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Statistical Correlation between Land Surface Temperature (LST) and Vegetation Index (NDVI) using Multi-Temporal Landsat TM Data

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Abstract Remote sensing TIR as a part of the electromagnetic spectrum is one of the best observations of Land surface temperature (LST). Our earth contains heterogeneous land feature and it is composed of a variety of materials. Now-a-days there are many remote sensing satellites that provide thermal data. In the present study, the Landsat TM data with multi temporal periods such as 1992, 2001 and 2010 were utilized to study LST in the mining area. The aim of the study is to prepare LST mapping for estimating land surface temperature from multi temporal Landsat TM thermal bands and compare with the associated phenomenal condition. The Landsat 5 TM data of 11-03-1992, 09-02-2010 and Landsat 7 data of 15-05-2001 were used and the land surface emissivity's for these particular periods were estimated. The Normalized Difference Vegetation Index (NDVI) was calculated in the same period. The image processing was adopted using the ENVI 4.7 software. The results of emissivity and vegetation index interpreted for each period indicated that when the emissivity increases vegetation index shows negative anomaly. The standardization of error coefficient was founded with the aid of statistical software SPSS, which strengthened the approach of the study. The statistical regression analysis of NDVI and LST were shown in Standardized regression coefficient (B) value as -0.209, -0.143 and -0.190 in the years of 1992, 2001 and 2010 respectively. Comparison of LST and its associated constraint will precisely indicate that these variables are mutually important. Remote sensing multi temporal satellite data when coupled with an image processing technique will support for estimate land surface temperature, normalized vegetation index and preferably utilized for an empirical data report from the Indian Meteorological Department (IMD) ground based observation data.

Keywords *LST; NDVI; Remote Sensing; Image Processing; Regression*

1. Introduction

LST defines the remote sensing, monitoring surface temperature of ground as pixel based derived observation. These clustering of pixels can be grouped as different class features. LST possesses soil surface temperature, canopy, and vegetation body. In this context, the spatial resolution of satellite remote sensing thermal data can be defined as the average temperature of surface existing features represented on pixel scale that demarcate the differences in emissivity of the land.

Estimation of land surface temperature (LST) is an indication of surface emissivity changes due to anthropogenic activities. Many researchers have estimated the temperature by using land observation stations and well equipped instruments which are expensive, in relationship with the remote sensing thermal band being utilized and it was found as easy and low cost effective tool to identify the surface emissivity. The TIR remote sensing data for land surface temperature estimation in Band 3 and Band 4 for Normalized Difference Vegetation Index studies were carried out by many researchers with various satellite data products as well as they adopted various statistical approaches to achieve their interpreted results (Valor & Caselles, 1996; Goetz, 1997; Sandholt et al., 2002; Kim et al., 2005). The temperatures of the region and vegetation condition were monitored through Landsat TM data for multitemporal periods. Land surface temperature emissivity in thick forest, usually low and NDVI remarks as positive, and the bare soil without vegetation surface temperature emissivity become high as represented in the negative indices (Anderson et al., 2008). The vegetation index may be varied based on terrain condition and types of trees cover. Surface emissivity can be measured by satellite data and the emissivity of temperature compared as a part of accuracy assessment (Srivastava, 2010). Satellite temperature estimation with strong correlation of IMD derived temperature data and vegetation indices were evaluated by NDVI observation. Land Surface Temperature is an important parameter to determine the energy exchange between the surfaces of the earth (Shah et al., 2013; Orhan et al., 2014) and the radiant temperature that will help to understand the change of the surface temperature. Identification of changes on LST over a period of time is one of the most important environmental parameters in the study domain. The radiant temperature can be calculated and interference for the terrain condition for future perspective (Balamurugan et al., 2009). NDVI can analyze the temporal changes over the study region to visualize the change in the concentration of temperature radiant with respect to time. The heat energy accounting from high to low by radiation, convection or conduction process and it is applied to surfaces emissivity studies (Gupta, 2005) for various applications. LST-NDVI estimated through satellite derived products and defines their relationship through conventional statistical approach. (Weng et al., 2004; Goetz, 1997). Finally, this review will support to study the relationship of land surface temperature and Normalized vegetation index. Meanwhile, the intend of parameters like meteorological earth observed temperature and annual rainfall is utilized from an IMD report for support parameters.

2. Study Area

The study area Salem magnesite mining zone lies in the southern part of India and it covers 190 sq. km area in between 78°06’16’’ E to 78°19’25’’ E longitude and 11°66’47’’ N to 11°78’76’’ N latitude and located in bottom of Shervroy hills (Figure 1), Salem magnesite mining landform located adjacent to dense forest (Kurumpampatti reserved forest), agriculture land, shrubs, rice crops and other plantation. Geologically, the study area bounded by ultramafic of Achaean age with a rich of magnesite ore as vein deposits and it appears white colour therefore termed as “Chalk hills”. The climate in mining area is dry and moderate with temperature ranges from 23°C to 38°C. The average annual rainfall varies from 800mm to 1600mm. The climate during January and February are generally pleasant, the dry summer begins in March, with the year's highest temperatures reach during May. The weather continues more temperate in June and July, and in August become cloudy. The northeast monsoon contributes rainfall during September to December.

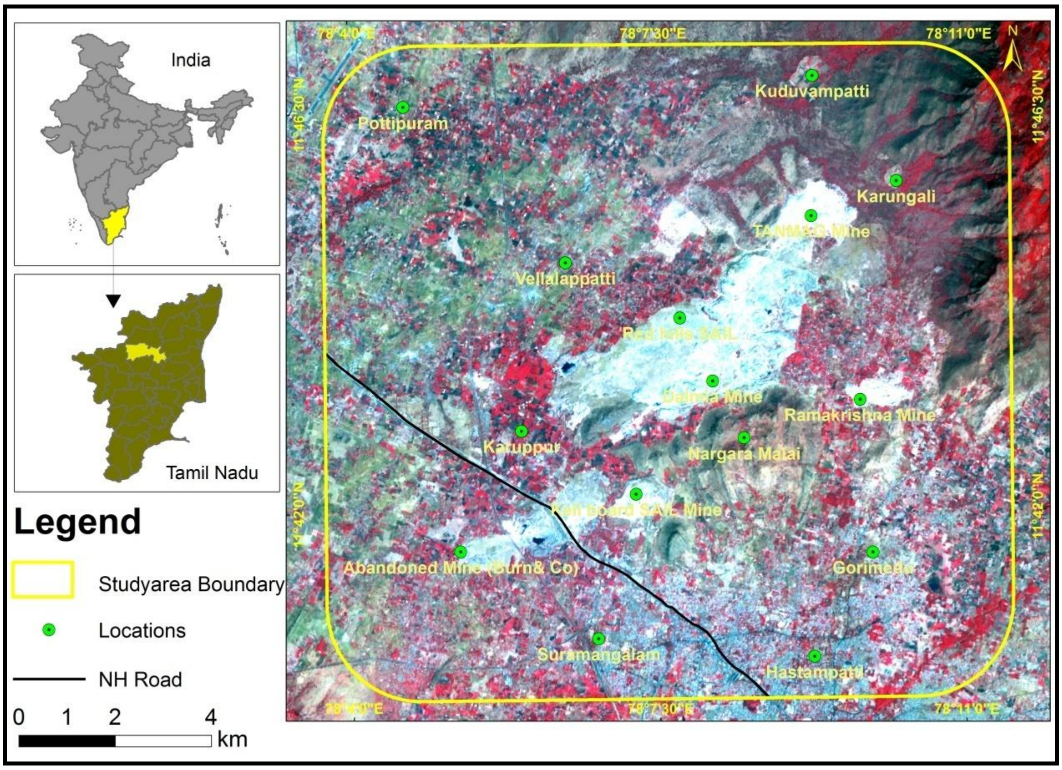


Figure 1: *LANDSAT TM 5 Satellite Data 2010 Show the Magnesite Mining Region Located in Parts of Salem, India*

3. Methodology

Landsat TM 5 and TM 7 satellite data were utilized for estimation of Land Surface Temperature (LST) and generate vegetation indices. The specifications of satellite data products are represented in Table 1. The ENVI 4.7 software image processing utilized to determine the LST & NDVI. The maximum and minimum values in study region were found in the generated map and the simple

Table 1*: Satellite Data used in this Study*

S. No.	Data Type	Resolution	Year of Product	Source
1	LANDSAT 5	30 m*	11-03-1992	USGS
2	LANDSAT 7	30 m*	15-05-2001	USGS
3	LANDSAT 5	30 m*	09-02-2010	USGS

**Spatial resolution in thermal infrared is 120 m, but it is resampled to 30 m pixels*

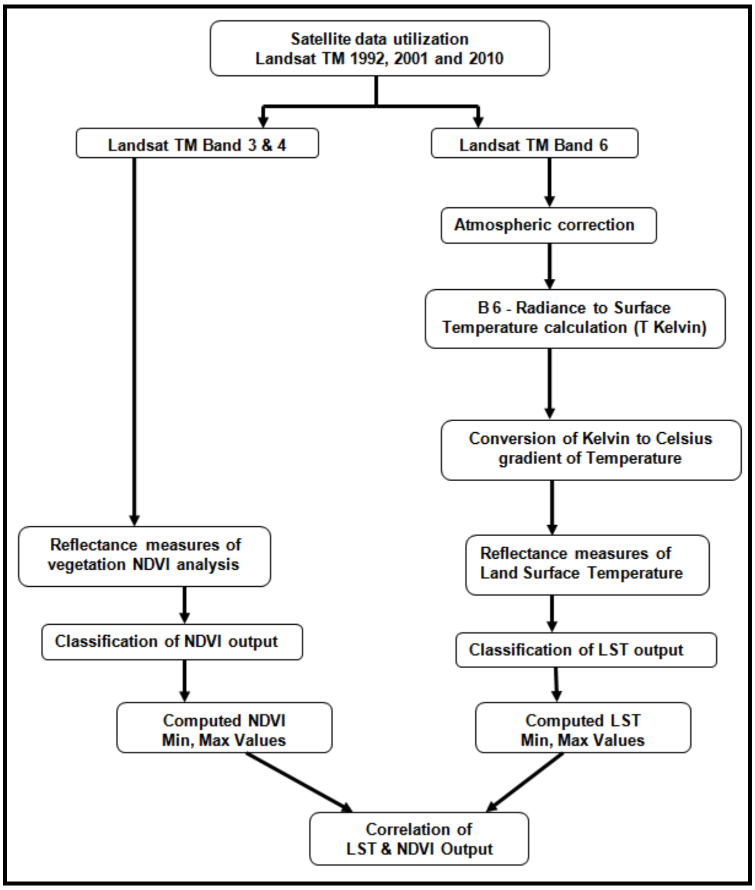


***Figure 2**: Methodology Adopted for Computation of LST and NDVI*

correlation was applied to improve results. TM data Band 6 with (1.40-12.50 µm resampled with 30m spatial resolution) is utilized for LST output NDVI analysis carried out with the help of Band 3 (0.63-0.69 µm) with 30m spatial resolution) and Band 4 (0.76-0.90 µm with 30m spatial resolution) were utilized. The detailed image processing technique adopted in this study is shown in Figure 2. The linear regression model was used to estimate (SPSS package) the regression coefficient for dependent variable LST and in the same way independent variable NDVI value ranges.

3.1. Land Surface Temperature Estimation

Surface temperature is a general, non-specific term referring to the aggregate temperature of all objects, comprising the existing surface. LST maintains by the incoming solar and long wave irradiation, (Li et al., 2013) the outgoing terrestrial infrared radiation, the sensible and latent heat flux, and the ground flux. It is a good indicator of the energy balance at the earth's surface. The LST measurement in satellite data to digital format of DN values and the defined utilization methods for computing land surface temperature by various workers (Chander and Markham, 2003; Chander et al., 2009; Srivastava et al., 2010; Sheela et al., 2011) find out the surface temperature measurements through satellite derived data. Based on reviews and better understanding methods would be followed to execute for surface temperature measurements in Landsat TM TIR data in 1992, 2001 and 2010 respectively. The following steps are strengthening to estimate Land surface temperature with a mathematically derived formula to find the surface temperature of particular domain pixel.

Step 1: Radiometric correction requires converting remotely sensed digital numbers (DN) to spectral radiance values and data comparable. To perform the conversion of DN to spectral radiance by using the equation (1)

$$L_\lambda = L\text{min} + (L\text{max} - L\text{min}) * \text{DN} / 255 \qquad Eq.(1)$$

Where,
L_λ = Spectral radiance
Lmin = 1.238 (Spectral radiance of DN value 1)
Lmax = 15.600 (Spectral radiance of DN value 255)
DN = Digital Number

The above equation (1) converts DN values into spectral radiance (L_λ)

Step 2: Conversion at sensor spectral radiance

In radiometric calibration, pixel values (Q) in the raw data and unprocessed image data were converted into absolute radiance value and the following equation (2) is performed for this conversion and satellite data scaled into 8 bits (Qcalmax=255) values.

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{Q_{calmax} - Q_{calmin}}\right)(Q_{cal} - Q_{calmin}) + LMIN_\lambda \qquad Eq.(2)$$

Or

$$L_\lambda = G_{rescale}\ X\ Q_{cal} + B_{rescale}$$

Where,

$$G_{rescale} = \frac{LMAX_\lambda - LMIN_\lambda}{Q_{calmax} - Q_{calmin}}$$

$$B_{rescale} = LMIN_\lambda - \left(\frac{LMAX_\lambda - LMIN_\lambda}{Q_{calmax} - Q_{calmin}}\right) Q_{calmin}$$

Where,
L_λ = Spectral radiance at the sensor's aperture [W/ (m^2 sr µm)]
Qcal = Quantized calibrated pixel value [DN]
Qcalmin = Minimum quantized calibrated pixel value corresponding to LMINλ [DN]
Qcalmax = Maximum quantized calibrated pixel value corresponding to LMAXλ [DN]
$LMIN_\lambda$ = Spectral at-sensor radiance that is scaled to Qcalmin [W/ (m^2 sr µm)]
$LMAX_\lambda$ = Spectral at-sensor radiance that is scaled to Qcalmax [W/ (m^2 sr µm)]
$G_{rescale}$ = Band-specific rescaling gain factor [(W/ (m^2 sr µm))/ DN]
$B_{rescale}$ = Band-specific rescaling bias factor [W/ (m^2 sr µm)]

Step 3: Conversion to TOA reflectance (L_λ-to- ρp)

Landsat TM Top of Atmosphere Reflectance (TOA), data must be corrected and processed because of variation in solar zenith angles due to the time difference between data acquisitions. The TOA reflectance of the Earth is computed according to the equation (3)

$$\rho_\lambda = \frac{\pi . L_\lambda . d^2}{ESUN_\lambda . COS\theta_S} \qquad Eq. (3)$$

Where,
ρ_λ = Planetary TOA reflectance [unitless]
π = Mathematical constant approximately equal to 3.14159 [unitless]
L_λ =Spectral radiance at the sensor's aperture [W/ (m^2 sr µm)]
d = Earth-Sun distance [astronomical units]
$ESUN_\lambda$ = Mean exoatmospheric solar irradiance [W/ (m^2 µm)]
θ_s=Solar zenith angle

Step 4: Radiance from sensor to effective at-sensor brightness temperature (L_λ to T)

The thermal band data (Band 6 on the TM and ETM+) need to be converted from at-sensor spectral radiance to effective at-sensor brightness temperature. At-sensor temperature uses the prelaunch calibration constants adapted from Table 2. The conversion formula for the at sensor's spectral radiance to at-sensor brightness temperature are in the equation (4)

$$\mathrm{T} = \frac{K2}{\mathrm{In}\left(\frac{\mathrm{K1}}{\mathrm{L}_\lambda} + 1\right)} \qquad Eq. (4)$$

Where,
T = Effective at-sensor brightness temperature [K]
K2 = Calibration constant 2 [K]
K1 = Calibration constant 1 [W/ (m 2 sr µm)]
L_λ = Spectral radiance at the sensor's aperture [W/ (m^2 sr µm)]
In = Natural logarithm

Table 2: *Pre- Launch TM Thermal Band Calibration Constants*

Constant	LANDSAT TM	LANDSAT ETM+
K1	607.76	666.09
K2	1260.56	1282.71

(Courtesy: NASA, LANDSAT Handbook, 2011)

Step 5: Conversion of temperature Kelvin (T_K) to Celsius (^{0}C)

The surface temperature output from satellite image is Kelvin (T_K) and the same temperature need to convert into Celsius (^{0}C), for that the temperature *T* in Kelvin (K) subtracted by 273.15 as illustrated in the equation (5)

$$T(^\circ C) = T_{(K)} - 273.15 \qquad Eq. (5)$$

The above steps were adopted for converting Landsat calibrated DNs to absolute units of at-sensor spectral radiance, TOA reflectance, and at-sensor brightness temperature.

3.2. Derivation of Normalized Difference Vegetation Index

The Normalized Difference Vegetation Index (NDVI) shows that the indices derived from remote data under visible and near infrared bands of the electromagnetic spectrum. NDVI were adopted for various applications (Pettorelli et al., 2005; Holm et al., 1987; Anbazhagan et al., 2014). The NDVI values directly related to land cover parameters like total count of biomass. In this context, the reflectance ratio calculated from the remotely sensed satellite data is used to derive the density of vegetation indices as expressed in the following equation (6)

$$NDVI = \left(\frac{NIR}{RED}\right)/(NIR + RED) \qquad Eq. (6)$$

Where, NIR and RED are the DN value of Near-infrared and red band respectively.

Generally, healthy vegetation will absorb most of the visible light that falls on it, and reflects a major portion of the near-infrared region. Unhealthy or sparse vegetation reflects more visible light and less near-infrared region. Bare soils on the other hand reflect moderately in both the red and infrared portion of the electromagnetic spectrum (Lillsand et al., 2009) and the results will appear zero. The NDVI outputs were obtained from the Landsat TM images for the year of 1992, 2001 and 2010 and respectively shown in the Figures 6, 7 & 8.

4. Results and Discussion

The primary objective of the study is to find out land surface temperature as well as vegetation index and correlation the variables using multi temporal Landsat TM data. The LST and NDVI obtained for the year of 1992, 2001 and 2010. Figures 3, 4 & 5 have shown that the spatial distribution of estimated LST respectively, for the years 1992, 2001 and 2010. The maximum and minimum temperature and statistics of LST are shown in Table 3. The minimum is 23.61^{0}C and maximum of 40.01^{0}C with the mean average of 16.4^{0}C. In Landsat TM 2001, the estimated value of LST represents a minimum of 22.28^{0}C and maximum of 35.72^{0}C and mean average of 13.44^{0}C. Using Landsat TM 2010 data, LST was calculated and the minimum temperature was found to be 30.99^{0}C and maximum of 33.58^{0}C and so the mean average of 12.35^{0}C. The maximum and minimum LST are graphically represented in Figure 9. An archive report obtained from the Indian Meteorological Department (IMD) as listed in Table 4. The satellite derived estimates LST and IMD ground station observed temperature is comparable and validated findings of estimated temperature. The IMD observations and satellite derived LST are nearly in agreement with respect to temperature values in the respective years. In the study region, high temperature is mostly plunge at middle and southwest portions. The middle portion covered by the magnesite mining act and there is no count of trees, meanwhile the other portions may exhibit high emissivity due to barren area and the rest of the area fall in medium temperature.

Figure 6, 7 & 8 shows the spatial distribution of NDVI indices derived from the Landsat image 1992, 2001 and 2010. NDVI of 1992, minimum of -0.23 and maximum of 0.65 values with mean value is 0.63. In 2001, NDVI value with minimum of -0.30 and maximum 0.48 with mean value 0.66 and NDVI values of 2010 signify as a minimum of -0.58 and maximum of 0.34 and mean value of 0.53. The statistics of NDVI are listed in Table 3 and the difference shown in Figure 10. It is observed that in all three years NDVI with negative values appeared in the central portions of the study area indicates that absence of vegetation or short vegetation cover like shrubs. This area located mainly in and around the magnesite mining region. The NDVI value corresponding high in the North-East portion indicating dense vegetation cover and tall plantations in the study region. A medium NDVI associated with seasonal crops and agricultural activities in the study region. In particular, NDVI of 2010 shows the lowest NDVI value in the south west portions which is due to increasing of urbanization in those regions. As such the combinations of LST and NDVI are the best tools to identify temperature of the region and NDVI support as a validation of study. The ground based IMD temperature results is also nearly identical to the estimated value. The middle portion has higher emissivity records because soil surfaces have an influence on the measured brightness temperature due to mining activities.

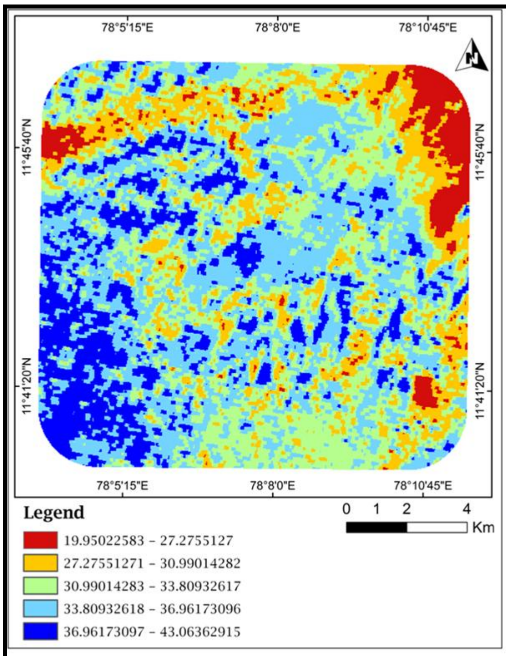


__Figure 3:__ Land Surface Temperature (Celsius) Gradient Derived from LANDSAT TM 5 for 1992 data

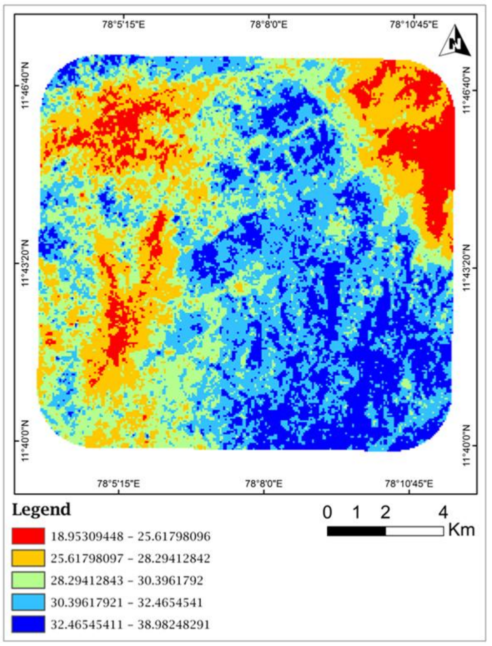


__Figure 4:__ Land Surface Temperature (Celsius) Gradient Derived from LANDSAT TM 7 for 2001 data

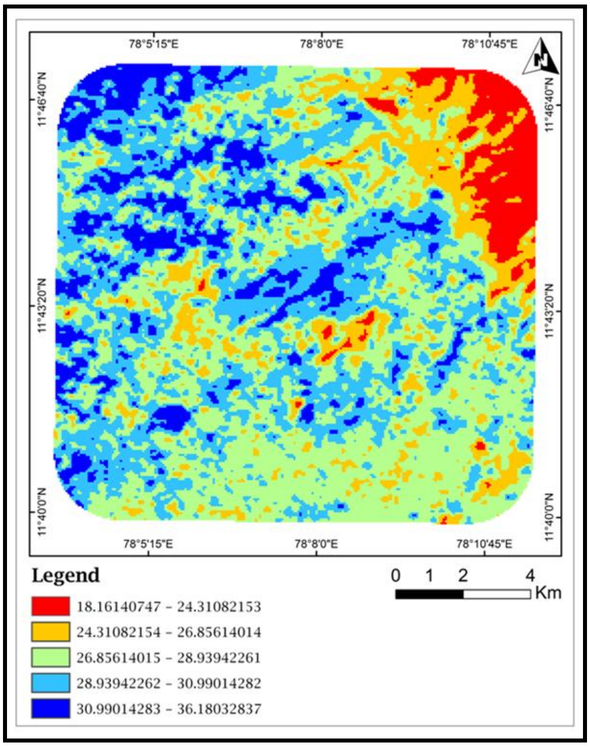


__Figure 5:__ Land Surface Temperature (Celsius) Gradient Derived from LANDSAT TM 5 for 2010 data

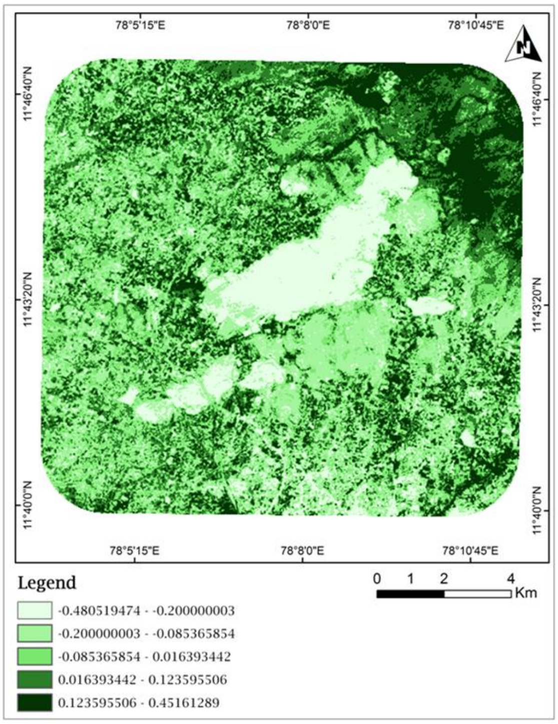


Figure 6: NDVI derived from LANDSAT TM 5 for the year 1992

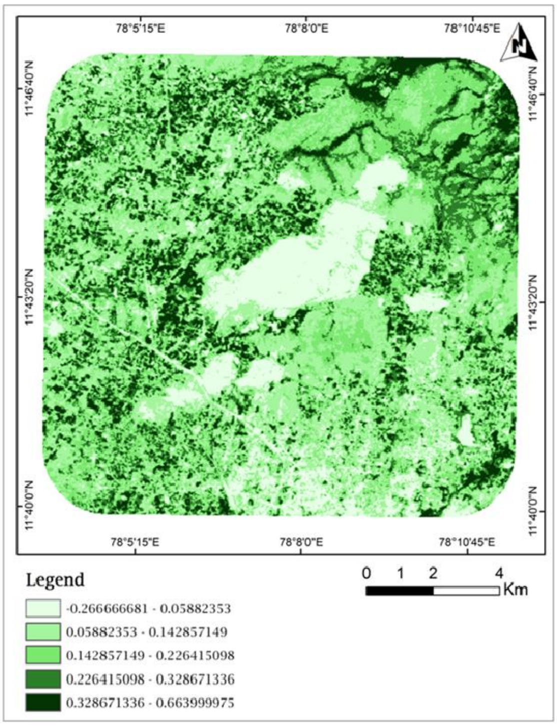


Figure 7: NDVI derived from LANDSAT TM 7 for the year 2001

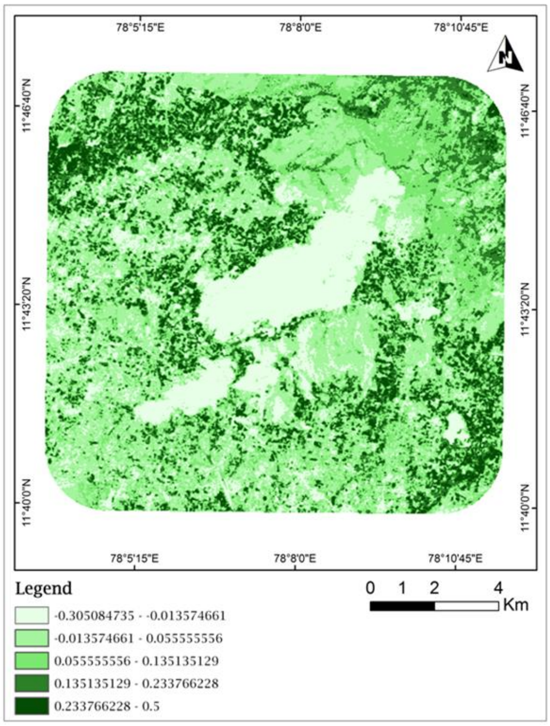


Figure 8: *NDVI Derived from LANDSAT TM 5 for the year 2010*

Table 3: *Satellite Data Derived Estimates Land Surface Temperature, NDVI Index and Range calculations*

	LST		NDVI		LST & NDVI Range	
Year	Minimum (^{0} C)	Maximum (^{0} C)	Minimum	Maximum	Temperature Range	NDVI Range
1992	23.61	40.01	-0.23	0.65	16.4	0.63
2001	22.28	35.72	-0.30	0.48	13.44	0.66
2010	30.99	33.58	-0.58	0.34	12.35	0.53

Table 4: *IMD observations on Land Surface Temperature & Annual rainfall*

Year	Minimum Temperature (^{0} C)	Maximum Temperature (^{0} C)	Average Annual Rainfall (in mm)
1992	22.5	33.7	162.7
2001	25.5	36.8	110.9
2010	20.2	33.7	0.00

(Courtesy: IMD, Meteorological Observatory Data)

Table 5: *Interpreted Temperature Ranges from LST & NDVI Indices and Associated Pixel Count during 1992, 2001 & 2010*

Years	LST		NDVI	
	Temperature (^{0} C)	Pixel counts	Indices	Pixel counts
1992	20-27	2538	-0.48 - -0.20	11126
	27-31	7613	-0.20 - -0.09	21219
	31-34	18468	-0.09 - 0.01	15176
	34-37	22361	0.01 - 0.12	10287
	37-43	12244	0.12 - 0.45	5373
2001	19-26	4811	-0.26 - 0.05	6959
	26-28	12185	0.05 - 0.14	13896
	28-30	14905	0.14 - 0.23	16659
	30-32	19785	0.23 - 0.33	15761
	32-39	11423	0.33 - 0.66	9905
2010	18-24	3378	-0.30 - -0.01	8351
	24-27	7746	-0.01 - 0.05	19243
	27-29	25224	0.05 - 0.13	18187
	29-31	19595	0.13 - 0.23	11197
	31-36	7107	0.23 - 0.5	6215

Ultimately, it exhibits high emissivity cluster appearing in temperature value. The present study reveals that the maximum surface temperature observed in the middle portion of the mining area because of lower contributions of evaporation and transpiration in the absence or lesser vegetation cover. Soil surfaces have an influence on the measured brightness temperature. Perhaps some places of vegetation regions show high temperature due to short shrub coverage. The comparison of maximum and minimum values makes an impact on the statistics in the particular region. (Figure 11 and Table 3)

The standardized regression coefficient value obtained with the aid of the SPSS statistical package to find the B-Standardized regression coefficient parameters were observed in the regression analysis. The regression value indicates that NDVI B-values show negative (Table 6). Hence, it is to be concluded that in the study region, NDVI shows a negative result due to absence or limited vegetation cover. The vegetation indices not only based on temperature emissivity, but also depend on rainfall and circumstance of the season. The rainfall data obtained from IMD for the periods of 1992, 2001 and 2010 and the average annual rainfall distribution are 162.7 mm, 110.9 mm and zero respectively (Table 4).

Table 6: *Statistical Regression Analysis between LST Vs NDVI*

Dependent Variable	Independent Variable	B value
LST 1992	NDVI 1992	-0.209
LST 2001	NDVI 2001	-0.143
LST 2010	NDVI 2010	-0.190

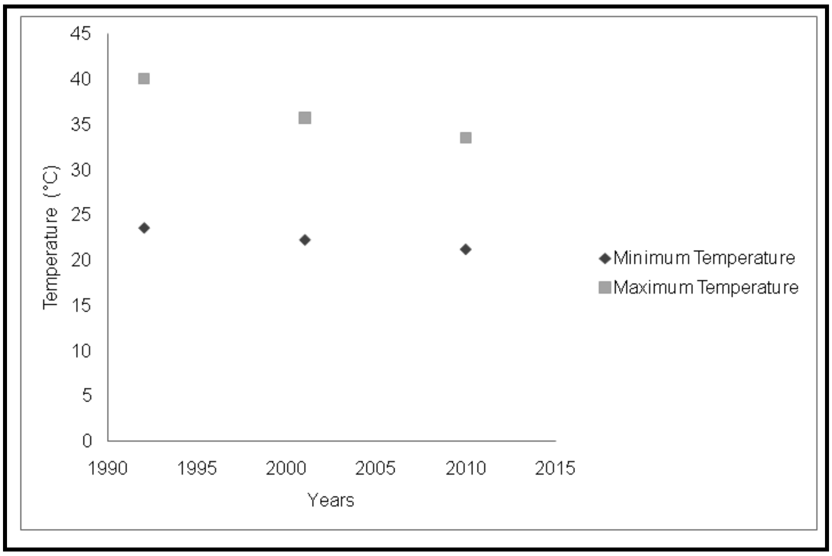


Figure 9: *LST Minimum and Maximum during 1992, 2001 and 2010*

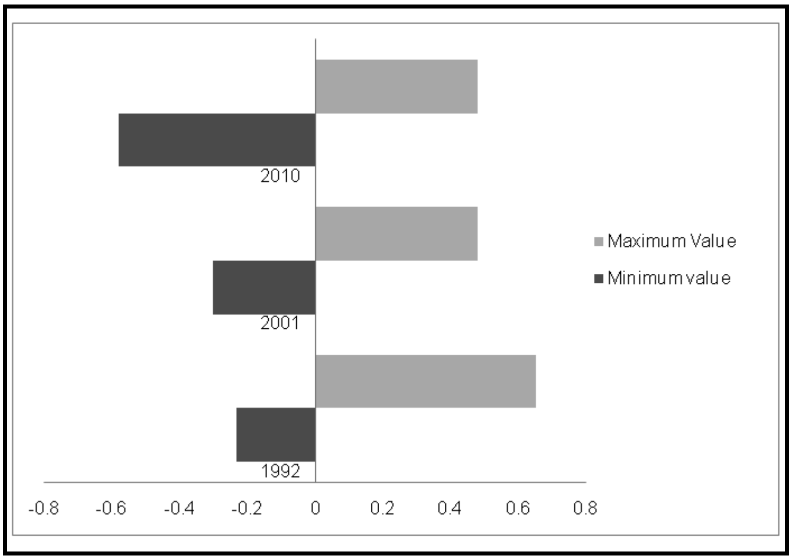


Figure 10: *Minimum and Maximum NDVI during 1992, 2001 and 2010*

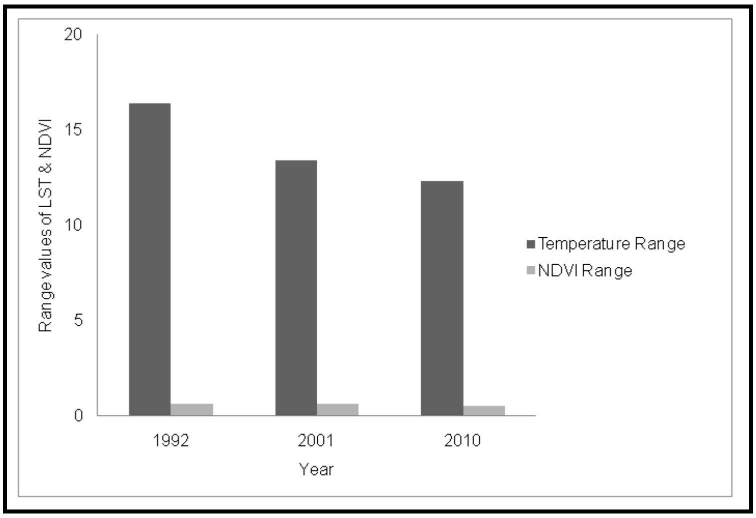
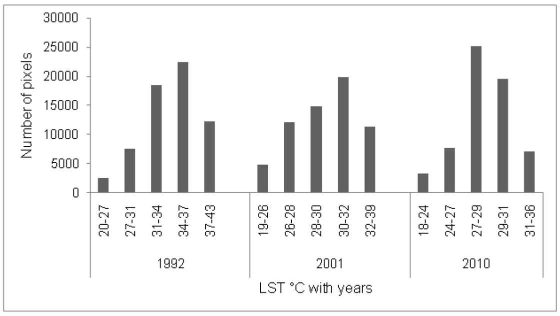


Figure 11: *The range of LST Vs NDVI during the years of 1992, 2001 and 2010*

This implies that in the year of 2010 there was no rainfall and it was a prime cause for negative vegetation indices. The number of pixels presence in each category of LST and NDVI was calculated. For better understanding the phenomenal changes were observed through histogram generation in each category with the respective years (Table 5). The histogram difference clearly indicates that increase of temperature with decreases of vegetation indices (Figure 12, 13). Meanwhile, in numerical statistical regression analysis, the results of standard regression coefficient (B) show that negative values of NDVI in the domain region with the correlation of the LST. The resultant image depicts the statistical approach used to find the LST and NDVI values of area in and around magnesite mining region.



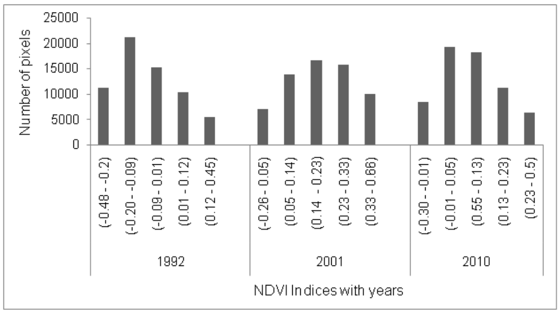


Figure 12: *LST histogram distributions in the mining area during different time period*

Figure 13: *NDVI histogram distributions in the mining area during different time period*

4.1. Statistical Regression Analysis

The statistical analysis was carried out by SPSS (version 22) to find out the regression analysis between LST & NDVI parameters. Logistic regression estimates numerical comparison of input variable derived from output results. In this method LST has considered as dependent variable and NDVI as independent variables to find out the regression coefficient. The standard regression coefficient (B) values are - 0.209, - 0.143 and - 0.190 respectively for the years of 1992, 2001 and 2010 as shown in Table 6.

5. Conclusion

The results have shown that satellite derived LST values and NDVI of vegetation cover have shown the surface condition of the region. The LST is comparable with NDVI provided valuable results for the study region. It's bringing out an idea of surface temperature for the entire region. In the absence of meteorological data, we can find out the surface temperature using satellite thermal data. Also the same could be employed to find the vegetation condition of the terrain because both are identical parameters. Thus, it informs, that the studies attempted will be merely an estimation of LST in correlation with NDVI parameters. The surface temperature is increased due to intrusion of mining, deforestation of vegetation, settlement and imbalanced climatic changes. Active mining region exhibit NDVI with negative values and at the same time, the reclaimed region in the presence of vegetation appears as positive values. The utilized satellite data fall in the dry season and the rainfall in those periods derived from IMD ground based observed data were shown as an asymmetrical pattern in the study region. Persistently, the measures of the region will support developmental implementations and optimistic approach for future environmental deeds.

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