT, WEST BENGAL USING LANDSAT IMAGERY

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Abstract

Anthropogenic activities have increased the temperature of urban areas as compared to its surrounding rural areas, and a climatic island is created which is termed as urban heat island (UHI). Calculating Land Surface Temperature (LST) is the primary and an important step in the urban heat island analysis as it is mainly represented in the spatial distribution of Land Surface Temperature (LST). The monitoring of Land Surface Temperature (LST) has been done using Landsat imagery of Asansol and Durgapur sub-division of Burdwan district, West Bengal. Mono-window algorithm has been used which basically focuses on four parameters for computing land surface temperature. These are, at sensor brightness temperature which is calculated from DN values of the image; emissivity which calculated from NDVI values; Atmospheric transmittance calculated from water vapour content and mean atmospheric temperature using near surface air temperature. Erdas imagine model maker tool has been used to build model for calculating land surface temperature. A comparative study has been made for past 30 years to evaluate changes in land surface temperature over the specified time span. The prediction has also been made for the same. Studies show that the rapid rate of urbanization is greatly responsible for increasing land surface temperature on Asansol and Durgapur sub-division of Burdwan district.

Keywords LST, NDVI, UHI, Asansol and Durgapur

Introduction

It is well known and documented that urbanization can have significant effects on local weather and climate (Landsberg, H.E.). The buildings, concrete, asphalt and industrial activity of urban areas causes the urban heat island. Replacing natural land cover with pavements, buildings and other infrastructures takes away the natural cooling effects. Also, tall buildings and narrow streets can heat the air trapped between them and reduce airflow. In addition, heat from vehicles, factories and air conditioners adds warmth to the surroundings, further exacerbating the heat island effect.

The Landsat TM data is one of the most widely used satellite images for LST retrieving because of its high resolution (120 m) and free download availability from the website of US Geological Survey (USGS), which has one thermal infrared (TIR) band. This makes retrieving LST from a single band more difficult than from multiple thermal bands. In 2001, Qin et al. proposed a mono-window algorithm for retrieving LST using Landsat TM TIR band data.

In tropical climates, the day season may affect the large island magnitudes. Thus, there are differences in day, night and seasonal measurements of LST. Sowhen the land surface temperature is unavailable in the case studies; the near-surface air temperature can also be used to validate the urban heat island effect. Traditionally, urban heat island analysis is based on the LST data observed at the meteorological points always with in situ measurements.

Study area

The study area is located in Burdwan district from latitudes $23^0$19' to $23^0$53' and from longitudes $86^0$48' to $87^0$34' (Figure-1). Asansol and Durgapur sub-division is the most important and at the same time is the major industrial belt in the Burdwan district, covers an area around 1860.54 km^2. The climate is extreme with maximum temperature up to 44^0C and minimum temperature down to 8^0C. The average annual rainfall of the study area is 1399 mm. The maximum amount of rainfall received during the monsoon season from June to September about 80.73%. This study area is located at an average elevation of 40 meters above sea level. The Burdwan District has total six numbers of sub-division where total 32 police stations are there. Asansol and Durgapur sub-division are two of them where total 17 police stations are there.

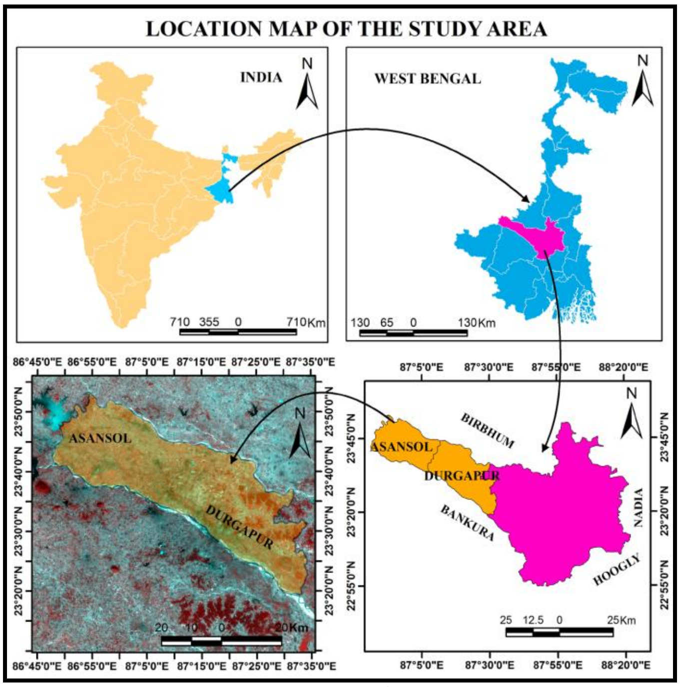

Figure 1: Location Map of the Study Area

Data & Methods

The primary source of the data used for the investigation of land surface temperature on Landsat TM satellite image Table 1 shows the details of the data used. Thermal band is the important which after processing, yields land surface temperature.

Table 1: Characteristics of the Landsat 5 TM Sensor

Launched	March,1984
Decommissioned	--------------
Altitude	705 km
Sensor	TM
Spatial Resolution	Band 1 to 5,7 (30 m) and Band 6 (120 m)
Spectral Resolution	Band 1 – 0.45-0.50 Band 2 – 0.52-0.60 Band 3 – 0.63-0.69 Band 4 – 0.78-0.90 Band 5 – 1.55-1.75 Band 6 – 10.4-12.5 Band 7 – 2.08-2.57
Temporal Resolution	16 days
Swath	185 km
Period	99 minutes
Inclination	98.2^0

Table 2: Software Used

Sl. No.	Software used	Version
1	ERDAS Imagine	9.0
2	Arc GIS	9.3
3	ENVI	4.7
4	TNT Mips Pro	2008
5	Adobe Photoshop	CS 5
6	Microsoft Office	2013

Methods

Land surface temperature (LST) is an important parameter for formulating surface– atmosphere interactions (Dickinson 1996, Sobrino et al. 2003a, b, 2004). Surface temperature of the earth surface depends on rocks, soil, vegetation cover, land use patterns and local climate. The Atmospherically corrected red band & infrared band use for NDVI calculation to extract surface emissivity. Through the help of Erdas (Table 2) Community & SEBAL model and using NDVI, emissivity & thermal band make a temperature mapping algorithm of Landsat-TM sensors images (Figure 2).

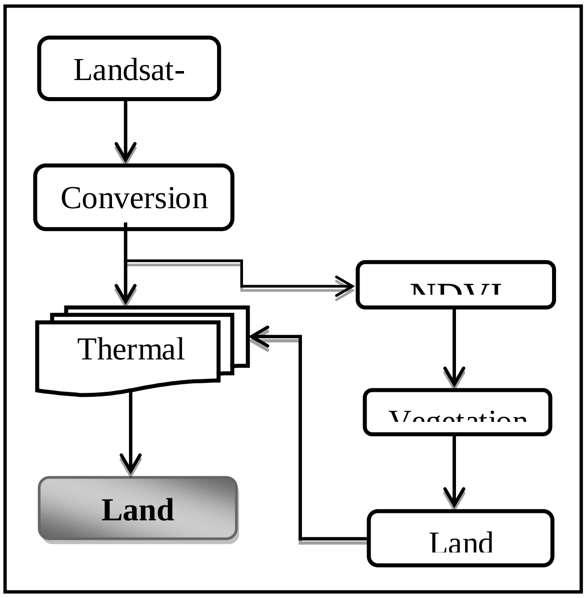

Figure 2: Methodology Flow Chart of the Study

All objects having temperature above absolute zero (0 K or -273 ºc) continuously emits EMR. In thermal remote sensing, sensors record this emitted or radiated or radiated energy instead of reflected energy. Therefore, in thermal remote sensing, the object itself is the source of energy.

Although real objects do not behave as black bodies, this concept of blackbody is a convenient theoretical vehicle to describe the radiation principles of a material. The amount of radiation of a blackbody differs with the change of wavelength and its kinetic temperature. The amount of energy in object radiates in per unit area (considering all wavelengths) can be expressed by Stefan- Boltzmann law-

$$M = €T^{4} \text{……………………………………} \quad (1)$$

Where, M= total radiant existence from the surface of a material, measured in W/ M^2., €=Stefan-Boltzmann constant=5.6697×10^{-8} W/m^2/K^4. and T= Temperature of emitting body, measured in K.

The above equation tells us that doubling the absolute temperature of a body would render 16 times more radiation. The wavelength in which the maximum energy will be radiated or emitted is given by Wien's displacement law-

$$€_{MAX} = b/T \text{……………………………………………………} \quad (2)$$

Where, $€_{MAX}$= wavelength of maximum emitted energy, measured in µm., b = Wien's displacement constant= 2.897.7685 µm K and T = temperature of emitted body, measured in K.

According to this law, for the sun, with a temperature of about 6000 K, the peak radiation is at 0.58 µm. the objects over the earth, as observed from, have peak radiation within 8-14 µm regions.

In 1990, Max Planck published a paper on the thermal properties of blackbodies that become one of the foundation stones from which quantum physics was built on. The plank blackbody radiation law gives the rate at which blackbody objects radiate thermal energy. Depending on what terms (parameters) and unit systems are used, the Planck equation can be written in various ways. One such form is as follows-

$$E(\lambda T) = \frac{2\pi h c^2}{\lambda^5 \left(\frac{hc}{e^{\lambda KT} - 1}\right)} \text{……………………………. (3)}$$

Where, E = blackbody spectral radiance, measured in W/m/m., λ =wavelength, measured in m, c= speed of light = 2.998 * 10^8 m/s, h= plank's constant = 6.626 * 10^{-23} J/K, T= temperature of blackbody, measured in K and e = base in natural algorithm = 2.71828

Equation (3) can be rearranged as follows (T. R. Martha et al. 2008)

$$T_{rad} = c_2/[\lambda\ \text{In}\{(Ec_1\lambda^{5/}\pi L_\lambda) + 1\}] \text{………………… ………………….....………… (4)}$$

Where, T_{rad} = radiant temperature in K, C_1 = $2\pi hc^2$ = 3.742 × 10^{-16} w/m^{-2}, C_2 = hc/k = 0.0144 Mk and E= emissivity

The corrected landsat TM thermal infrared band (10.40 to 12.50µm) has been commonly used for surface temperature mapping.

Spectral Radiance:-The extraction of surface temperature from thermal band of the landsat TM data involves. First the digital numbers (DNs) of the thermal band were converted to spectral radiance using the following equation-

Firstly, the digital number (DN) of band 3, 4 and 6 were converted to space reaching radiance or top-of-atmospheric (TOA) radiance (at-sensor spectral radiance) by using the equation 1. (Markham and Baker 1986)

$$L_\lambda = \left(\frac{\text{LMAX}-\text{LMIN}}{\text{QCALMAX}-\text{QCALMIN}}\right) \times (\text{QCAL} - \text{QCALMIN}) + \text{LMIN} \text{ ……………………... (5)}$$

Where, L_λ = spectral radiance at the sensor aperture in watts/(meter^2 *ster* µ m), QCAL=the quantized calibrated pixel value in DN, LMIN= the spectral radiance that is scaled to QCALMIN in watts/(meter^2 *ster* µ m), LMAX = the spectral radiance that is scaled to QCALMAX in watts/(meter^2 *ster* µ m), QCALMIN= the minimum quantized calibrated pixel value (corresponding to LMIN) in DN, QCALMAX = the maximum quantized calibrated pixel value (corresponding to LMAX) In DN, LMAX And LMIN are the spectral radiances for each band at digital number 1 and 255 (i.e.QCALMIN,QCALMAX), respectively, Qcal = DN value at band *i*.

Radiant Temperature:-Thermal infrared data (band 6) of the landsat TM can also be converted from spectral radiance ($L\lambda$) to radiant temperature (T_R) directly by the following equation-

$$TR = \frac{K2}{\text{InK1}/L\lambda+1} \text{ ………………………………….. (6)}$$

Where, TR = the radiant temperature at the satellite sensor (K), $L\lambda$ = the spectral radiance of TIR band, K1 = the calibration constant 1 for landsat TM (607.76 wm-2 sr-1 m-1) and K2 = the calibration constant 2 for landsat TM (1260.57 K).

The radiant temperature is based on the blackbody hypothesis. In reality, however, the correction for spectral emissivity is needed for the estimating the surface temperature of a target objects.

Kinetic Temperature:-From the radiant temperature (TR) can be converted into kinetic temperature (TK) by using following equation-

$$TK = \frac{TR}{\varepsilon 1/4} \text{ ………………………………………………………… (7)}$$

Where, TK = kinetic temperature, TR = radiant temperature and ε = spectral emissivity.

Emissivity:-Although several methods exist for the estimation of spectral emissivity, here we use NDVI *(Normalized Different Vegetation Index)*. To calculate the emissivity by using the following equation-

$$\varepsilon = a + b \times \text{In(NDVI)} \text{ ……………………………………………………… (8)}$$

Where, $\varepsilon$and NDVI are average thermal emissivity and average normalized difference vegetation index for individual surface covers respectively, *a* and *b* are two constant (*a* = 1.0094 and *b* = 0.047 for a correlation coefficient of 0.941 at 0.01 level of significance).

Normalized Different Vegetation Index (NDVI):- its measures the greenness of the environment and the amount of vegetation. The NDVI is computed form the following equation-

$$NDVI = \frac{NIR-RED}{NIR+RED} \text{ ………………………………… (9)}$$

Where, NIR is the near infrared radiance from *band 4* and RED is the red radiance from *band 3* of landsat TM.

Distribution of NDVI in linear way, converting the NDVI image on positively by using the following equation-

$$(NDVI + 1)/2$$

Temperature in Celsius:-Conversion kinetic temperature to land surface temperature in degree Celsius by using following equation-

$$LST = (TK - 273) \text{ …………………………… (10)}$$

Where, LST = the land surface temperature and TK = kinetic temperature.

Results and Discussion

In this study, we selected five years (same interval) Landsat images, i.e., the Landsat 5 TM images on April (1st weak), 1990, 1995, 2000, 2005 & 2010. Temperatures were retrieved from Landsat images to analyze the changes of temperature distributions for the past 20 years. The results in the study suggest that the spatial temperatures are gradually increased along with the expansion of the regional industrial belt.

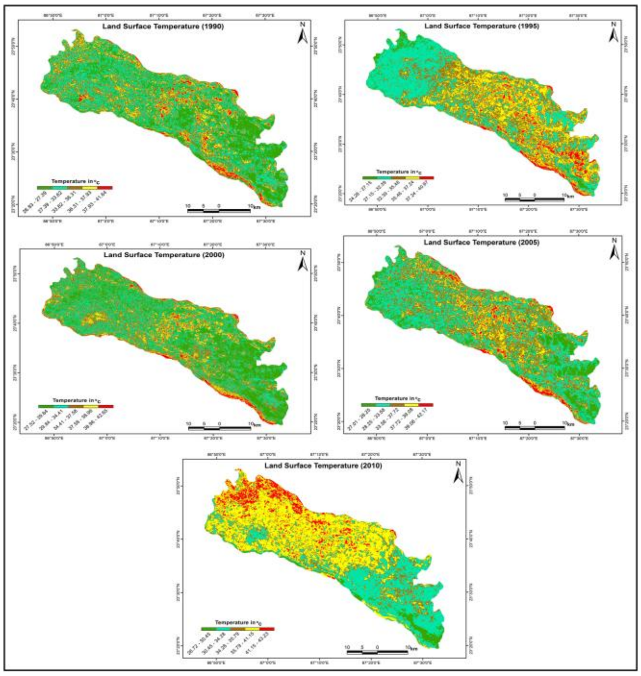

Figure 3: Land Surface Temperature from 1990 to 2010

Years	Minimum Temperature	Maximum Temperature
1990	26.83	41.64
1995	24.28	40.97
2000	27.52	42.65
2005	27.01	42.17
2010	26.72	43.23

Table 3: Maximum and Minimum Temperature

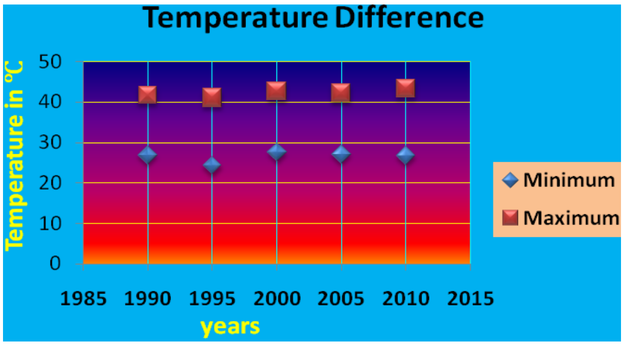

Figure 4: Temperature Difference

Conclusion

From the above study it can be stated that the surface temperature is increasing rapidly throughout the study area due to huge agglomeration of settlement, industry and clearing the original species or the natural vegetation. It has been observed that the surface temperature is higher in urban areas than vegetation and water body areas, because of lower contributions of evaporation and transpiration in non-vegetation areas. It is noted that occasionally vegetation areas might show higher temperature when the area is covered with relatively shorter plants such as shrubs or dried paddy fields.

Reference

1. Chander, G., Markham, B.L. and Helder, D.L. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+ and EO-1 ALI sensors. *Remote Sens. Environ.*, *113*, 893–903.
2. Landsberg, H.E. (1981). The Urban Climate; Academic Press: New York, NY, USA, 84-89.
3. LANDSAT 7 SCIENCE DATA USERS HANDBOOK (2008). Level 1G product–band 6 conversion to temperature. Available online at: http://landsathandbook.gsfc.nasa.gov/handbook/handbook_htmls/chapter11/chapter11.html (accessed 15 May 2008).
4. Lu, Y., Feng, P., Shen, C. and Sun, J. (2009). Urban Heat Island in Summer of Nanjing Based on TM Data. Joint Urban Remote Sensing Event, Shanghai, China, 1-5.
5. Mansor, S. B., Cracknell, A. P., Shilin, B. V., and Gornyi, V. I. (1994). Monitoring of Underground coal fires using thermal infrared data. *International Journal of Remote Sensing*, vol-**15**, 1675-1685.
6. Oke T.R. and Cleugh H.A., 1987, Urban Heat Storage derived as Energy Balance Residuals, Boundary-Layer Meteorology, 39, 233–245.
7. Prakash, A., Gupta R. P., and Saraf, A. K., 1997, A Landsat TM based comparative study of surface and subsurface fires in the Jharia coalfield, India. *International Journal of Remote Sensing*, 18, 2463-2469.
8. Qin, Z., Zhang, M., Amon, K. and Pedro, B. (2001). Mono-window Algorithm for retrieving land surface temperature from Landsat TM 6 data. Acta Geogr. Sinica, 56, 456-466.
9. Reddy, C.S.S., Srivastav, S.K. and Bhattacharya, A. (1993). Application of Thematic Mapper short wavelength infrared data for the detection and monitoring of high temperature related geo environmental features. *International Journal of Remote Sensing*, 14, 3125–3132.

Sobrino, J.A., Jimenez-Munoz, J.C. and Paolini, L. (2004). Land surface temperature retrieval from LANDSAT TM 5. Remote Sens. Environ. 90, 434-440.

Streutker, D.R. (2002). A remote sensing study of the urban heat island of Houston, Texas. Int. J. Remote Sens. 23, 2595-2608.