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Effects of Green Space Spatial Distribution on Land Surface Temperature: Implications for Land Cover Change as Environmental Indices

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Abstract: *This research presents the study for the evaluation of Land surface temperature (LST) and Vegetation relationship of the Noamundi Iron ore mines areas, West Singhbhum district. The authors are utilizing a geographic information system (GIS) and advance Remote sensing technique to estimate the land surface emissivity (LSE), Normalized Difference Vegetation Index (NDVI) and LST. LST is strongly influenced by the ability of the LSE, depends on Surface vegetation cover (SVC). The experiment has carried out on Landsat ETM+ satellite images for the studies. The maximum LST of the study area are 32.1^{o}c and mean values are 23.99^{o}c as the period of December is winter season but the LST may increase in summer season. Other side the distribution of NDVI values are varying from -0.378 to 0.516. Due to some active surface mines or some non-vegetated surface are situated in the area, indicating high LST. The statistics indicates the strong negative correlation of 0.932 between NDVI and LST. Further, this analysis may use as a part of sustainability model or environmental sustainability Index (ESI) and Human comfort analysis.*

***Keywords:** Land surface temperature, NDVI, Land surface emissivity, TIR and Linear correlation.*

1. Introduction

Land and water are the two basic natural resources, which are being exploited for various developmental activities, like India, where the population is over one billion (1.3 billion in May, 2016), one-fifth of the world's population (2nd most populous country in the world); affects the natural & commercial resources [1, 13]. In Indian scenario, Mining Industries are increasing day to day. A rapid growing of mining industry may change the surface cover, Surface energy balanced and many other environmental Issues. Surface mining is an important indicator to increase the Land surface temperature and changed the surface cover. On the other hand, the Land surface temperature (LST) is a good indicator of energy balance at the Earth's surface [2]. LST has an important factor for several of applications such as: agricultural, hydrological, environmental, biogeochemical, energy balance and climate change etc.

Active surface Mining changed the natural landscape of the earth surface from vegetated areas to bear surfaces that can affect on net radiation, water balance and surface heat budget (albedo) etc. These are influence to change the local weather; land surface temperature (LST) and change of biophysical factors such as vegetation cover [3].

Remote sensing (RS) and geographic information system (GIS) technologies are been applied for the study and analysis of LST, Normalized Difference Vegetation Index (NDVI) and the relation between them. A series of satellite sensors are been developed to collect TIR data from the earth surface, such as Landsat Thematic Mapper (TM) data, Enhanced Thematic Mapper Plus (ETM+), Advanced Spaceborne Thermal Emission and Reflection Radiomete [4], and Thermal Infrared Multispectral Scanner etc. The Landsat ETM+ data (Date: 10th Dec, 2009 from GLCF) are utilized to obtain LST, emissivity and NDVI data have been used in the analysis of the temperature–vegetation abundance relationship.

NDVI was first used in 1973 by Dr. John Rouse, Director, Remote Sensing Centre of Texas A&M University. The NDVI is a numerical indicator that adopted to analyze the remote sensing measurements and review whether target being observe contains live green vegetation or not. Generally, healthy or green vegetation absorb most of the visible light, and reflects the near-infrared light, falls on it. Unhealthy or meager vegetation reflects less near-infrared light and more visible light. On the other hand, bare soils reflect moderately in both the red and infrared portion of the electromagnetic spectrum [5].

This study focused on the LST of Noamundi Iron ore mine areas, located in Jharkhand. The LST is gradually changing due to Mining (Iron ore) activities. The area is now being mined by TATA Steel. To assess the present situation of Noamundi Iron ore mine areas, several techniques are adopted. This paper presents a preliminary study as a part of Environmental Sustainability (ES) of the Noamundi

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areas situated at West Singhbhum district, Jharkhand. The objectives are: (1) Derive the land surfaces temperature distribution as an environmental indicator of the study area; (2) Indicating the relation between Vegetation cover and LST and (3) to describe present scenario of the existing surroundings environment.

2. About Study Area

This area is situated at Noamundi of Jharkhand state in India. The geographical location of these mine areas is in between 22°04'14"N to 22°10'41"N latitude, and 85°27'09E to 85°30'06E longitude. The main highlighted geographical location is Noamundi market area and its 6 km. Buffer areas. The area is located on the hill top at about 400 m to 650m above Mean Sea level.

3. Data used and Methodology

Land surface temperature

The LST has derived from the corrected ETM+ TIR band in the atmosphere window of 10.44–12.5 µm, spatial resolution of 60 m and generally well calibrated to ground truth data [6]. The first step is to convert the digital number (DN) of Landsat ETM+ TIR band into at-sensor spectral radiance (Landsat 7 Science Data Users Handbook, NASA) by using following equation:

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

Where, L_λ is Spectral radiance at the sensor's aperture [W/(m2sr µm)], Q_{cal} is Quantized calibrated pixel value [DN], Q_{calmin} is Minimum quantized calibrated pixel value corresponding to LMIN $_\lambda$ [DN], Q_{calmax} is Maximum quantized calibrated pixel value corresponding to $LMAX_\lambda$ [DN], $LMIN_\lambda$ is Spectral at sensor radiance that is scaled to Q_{calmin} [W/(m2sr µm)] and $LMAX_\lambda$ is Spectral at sensor radiance that is scaled to Q_{calmax} [W/(m2sr µm)], from Image meta data.

The next step is to convert the spectral radiance to at satellite brightness temperature (i.e., blackbody temperature, B_T) under the assumption of uniform emissivity [7]. It also called radiometric temperature [8]. The conversion formula is:

$$B_T = \frac{K2}{in\left(\frac{K1}{L_\lambda} + 1\right)}$$

Where, B_T is Brightness temperature at sensor in degrees Kelvin (K), L_λ is the cell value as radiance [W/(m^2srer µm)], K1 and K2 are the pre-launch calibration constant value of Landsat-7 ETM+ data (K2: 1282.71 K, and K1: 666.09 watts/(meter squared * ster * µm)

Emissivity corrected LST

At first, the NDVI has derived for spatial distribution of green space. The NDVI has derived from the corrected ETM+ NIR band (0.78 - 0.90 µm) and Red band (0.63 - 0.69 µm) with spatial resolution of 30 m. Spectral emissivity (€) are also use for the analysis of the temperature–vegetation abundance relationship by using following equations:

$$NDVI = \left(\frac{NIR - R}{NIR + R}\right)$$

Where, NIR and R representing the Near IR band and Red band (light reflected) of Landsat ETM+. The results of the simple ratio scale varying between -1.0 and 1. Pixels are representing the land surfaces that are usually representing the surfaces-types such as vegetation and soil as mixed pixels. *Van de Griend and Owe* (1993) found a high correlation between measured emissivity (**€**) and NDVI, which are derive from visible and near-infrared spectral reflectance [2, 9]. They gave the following relation:

$$€ = 1.0094 + 0.047 * NDVI$$

The result of land surface emissivity (LSE) varied between 0 and 1. But this relation is only valid for those areas where a large patches covered by vegetation or soil. Therefore, Noamundi is the part of Chaibasa South Forest Division; this equation is adopted to measure the emissivity (**€**) for the study. Now the emissivity corrected land surface temperature (LST) were computed by following equation [10].

$$T_R = €^{1/4} T_k$$

$$\text{or,} \quad T_k = \frac{T_R}{€^{1/4}}$$

$$\text{or,} \quad T_k = \frac{B_T}{€^{1/4}}$$

Where, T_R (B_T) is the radiant temperature (K); € is the spectral emissivity; T_k the kinetic temperature or surface temperature of natural object (K). Kelvin is a unit of measure for temperature, assigned the unit symbol K. In 1804 William Thomson (Lord Kelvin), developed a universal thermodynamic scale based upon the coefficient expansion of an ideal gas and used as its null point absolute zero. In Kelvin (k) absolute zero is equivalent to −273.15 °C or −459.67 °F [11]. Kelvin (k) is converted into Celsius (C) by subtract of 273.15. Then we converted the LST (Kelvin) values to Celsius (C) temperature values using Eq., in order to make the results more interpretable.

$$C = (\text{Kelvin value} - 273.15)$$

4. Result and Discursion

Statistics for NDVI and LST are computed using ENVI (Environment for Visualizing Images) software. The figure1b shows the distribution of NDVI values; vary from -0.378 to 0.516. The mean value for the study area is 0.178, with the standard deviation of 0.136. From figure1b, the bright areas are low NDVI values, medium bright areas are medium NDVI values and medium to deep green values are vegetation, found in the surrounding areas. Figure1c shows the statistics of NDVI values of whole scene. The LST are retrieved from the LSE and brightness temperature shows the figure 1d, representing the spatial distribution of emissivity-corrected LST. The statistics of LST indicate that the maximum temperatures of the study area are 32.1^{o}c, mean values are 23.99 ^{o}C shows in figure 1d compared with the in-situ measurements (Table 1). The result is showing in Table 1. Column 2 of the table displays NDVI values and column 3 LST. The mean and standard deviation values of NDVI and LST are display in the table. It is clear that the lowest temperature observed in forest (21.70^{o}c). These are only instantaneous results that the image was recorded in the cool period of December (winter season) but the LST may increase in summer season.

There is a significant strong negative correlation of 0.932 between NDVI and LST, through correlation analysis shows in figure 2. Since the correlation analysis of both vegetation and land surface temperatures, it can be conclude that the lower the land surface temperature has the higher biomass or higher vegetation area. On the other hand, the higher LST has less-vegetated cover. The non-vegetated or less-vegetated surfaces, including open cast mining are indicating the higher LST from the comparative analysis, which shows in figure1a, 1b and 1d. As some active surface mines are situated in the area, surface are open form vegetation cover or have some non-vegetated surface are indicating high LST (figure 1a).

Table 1: *Statistical results between NDVI and LST of the study area*

Sl no.	NDVI values	LST in ^{o}c
1	-0.097744652	32.09997559
2	-0.027651939	28.80021805
3	0.031926867	27.71536626
4	0.084496402	26.85652526
5	0.137065937	25.99768425
6	0.196644743	25.18404541
7	0.256223549	24.32520441
8	0.315802355	23.46636341
9	0.382390432	22.6075224
10	0.515566587	21.70347924
Min	-0.378115505	20.57342529
Max	0.515566587	32.09997559
Mean	0.177846213	23.99133655
Std dev.	0.135675521	1.603099241

5. Conclusion

In this paper we applied thermal remote sensing to study the LST distribution in Noamundi mines area. Obtaining some reasonably stages for the analysis, are: (1) conversion of DN to spectral radiance, (2) conversion of spectral radiance to at-sensor brightness temperature, (3) Derivation of NDVI and (4) emissivity-corrected LST. The distribution of LST is higher at non-vegetated area and lower at vegetated area as well as related to the land cover areas. We reviewed the NDVI method for estimating the emissivity-corrected LST and estimate the green space distribution of the area. The research also investigates the LST–NDVI relationship. The result reflects the significant strong negative correlation of 0.932 between NDVI and LST by Linear correlation. LST measurement of each object in the whole area by field survey are not possible, because it requires more human labor, lot of measured instruments with cost effective. Therefore, the remote sensing for estimating the LST will be preferred. Further, this analysis may use as a part of environmental sustainability Index (ESI) and great potential for characterization Human comfort [12].

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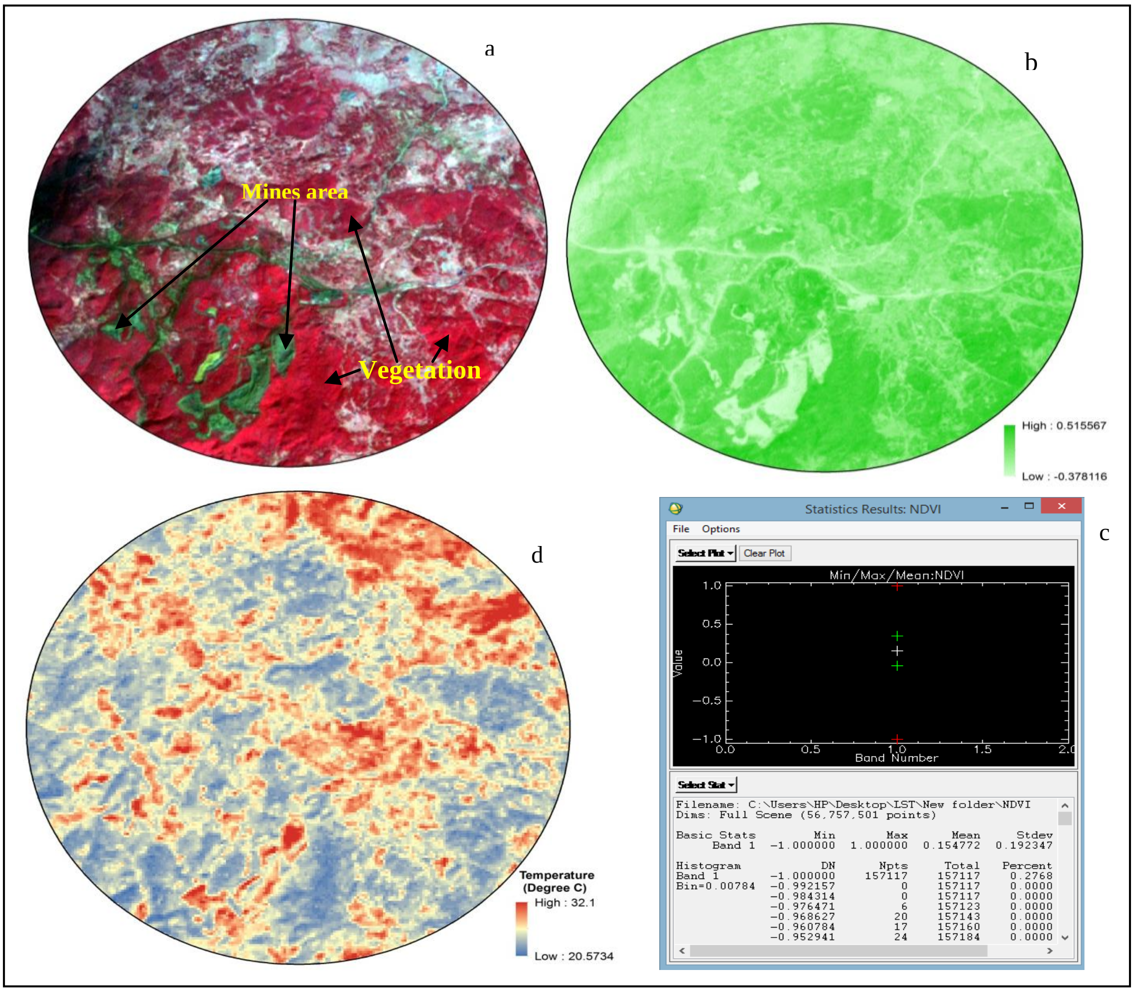

Figure 1: *Original ETM+ MSS image of 30-m resolution (a), spatial distribution of green space of NDVI (b), whole scene statistics of NDVI (c) and Spatial distribution of LST (d)*

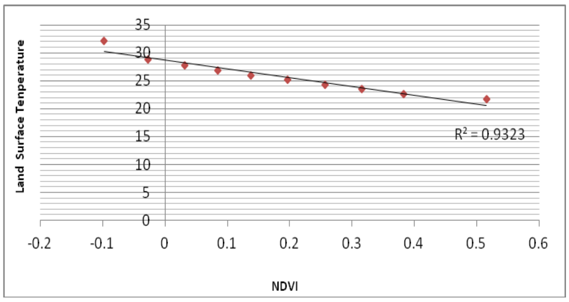

Figure 2: *Linear correlation between NDVI and LST*

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