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LAND SURFACE TEMPERATURE AND ITS CORRELATION WITH VEGETATION COVER USING LANDSAT DATA -A STUDY OF GORAKHPUR, UTTAR PRADESH

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Abstract- Urban sprawl has led to a decline in the agricultural land and rise in the congested built-up area in all the developing countries while increasing the temperature of the urban atmosphere. Rising temperature has slowly started risking human and plant health. By using Landsat 8 (Operational Land Imager) OLI/ (Thermal Infrared Sensor) TIRS thermal bands 10 and 11 the Land Surface Temperature (LST) was measured as it is considered an important aspect of land environment because it measures the emission of heat radiance from the surface of the earth and heats up several features of the earth. The satellite data of the Gorakhpur City, Uttar Pradesh was taken at the peak summer time and the data included was from the month of May,2013,2016 and 2019 respectively to measure the rise in Land Surface Temperature from 17.34 C (2013) to 20.785 C (2019). Vegetation cover has a significant effect on LST because it lowered down from 0.345(2013) to 0.171 (2019) showed an inverse relationship

The data obtained was co-related with Land Surface Temperature (LST) and the greenery of the area or Normalized Differential Vegetation Index (NDVI). The Correlation coefficient obtained was~-0.8 which indicated that surface temperature of the land increases with the decrease in the vegetation cover forming a strong negative co-relation. This study showed the relationship between rise in land temperature with the decrease in the vegetation cover.

Keywords: **Urban sprawl, Thermal Remote Sensing, Land Surface Temperature (LST), Normalized Differential Vegetation Index (NDVI), Operational Land Imager (OLI), Thermal Infrared Sensor (TIRS)**

Introduction:

Thermal Remote Sensing has helped in the acquisition of such data which has helped in several applications. One such is the detection of land surface temperature and urban heat island analysis (Sekertekin and Bonafoni,2020).

The Landsat 8 OLI and TIRS satellite has several bands which help in the detection of Land surface temperature with the help of Band 10 and Band 11 and NDVI with the help of Band 4 and Band 5(Ayse, Dagliyar et.al, 2015).

There are several researches and studies done over finding a relation between land surface temperature and the vegetation cover which is done on major cities of India and worldwide.

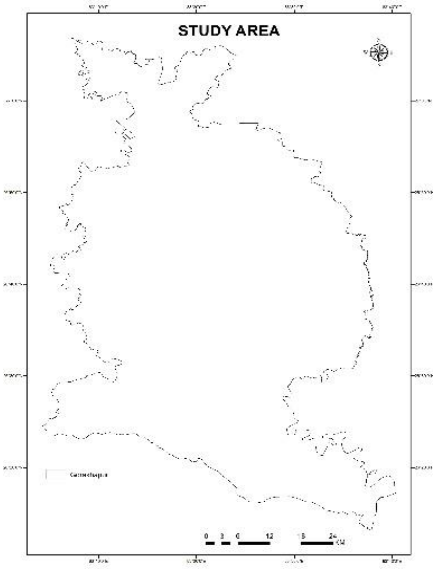
An almost identical study was conducted in Tokyo (Kawashima;200), the Atlanta Metropolitan Area, Beijing, the Pearl River Delta, China and Wuhan City, China, using the Landsat dataset. Although the investigations with respect to UHI and NDVI are bountiful for major cities of the developed world, there is a scarcity of research with respect to the urban areas of India. Issues pertaining to land surface emissivity, LST and NDVI are explored by Mallick et al., Sharma and Joshi and Kant et al. for Delhi, A comparative study of Delhi and Mumbai was also done by (Grover and Singh,2015).

Study Area:

Gorakhpur is located in the spatial extent of 26.7606° N, 83.3732° E and covers an area of 226.6Km^2 with an elevation of 84m from the main sea level (msl). It is situated on the banks of Rapti river and Rohin river is the north-eastern part of the Uttar Pradesh state.

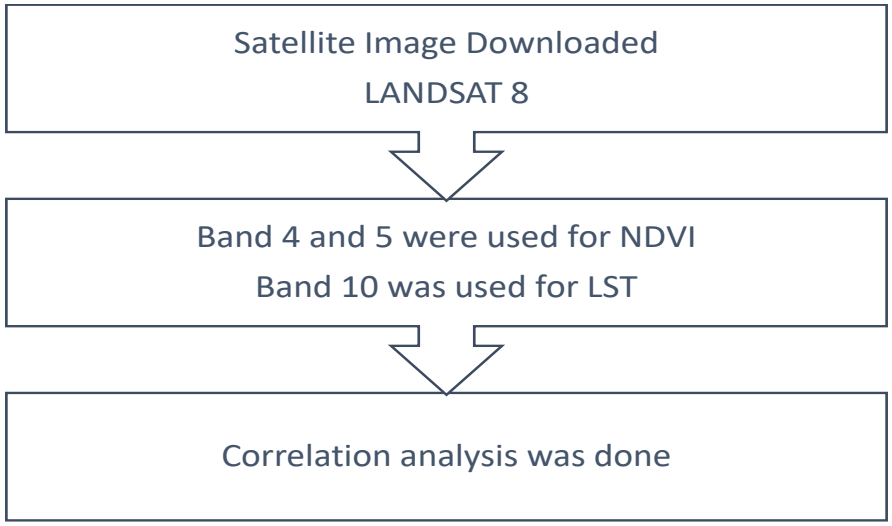
It has an international border with Nepal on north while Azamgarh marks the periphery on south, Basti on west and Deoria district on east.

Gorakhpur is famous as the religious centre for the Nath sect/sampradaya and is named after saint Baba Gorakhshnath. It is also the headquarters to the North Eastern Railway Zone of the Indian railways. It has also got the world's second longest railway station. Geeta Press is the world's largest publisher of Hindu texts situated in Gorakhpur.



Database and Methods:

The Landsat 8 OLI/TIRS data were downloaded from the United States Geological Survey Website www.earthexplorer. usgs website of the peak summertime months of May 2013,2016 and 2019.The thermal bands 10 and 11 were used to extract LST. The near-infrared (NIR) and red (R) were used to measure vegetation cover and NDVI was calculated. The Landsat images were used to compare LST and NDVI. The cloud cover data of the year 2013 was 1.02/0.13, 2016 was 3.80/9.09 and 2019 was0.13/3.0. The gap of 2 years has been taken to see the changes in LST and Vegetation cover of the area.



Software used:

ArcGIS (version 10.8)

MS Office

Details of Satellite images used:

Satellite Name	Sensors	Aquired date of the data	Band	Spatial Resolution (meters)	Path/Row	Cloud Cover (
Landsat 8	OLI/TIRS	17 May,2013 09 May,2016 18 May,2019	Band 10	100	142/041 142/042	1.02/0.13 3.80/9.09 0.13/3.0
Landsat 8	OLI/TIRS	17 May,2013 09 May,2016 18 May,2019	Band 11	100	142/041 142/042	1.02/0.13 3.80/9.09 0.13/3.0
Landsat 8	OLI/TIRS	17 May,2013 09 May,2016 18 May,2019	Band 5	30	142/041 142/042	
Landsat 8	OLI/TIRS	17 May,2013 09 May,2016 18 May,2019	Band 4	30	142/041 142/042	

Parameters to be found:

- Temperature of Atmosphere (ToA) Radiance
- Brightness Temperature (BT)
- Normalized Difference Vegetation Index (NDVI)
- Proportion of Vegetation (PV)
- Land Surface Emissivity (LSE)
- Land Surface Temperature (LST)
- Change/Difference in the NDVI and LST
- Correlation between NDVI and LST

Methodology:

The LST was extracted with the Mono-window algorithm which involved finding out several parameters such as ToA, BT, NDVI, PV, LSE, LST.

The formula is given as follows:

Step 1: (ToA)Radiance

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

Where,

- $L\lambda$=TOA spectral radiance
- ML=Radiance multiplicative Band (No.)

- Q_{cal}=quantized and calibrated standard product pixel values (DN)
- AL=Radiance add band (No.)
- Oi=correction value for band 10 is 0.29

Step 2: Conversion to TOA Brightness temperature

BT= (1321.0789/Ln (K1/ Lλ +1)-273.15

Where;

BT=Top of Atmosphere brightness temperature (° C)

Lλ=TOA spectral radiance (watts/ (m^2*sr* μm)

K1=K1 constant band (No.)

K2=K2 constant band (No.)

Step 3: NDVI

NDVI is a dimension less index which estimates the vegetation cover of an area. The high NDVI values indicate healthy vegetation cover while the low NDVI is related to sparse vegetative cover of an area (Weier, Herring,2000)

NDVI=(NIR-RED)/(NIR+RED)

NDVI= (Band 5- Band 4)/(Band5-Band4)

Where;

- RED=DN values from the red band
- NIR= DN values from the NIR band
- Add data >Band 4 and Band 5>Rename it.
- Float (Band5-Band4)/Float (Band5+Band4)
  Step:4 Land Surface Emissivity (LSE)

$$PV=((NDVI-NDVI_{min})/(NDVI_{max}-NDVI_{min}))^2$$

- Where;
- PV= Proportion of Vegetation
- NDVI= DN values for DN images
- $NDVI_{min}$= Min DN values from NDVI images
- $NDVI_{max}$=Max DN values from NDVI images

Step 4: LSE or Emissivity

E=0.004*PV+0.986

Where;

E=Land surface emissivity

PV=Proportion of Vegetation

0.986 corresponds to a correction of the equation

Step 5: Land Surface Temperature

LST=BT/(1+λ*BT/C2*In(E))

Here,

C2=14388μmK

Λ=Band 10=10.8,

Band 11=12.0

Where;

BT=Top of atmosphere brightness temperature(C)

Λ=wavelength of emitted radiance

E=Land Surface Emissivity

C2=h*c/s=1.4388*10^2 =14388mK

H=Planck's constant=6.626*10^{34} J/S

S=Boltzmann constant=1.38*10^{23} Jk

C=velocity of light=2.998*10^8 m/s

The study area was extracted from the satellite data and two bands, band no 10 of each satellite images were mosaicked using "mosaic to new raster "tool in ArcGIS because the study area was bigger. The same was done with the Band No. 5 and Band no.4. District boundary of the Gorakhpur area was then masked from the satellite data with the help of "extract by mask" tool in the ArcGIS software. This involved the image processing of the two satellite images to make them one as this would have a great amount of impact on the results. The parameters were calculated by using the "Raster Calculator" in ArcGIS.After finding out several parameters, the change in land surface temperature (LST) and NDVI was calculated by using MS Excel of the Gorakhpur City.

Results:

ANALYSIS OF NDVI:

The Normalized Difference Vegetation Index (NDVI) is a dimensionless index that describes the Visible and NIR reflectance of vegetation cover on an area (Weier and Herring,2000)

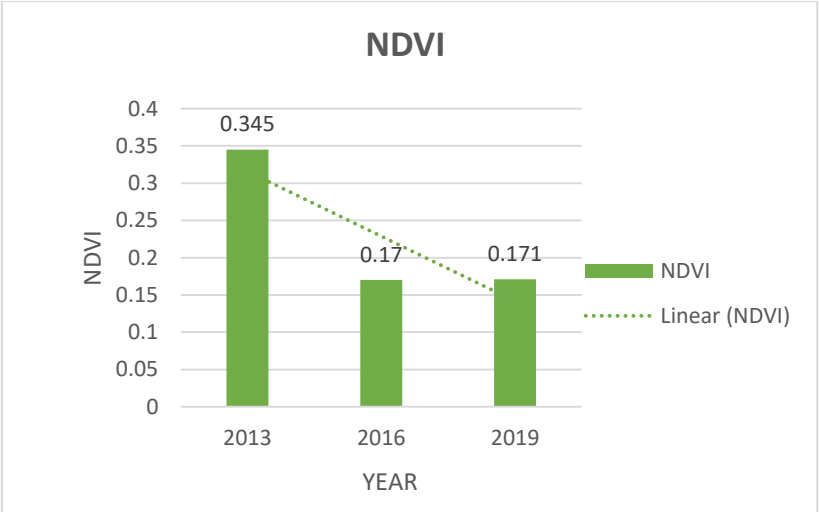
The NDVI classification range is as follows:

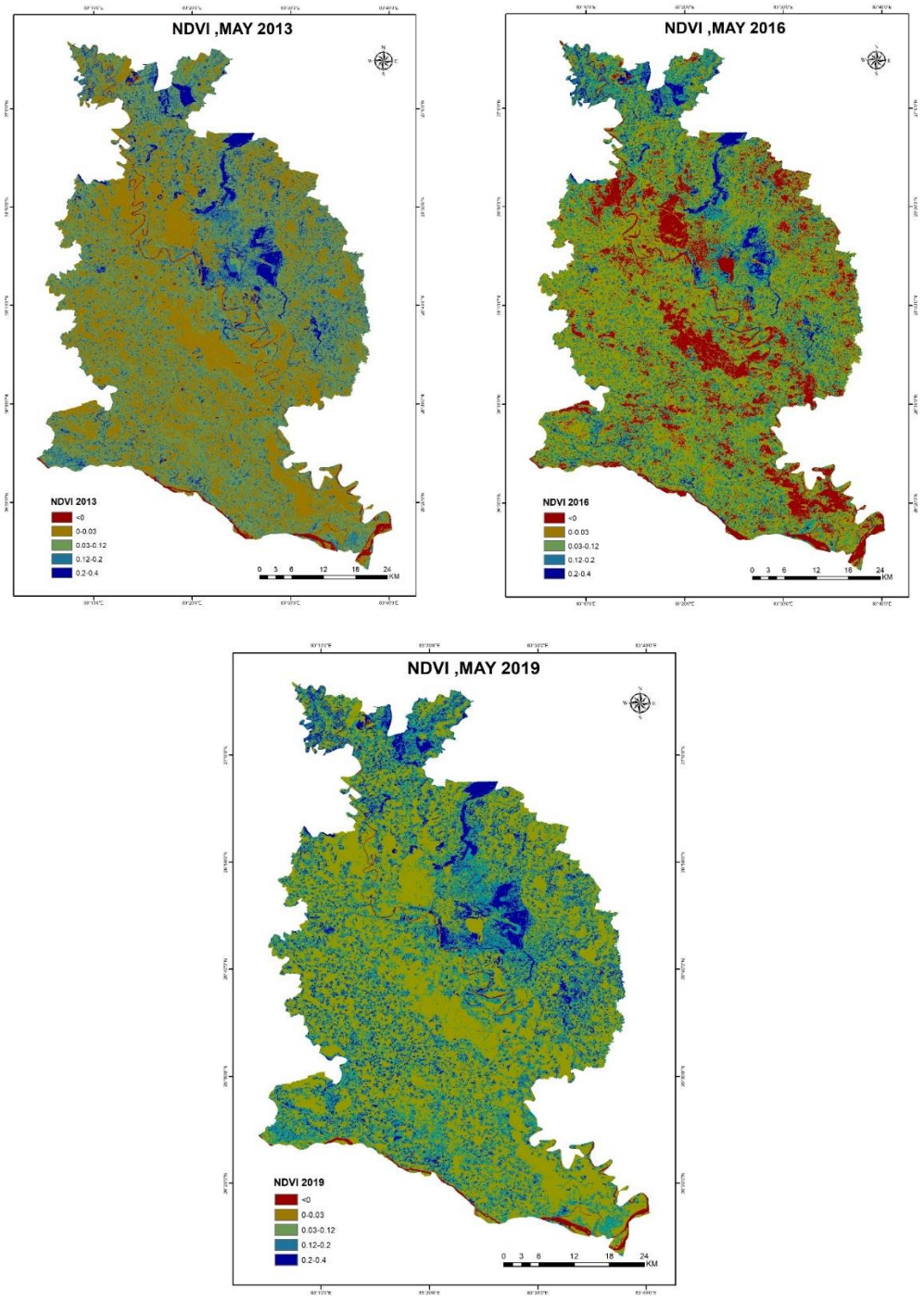
-1 to 0 represents Water/ Snow/cloud

0-0.2 represents Barren Land/Built-up area/Rocks

0.2-1 represents Vegetation, (Alex, Ramesh, et.al;2017)

In this study it was found that the vegetation index ranged from <0 to 0.4. In the year 2013, mean NDVI was found to be 0.345, while in the year 2016 it was 0.17 and in the year 2019 it was almost same as that of 2016 which was 0.171.

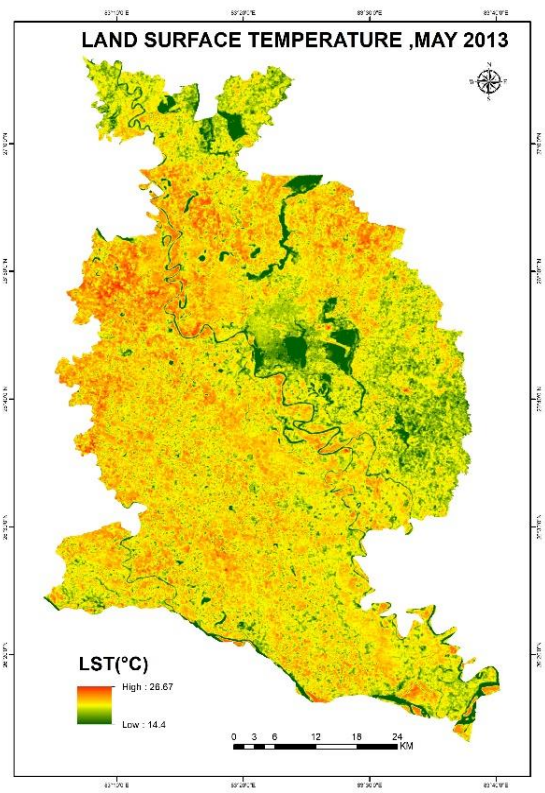


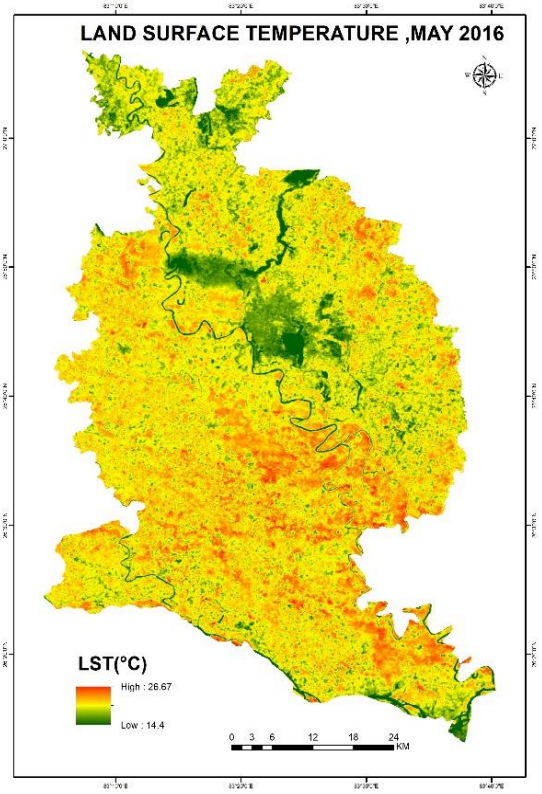


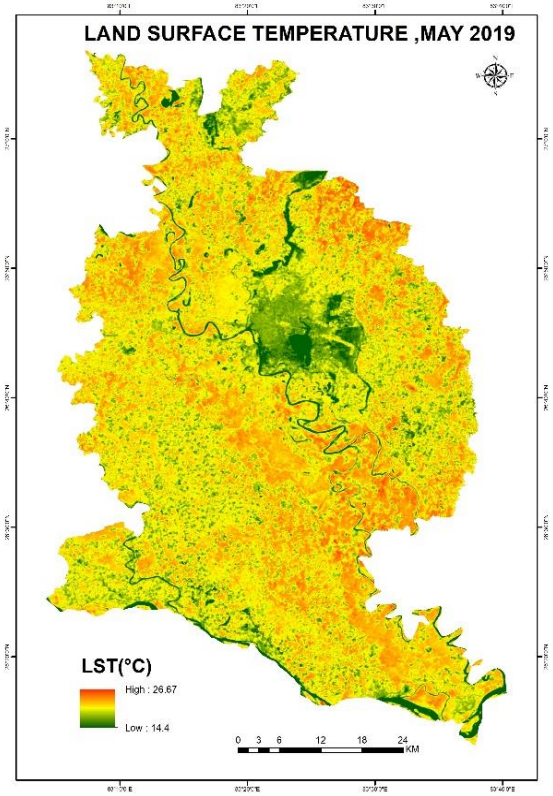
Analysis of LST:

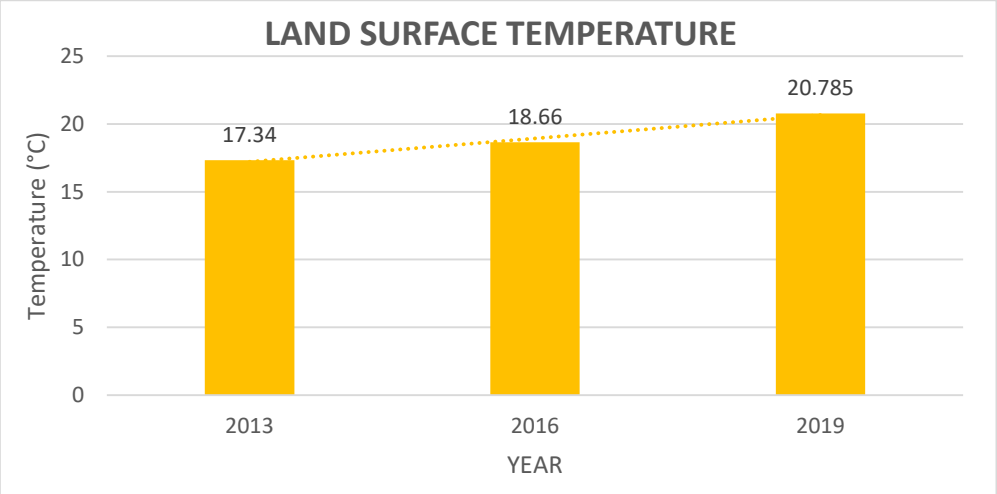
Land Surface temperature (LST) was seen in the increasing order every year.

In the year 2013, the mean LST was 17.34 °C, In the year 2016, the mean LST was 18.66 °C while in the year 2019, the mean LST was found to be 20.785 °C. Hence with the data of every increasing year, there was a rise in the LST.


LAND SURFACE TEMPERATURE ,MAY 2013
LST(°C)
High : 26.67
Low : 14.4
0 3 6 12 18 24
KM

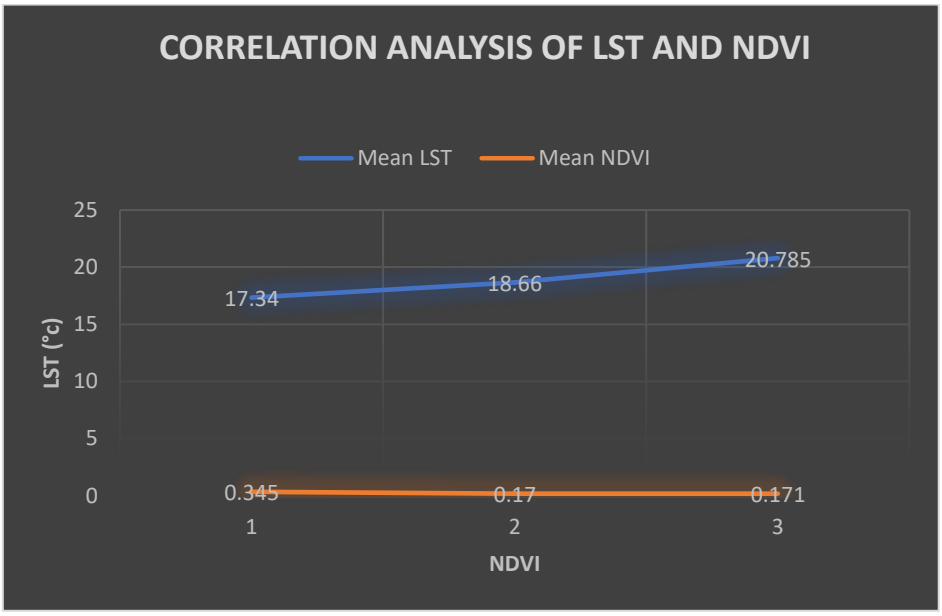

LAND SURFACE TEMPERATURE ,MAY 2016
LST(°C)
High : 26.67
Low : 14.4
0 3 6 12 18 24
KM


LAND SURFACE TEMPERATURE ,MAY 2019
LST(°C)
High : 26.67
Low : 14.4
0 3 6 12 18 24
KM



Co-relation of LST AND NDVI:

The correlation analysis of LST and NDVI was done and it was found that in the year 2013, the vegetation cover was 0.345~0.4 which means there was vegetation cover according to (Alex, Ramesh, et.al;2017) with 17.34°C but in the year 2016 the vegetation cover reduced to 0.17~0.2 with an increase in the temperature of 1.32°C. In the year 2019, the NDVI remained same which was 0.171 but the LST increased to 20.785°C. The correlation coefficient (r) was found to be -0.788357~ -0.8.



Result and Discussion:

There was a rise in LST from 2013 to 2019 but in case of NDVI, the vegetation index went from 0.345 to 0.17 from 2013 to 2016 but was almost same from 2016 to 2019 (i.e 0.171) but LST continued to increase. This takes our attention to the fact that NDVI 0.2 indicates built-up areas and barren lands. Not only this, the anthropogenic activities such as transportation and construction have also increased leaps and bounds in these years which had led to increase in temperature change and thus adding to Global warming and Climate Change.

An approximately -0.8 coefficient correlation indicates a strong association between the two variables that is LST and NDVI.

Conclusion:

A negative correlation between LST and NDVI indicates that the vegetation cover is important to keep our land surface cool and activities such as deforestation should be stopped and afforestation or reforestation should be adapted. Green roofing might also affect temperature changes.

In this study, a rise in the land surface temperature was detected in the year 2013,2016,2019 by finding out the NDVI and LST. There was a strong negative correlation between the two. The Peaks in LST showed the impervious surfaces have increased through the years and continue to do so while the low values of NDVI indicates over the little vegetation.

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