Estimation of Land Surface Temperature to Study Heat Effect and Trends Using Thermal Remote Sensing and GIS in Part of Southern Tamil Nadu, India

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Abstract

The earth's average temperature has been a big issue on the global warming. The warming of the earth is largely the results of emission of carbon dioxide and other greenhouse gasses (GHG) from human activities. Urban areas considerably vary in land coverage, emission of pollutants and anthropogenic heat release from the natural surroundings. As a result, an alteration of meteorological variables (e.g. temperature, wind, moisture) is detected in the cities, which can fundamentally be observed with three methods: in-situ measurements, numerical mesoscale meteorological models and remote sensing products. In this work, a satellite imagery algorithm was utilized to investigate the spatial distribution of land surface temperature (LST) for the study area. LST is derived using Landsat images of 2004, 2010 and 2017 and Arc-GIS and ERDAS were used to calculate the LST. Higher temperature variations were identified in the southern part of the study area in the year 2004 and 2010. In the year 2017northern part of the study area has recorded more temperature. These results can be considered in urban planning, designing and policy making so as to minimize the vulnerability and bring out strategies for mitigating the vulnerability of higher temperature since these urban areas is still growing.

Keywords: Landsat, ERDAS, Remote Sensing, Change Detection, GIS, Land Surface Temperature.

Introduction

The global warming has been an international issue that attracting the international attention. At the site level, the land surface temperature (LST) has been used by many researchers as an indicator of energy balance. Specifically, the LST has been used as a key parameter that describes the land surface processes (Ema Kurnia., 2016). After the industrial revolution, the population started to increase explosively, and this process caused a rapid urbanization. Whilst 3% of the global population lived in urban areas in the 1800s, nowadays this ratio exceeds 50%. The tendency will likely continue in the forthcoming decades: according to some estimations (e.g. UN 2015), the expansion of urban areas can reach 66% by the 2050s. The modification of the surface energy balance can also be observed in the urban areas. Because of the lower albedo, less incoming (shortwave) radiation is reflected from the ground, thus more heat (energy) is stored in the urban fabric. The reflected shortwave beam is strongly absorbed and backscattered by the pollutants. Long wave components are also attenuated by the absorbtion and re-emission of the aerosol particles. Traffic, industry, domestic energy usage (heating, cooling, cooking etc.) induces a large quantity of anthropogenic heat (AH) emission. Emission of stored and anthropogenic heat leads to an energy surplus in the inner cities. Subsequently, a temperature difference occurs between the urban and rural areas, which is named the urban heat island (UHI) phenomenon. As reported by most studies (e.g. Miao et al. 2009, Wang et al. 2013, Chen et al. 2014), the proportion of AH release in a heat island may attain 30% depending on the land cover categories (MOLNÁR G., 2016).

According to Ustin et al., (2004), there is a growing awareness among environmental scientists that remote sensing can and must play a role in providing the data needed to assess ecosystems conditions and to monitor change at all spatial scales. Thus, acquiring LST from remotely sensed data becomes one of the significant factors in this study. As a key parameter of the surface energy budget, LST is directly related to surface energy fluxes and to the latent heat flux, evapotranspiration and water stress Torrion et al., (2014), surface longwave emission and computing soil moisture Cammalleri and Vogt, (2015) and for understanding meteorological and hydrological processes in a changing climate (Ayodeji Ogunode, Mulemwa Akombelwa., 2016). Nowadays LST (land surface temperature) is used to determine the temperature distribution at the change global, regional and local scale. Also it’s used in climate and acclimate change models in particular. LST, calculated from remote sensing data is used in a lot of sphere of science, like: agriculture, climate change, hydrology, forestry, urban planning, oceanography etc. Obtaining surface temperatures and using them in different analysis is important to determine the problem associated with the environment (Orhan et al., 2014).

Study area Description

Geographical coordinates of the study area extend from 77°48'31.035"E to 78°22'24.481"E longitude and 8°18'51.239"N to 9°10'28.263"N latitude. The study area Tuticorin district is located in southern part of Tamil Nadu; it is covering a distance of about 163.5 Km and covers a study area of 1630.32 Sq.km (Fig.1). It is bounded by Virudhunagar and Ramanathapuram in the north, Tirunelveli in the south and Gulf of Mannar in the east. The annual mean minimum and maximum temperature are 24.4°C and 35.7°C. The study area comes under low rainfall region, normal annual rainfall over the district varies from about 570 mm to 740 mm. South west monsoon accounts for 9%, north east monsoon for 65%, winter being 9% and summer being 17% of total rainfall. The district enjoys a hot tropical climate, depends mainly on north east monsoon, which are brought by the troughs of low pressure developing in south Bay of Bengal between October and December. Summer season started from the march and it extends to till may. Tuticorin district is divided into 8 taluks. The taluks are further divided into 12 blocks, which further divided into 462 villages. The river originating from the Western Ghats and Tamil Nadu uplands have power over the drainage network of the district. A few streams begin in the hillocks within the district and confluences directly with the sea after flowing 10 to 20 km.

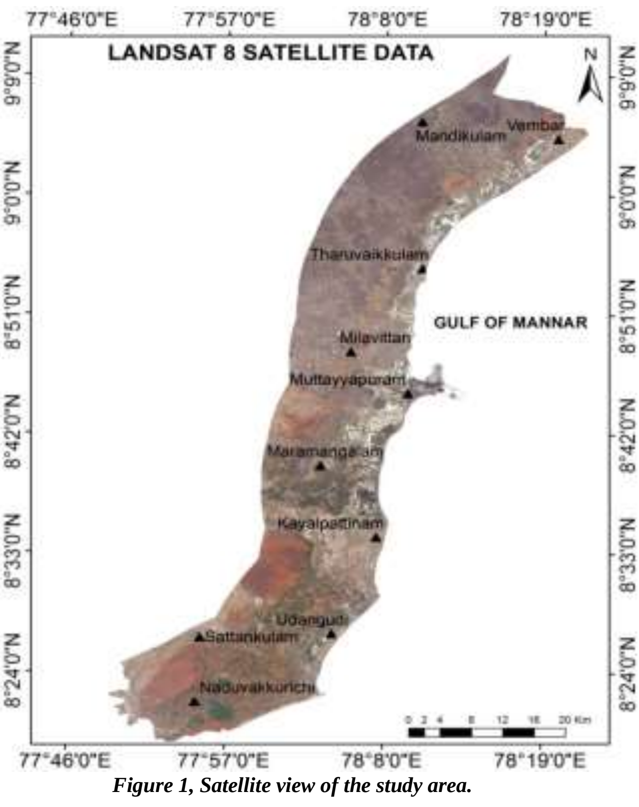

Figure 1, Satellite view of the study area.

Vaipar, Tambraparani and Karamanaiyar are the major rivers draining the district. The major soil types are black soil, red soil & sandy soil. District irrigation by different sources is dug, tube, tanks, and canals. Tuticorin constitutes 70 per cent of the total salt production of Tamil nadu and 30 per cent of that of India. Tamil nadu is the second largest producer of salt in India next to Gujarat.

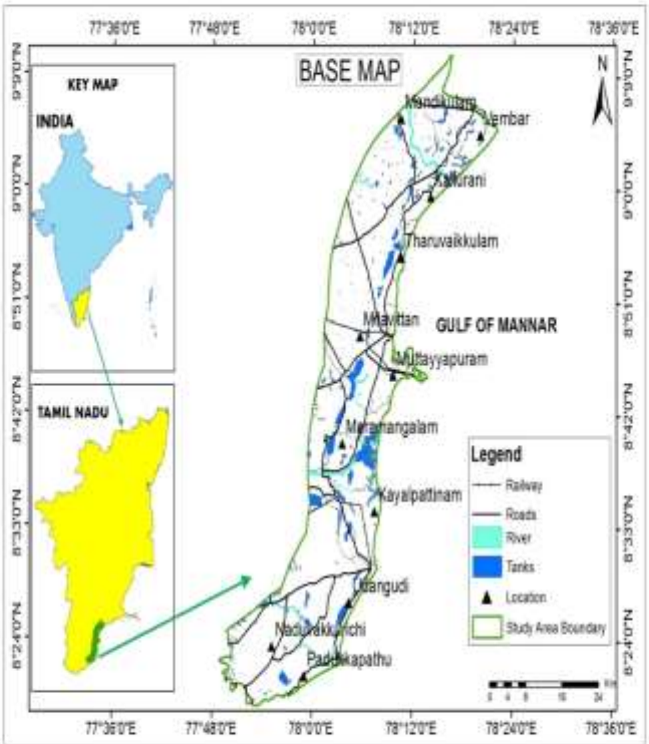

Figure 2, Study area Base Map

Data used for the Analysis

Table 1, Satellite data Used

Sl.No	Sensor	Year
1	Thematic Mapper	2004
2	Thematic Mapper	2010
3	Operational Land Imager/ Thermal Infrared Sensor	2017

Table 2, Bands, Wavelength and Resolution of Landsat8

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
Band 2 - Blue	0.452 - 0.512	30
Band 3 - Green	0.533 - 0.590	30
Band 4 - Red	0.636 - 0.673	30
Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
Band 8 - Panchromatic	0.503 - 0.676	15
Band 9 - Cirrus	1.363 - 1.384	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	30
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	30

Table 3, Bands, Wavelength and Resolution of Landsat5 TM

Bands	Wavelength (micrometers)	Resolution (meters)
Band 6 - Thermal	10.40-12.50	120* (30)

Methodology

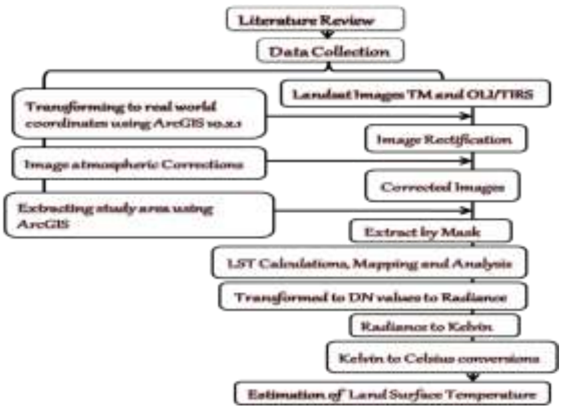

Figure 3, Methodology

Land surface temperature (LST) is generally defined as the skin temperature of the ground. It is calculated by the following formula,

1. Conversion of DN Value to Spectral Radiance

$$L_\lambda = \frac{(R_{MAX} - R_{MIN})}{QCALMAX - QCALMIN} \times (DN - QCALMIN) + R_{MIN}$$

Where,

Lλ= Spectral Radiance at the sensor's aperture (w/m2*sr*µm)
DN= Quantized calibrated pixel value (Q cal)
QCALMIN =1
QCALMAX=255
However, QCALMAX for Landsat 8 is 65535
RMIN= Spectral at-sensor radiance that is scaled to Qcalmin (W/m2* sr * µm)
RMAX=Spectral at-sensor radiance that is scaled to Qcalmax (W/m2* sr * µm)

2. Conversion of Spatial Radiance into Temperature Kelvin

$$T = \frac{k_2}{alog[\left(\frac{k1}{L_\lambda}\right) + 1]}$$

Where, T= Temperature in Kelvin, Lλ= Spectral Radiance

CONSTANTS (UNITS)	K1 (W/m2* sr * µm)	K2 (Kelvin)
L5 TM	607.76	1260.56
L8 TIRS	774.89	1321.08

3. Conversion of Temperature Kelvin to Degree Celsius

The temperature in Celsius was calculated using the equation

$$T(°C) = T(K) - 273.13$$

Where,

T (°C) = Temperature in Celsius,

T= Temperature in Kelvin,

273.13= Zero Temperature Kelvin.

Results and Discussion

Temperature changes during 2004-2017

Spatial distribution of LST in part of Tuticorin from 2004 to 2017 is demonstrated by Figure 4, 5 and 6.

From the above results, it can be observed that the southern part of the study area has more temperature in the year of 2004, 2010 and 2017. LST is not only influenced by landuse/land cover types, but also by elevation, vegetation coverage, local meteorological conditions, and landscape composition. Therefore, even for the same landuse type, the mean LST may be different in different locations along the urban–rural gradient.

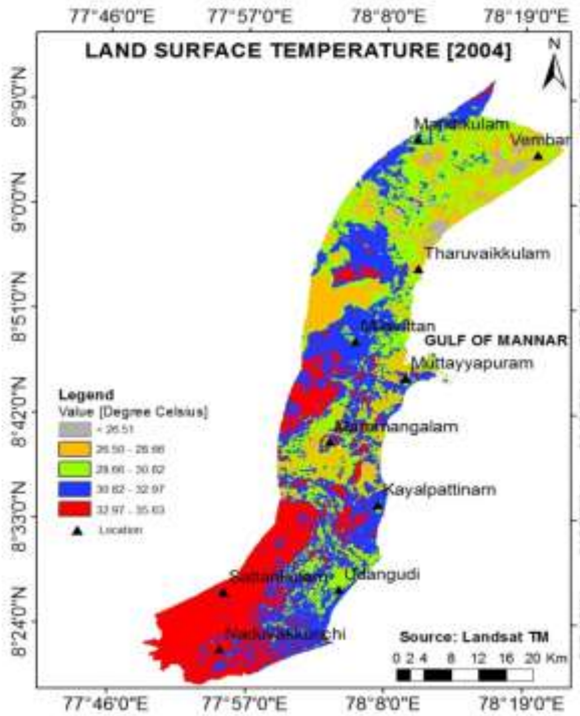

Figure 4, Land surface Temperature Map of 2004.

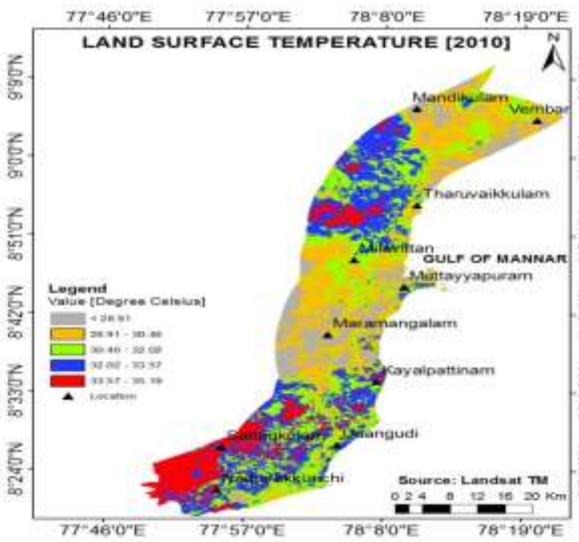

Figure 5, Land surface Temperature Map of 2010.

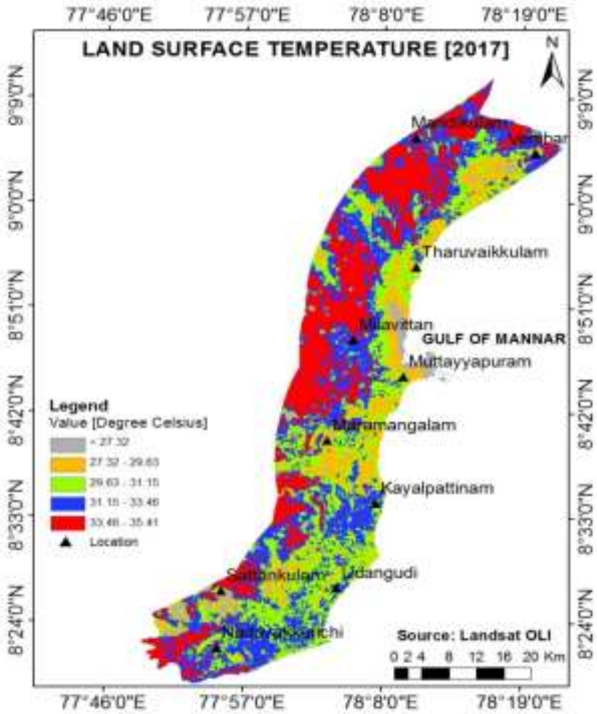

Figure 6, Land surface Temperature Map of 2017.

Conclusion

Tuticorin district has around 4621 Sq.Km and commercial capital for the state. The model created in ERDAS Imagine 2014, estimated the LST for the selected datasets over the study area. The algorithm was created using the brightness temperature of TIRS band 10 and emissivity of different land covers types, derived from visible and near infrared bands of LANDSAT 8 and band 6 in LANDSAT 5. Land surface temperature was prepared and the values are ranging from 16.18^{0}C to 41.95^{0}C for 2004, 19.05^{0}C to 42.73 ^{0}C for 2010 and 17.38^{0}C to 40.72^{0}C for the year 2017. The study reveals that the southern part of the study area has maximum temperature recorded in the year of 2004 and 2010. Based on the year 2017, temperature pattern has rapidly changed and maximum spread around northern part of the study area. For environmental studies and earth, land surface temperature is now considered an important parameter. Modeling for estimating land surface temperature from Landsat thermal imagery can be a good, time saving and effective options for researchers.

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