Changes in Land Surface Temperature due to Industrialization & Urbanization using geo-spatial technologies -A case study of Bhilwara city, Rajasthan

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Abstract →

Land Surface Temperature (LST) is the radiant temperature of the land surface, absorbed by the objects. Although, it's different than actual atmospheric temperature but, it's somewhere linked with the atmospheric temperature. Bhilwara is a textile city where industries as well as urbanization have occurred and grown up gradually. The study aims to track the change in the land surface temperature due to industrialization & urbanization of the city. The mean temperature of the area was 31.17ºC in 1999 which became 34.46ºC in 2009 & 32.29ºC in 2018. During the time period of 1999-2009 the temperature increased highly (3.29ºC). Although, in the time period of 2009-2019, We can see that the temperature decreased 2.17ºC .In the year of 2009 correlation between Normalized Difference Built-up Index (NDBI) & Land Surface Temperature(LST) is very highly positive (R^2=0.995).Where in 2018 found negligible positive correlation (R^2=0.230).Strong correlation is observed between Land Surface Temperature & Normalized Difference Vegetation Index (NDVI). Urban population is also growing rapidly, the growth rate of urban population in India between 2001-2011 was 2.63%.The growth rate of Bhilwara was also increasing below the average (1.01%) .No. of industries was registered in 1999 was 11859.But this number was decreased in 2009, was 627.Where the study suggests that how industrialization & urbanization controls the land surface temperature.

Keywords →

Land Surface Temperature (LST), Radiant Temperature, Atmospheric temperature, Normalized Difference Built-up Index (NDBI), Normalized Difference Vegetation Index (NDVI).

INTRODUCTION-

Land Surface Temperature (LST) means temperature of the surface or object. It depends on the nature of land surface .Generally water bodies, green fields, wet soil remains cooler than the bare soil, sand & build up area. Increasing urban population in Bhilwara city is also major reason of temperature rise. So there is a positive relation between industrialization, urbanization & LST.

LST changes with a change in climatic condition and other human activities where the exact prediction becomes challenging. Worldwide urbanization has significantly increased in greenhouse gases and reshaped the landscape, which has important climatic implications across all scales due to the simultaneous transformation of natural land cover and introduction of urban materials i.e. anthropogenic surfaces.

Industrialization is the process by which an economy is transformed from primarily agricultural to one based on the manufacturing goods. Individual manual labor is often replaced by mechanized mass production, and craftsmen are replaced by assembly line.It is the period of social & economic change that transforms a human group from an agrarian society This involves an extensive re-organization of an economy for the purpose of manufacturing.

Bhilwara, is a city in Rajasthan, is also famous for textile industry. It is also known as "Textile City". The major industry is textiles, with more than 850 manufacturing units in town.The main textile product is synthetic fabric which is used in trouser. It started with a spinning & kitting company named "Mewar textile & mills" in 1938.

The study will help us to know the relationship between LST & industrialization & urbanization. We can also get to know the trend of the temperature of the study area. Urbanization is a process of population concentration.

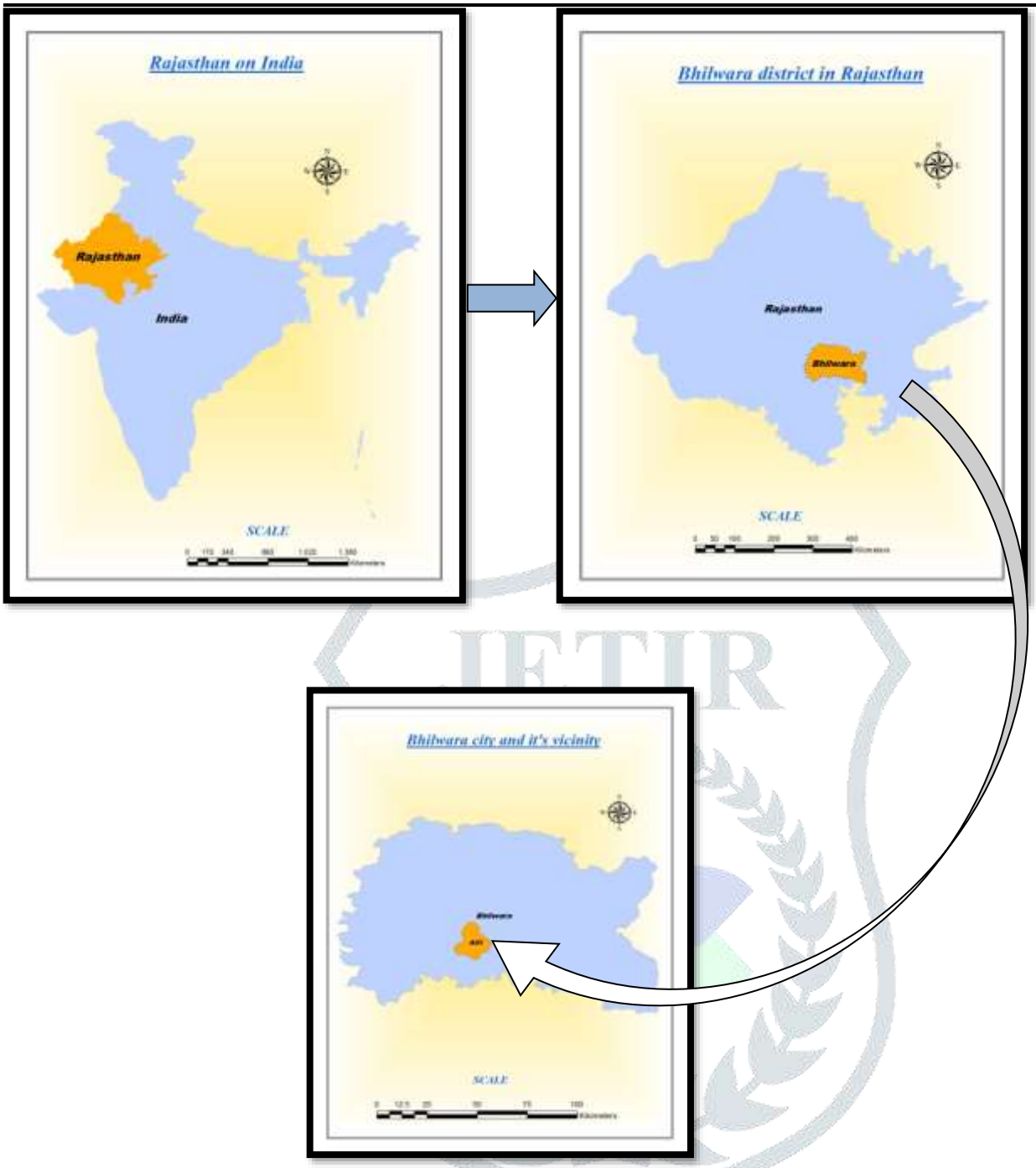
"**Urbanization is a result of population migration from rural areas in addition to natural urban demographic growth."-Urbanization**

According to World Health Organization (W.H.O.)

In 2001, Bhilwara city hold 13.91% (2,80,128) population among the population(20,13,789) of the whole district. Whereas in 2011, city hold 14.92% (3,59,483) population among the population(24,08,523) of the whole district. The growth rate of urban population is 1.01%.

STUDY AREA-

Bhilwara is a city in south western side of Rajasthan. Geographically the city is located at 25.359854^{o}N 74.652791^{0}E. It is mainly known as "textile city" of Rajasthan.2KMs of buffer is given of Bhilwara city boundary, which is selected as Area of Interest (AOI).



Map 01.Loaction Map

PRODUCTS-

The Landsat 5TM & Landsat 8 OLI&TIRS data are acquired from "Earth Explorer" a website of United States Geological Survey (USGS).Landsat 5 has a thermal infra-Red band (band 6),Landsat 8 has two thermal infra-Red band(band 10, band 11).Both products are processed in Arcgis 10.4.The details of Landsat data products are given below :-

Table: 01-***List of the Landsat Data used***

Sl.No	Satellite	Sensor	Acquisition Date	Time	Sun elevation
1	Landsat 5	TM	1999-10-29	-	46.98
2	Landsat 5	TM	2009-09-21	05:21:50	55.86
3	Landsat 8	OLI&TIRS	2018-10-16	05:31:51	50.39

Table: 02-***Band details of Landsat 5***

Sl. No	Band	Type	Spectral range (μm)	spatial resolution (m)
1	4	Red	0.76 - 0.90	30
2	5	NIR	1.55 - 1.75	30
3	6	TIR	10.40 - 12.50	120

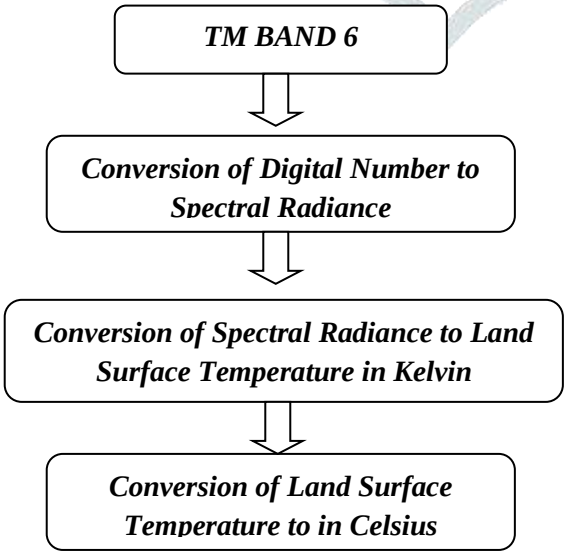
Table: 03-***Band details of Landsat 8***

Sl. No	Band	type	Spectral range (μm)	spatial resolution (m)
1	4	Red	0.64 - 0.67	30
2	5	NIR	0.85 - 0.88	30
3	6	SWIR	1.57 - 1.65	30
4	7	SWIR	2.11 - 2.29	30
5	10	TIR	10.60 - 11.19	100
6	11	TIR	11.50 - 12.51	100

METHODOLOGY & RESULTS-

- *Estimation of LST from **Landsat 5**:-*

  - *Flowchart* =



Process

Step 1. Using following formula, Spectral Radiance (Lλ) has been calculated through Conversion of the Digital Number (DN)

Lλ = ((LMAXλ - LMINλ)/(QCALMAX-QCALMIN)) * (QCAL-QCALMIN) + LMINλ where:

Lλ = Spectral Radiance at the sensor's aperture in watts/(sq.m)

LMAXλ = the spectral radiance that is scaled to QCALMAX in watts/(sq. m)

QCALMIN = the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN QCALMAX = the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN

Step 2. Next, Spectral Radiance has been converted to Temperature in Kelvin by following formula.

$$T=K2/\ln((k1/L\lambda)+1)$$

Where:

T = Effective at-satellite temperature in Kelvin

K2 = Calibration constant 2 from metadata

K1 = Calibration constant 1 from metadata

Lλ = Spectral radiance in watts/(sq. m)

Step 3. Land Surface Temperature (LST) has been calculated in Celsius using following formula.

$$TK=(T-273.15)$$

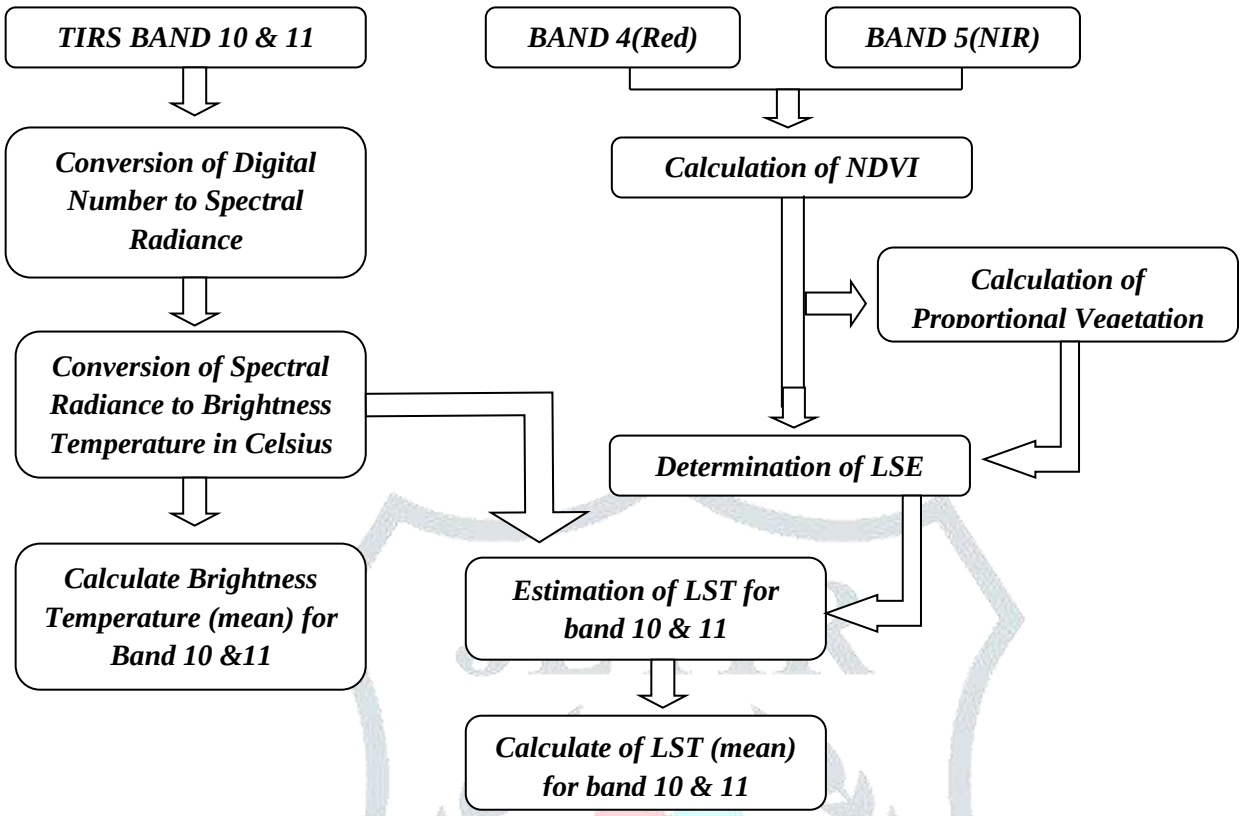
Where:

TK= Effective at-satellite temperature in Celsius

T= Effective at-satellite temperature in Kelvin.

- *Estimation of LST from **Landsat 8**:-*

Flowchart



Process =

Step 1. Top of Atmosphere (TOA) Radiance:

Using the radiance rescaling factor, Thermal Infra-Red Digital Numbers can be converted to TOA spectral radiance.

$$L\lambda = ML * Qcal + AL$$

Where:

Lλ = TOA spectral radiance (Watts/ (m2 * sr * μm))

ML = Radiance multiplicative Band (No.)

AL = Radiance Add Band (No.)

Qcal = Quantized and calibrated standard product pixel values (DN)

Step 2. Top of Atmosphere (TOA) Brightness Temperature:

Spectral radiance data can be converted to top of atmosphere brightness temperature using the thermal constant Values in Meta data file.

$$BT = K2 / \ln (k1 / L\lambda + 1) - 272.15$$

Where:

BT = Top of atmosphere brightness temperature (°C)

Lλ = TOA spectral radiance (Watts/(m2 * sr * μm))

K1 = K1 Constant Band (No.)

K2 = K2 Constant Band (No.)

Step 3. Normalized Differential Vegetation Index (NDVI):

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which Calculated using Near Infra-red (Bnad 5) and Red (Band 4) bands.

$$NDVI = (NIR – RED) / (NIR + RED)$$

Where:

RED= DN values from the RED band

NIR= DN values from Near-Infrared band

Step 4. Land Surface Emissivity (LSE):

Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth calculated from NDVI values.

$$PV = ((NDVI – NDVI\ min) / (NDVI\ max + NDVI\ min))^2$$

Where:

PV = Proportion of Vegetation

NDVI = DN values from NDVI Image

NDVI min = Minimum DN values from NDVI Image

NDVI max = Maximum DN values from NDVI Image

$E = 0.004 * PV + 0.986$

Where:

E = Land Surface Emissivity

PV = Proportion of Vegetation

Step 5. Land Surface Temperature (LST):

The Land Surface Temperature (LST) is the radiative temperature, which calculated using Top of atmosphere brightness temperature, Wavelength of emitted radiance, Land Surface Emissivity.

$$LST = (BT / 1) + W * (BT / 14380) * \ln (E)$$

Where:

BT = Top of atmosphere brightness temperature (°C)

W = Wavelength of emitted radiance

E = Land Surface Emissivity

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