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Remote sensing Based Assessment of Urban Heat Island Phenomenon in Nagpur Metropolitan Area

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Abstract

With the aid of an integrated GIS/RS based approach, methods including spatial autocorrelation, semi variance, and fractional analysis were used to quantitatively characterize the patterns of recent urban heat island in Nagpur City during 2003 and 2013.The land surface temperature is one of the key parameters in the physics of land surface processes from local through global scale. This paper compares the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Impervious Surface Index (NDISI) as indicators of Urban Heat Island (UHI) effect in Landsat imagery by investigating the relationship between the Land Surface Temperature (LST), percent impervious area(% ISA) and NDVI. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) data were used to estimate LST from different seasons and of different time period for Nagpur city. Our analysis shows that there is a strong co-relation between LST and percent impervious area for all seasons, on the other hand relationship between LST and NDVI is not that strong and varies by season. For the validation of this paper, Automatic Weather Station (AWS) data have been used.
Keywords- Remote Sensing, Urban Heat Island(UHI), Normalized Difference Vegetation Index(NDVI)

1. Introduction

One of the most important prerequisite of planning, utilizing and management of natural resources is spatial information on land use and cover. In the current context of development planning, information on land use/land cover and the changes over a period attain prominence because of its primary requirement in all the planning activities (NRSA, 2006). The changes made to land cover may also cause a change to biotic and abiotic components of the ecosystem such as biodiversity, evaporation, increase soil erosion and surface runoff. One of the characteristic features of urbanization is increase in Land surface Temperature (LST) and increase in impervious area percent, which lead higher surface area and degraded global environment. Urbanization has higher heat storage capacity as well as higher pollutants from industrial wastes and automobiles, which lead to higher temperature difference between rural and urban areas.

In this paper attempt has been made to investigate the impact of land use and land cover changes on thermal environment of Nagpur city over the past 10 years. Quantitative remote sensing techniques have been adopted investigate the changes. The other objective of this paper is to establish a relationship between LST, Normalized Difference Vegetation index (NDVI), Normalized Difference Impervious Surface Index (NDISI).

2. Study Area

Nagpur city having co-ordinates **21.15°N 79.09°E**. Nagpur is the largest city in central India and the sub capital of the state of Maharashtra. It is a fast growing metropolis and is the third most populous city in Maharashtra after Mumbai and Pune, and one of the country's most industrialized cities. Nagpur is the 13th most populous city and 13th largest urban agglomeration in India. Nagpur City total area of about 1500 sq. Mile and population density of about 2700 per sq. Mile. This paper was focused on this city because this city has been undergone large number of deaths due to various heat waves that have been took place very frequently. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) data were used to estimate LST from different seasons and of different time for Nagpur city.

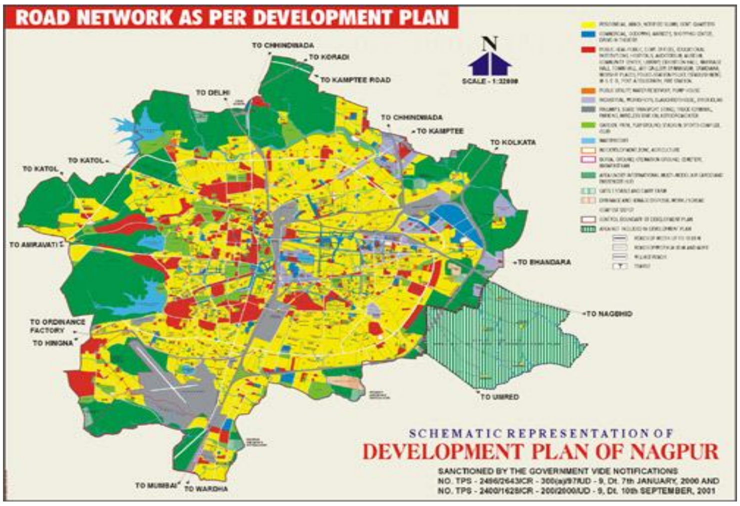


Fig: 1 Schematic Representation of Nagpur City

3. Methodology

The major variable needed for this research include temperature to determine areas of higher temperature. Satellite imagery was used for this purpose. The first step in the analysis was to make the land-cover classification using the Erdas imagine. In the study, supervised classification was employed to categorize the imagery into built-up, vegetation, water body, bare soil, shrubs and paved surfaces. The classification result was used to provide the emissivity of the land-cover categories. Emissivity was then used to estimate the land surface temperature from brightness temperature value in the thermal band image. Finally, the heat island impact was analyzed. However, the land surface temperature is influenced by the geographic conditions such as the climate and weather at the time in the area, so it is difficult to compel the temperature itself to indicate the heat island impact within the city. The normalized surface temperature was prepared using the following steps as outlined by (Weng, (2003):

3.1 Estimation of Land Surface Temperature

Step. I: Conversion of Digital number (DN) to spectral radiance (Lx)

Lx = (Lmax – Lmin) (Qcalmax – Qcalmin)* (Qcal. – Qcalmin) + Lmin

Where

Q Calmin = 1

Qcalmax = 255

Qcal = DN (built-up1 = 81, built-up 2 = 89, forest 1 = 58, Forest 2 = 54, Farmland = 69).

Lmin and Lmax are the spectral radiance for band 6 at DN 1 and 255 respectively.

Step. II: Conversion of the spectral Radiance to temperature using the following formula:

T = K2/ ln (K1/ Lx + 1)

Where:

T = Effective as satellite temperature in Kelvin

K1 = Calibration Constant + 1 in Watts (666.09)

K2 = Calibration Constant + 2 in K (1283.7)

Lx = Spectral radiance in watts

Step. III: Computation of the emissivity corrected surface temperature using the formula:

Ts = T/ { 1 + (^t/ α) InE}

Note that:

(a) Thermal infrared band of land sat 8 is (10.44-12.42NM) = 11.43

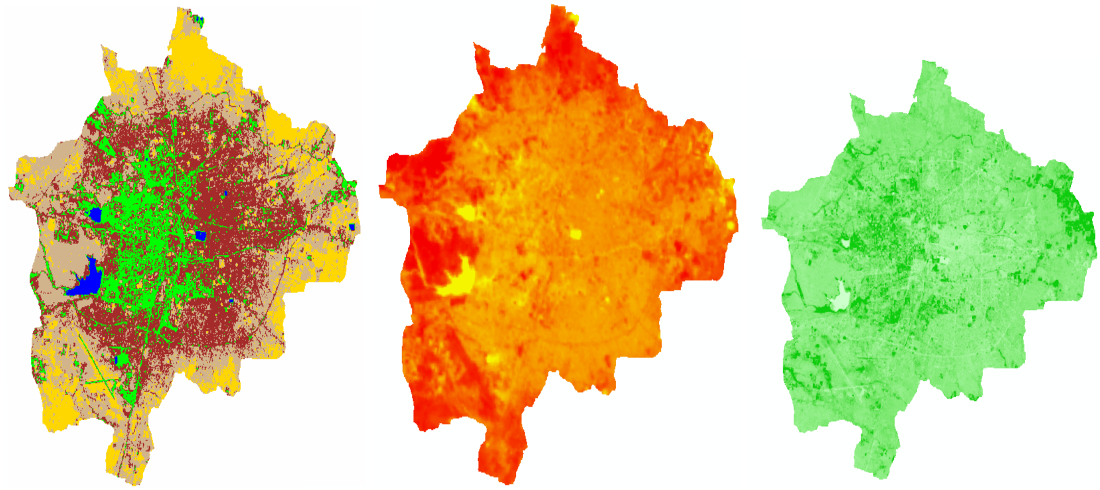
(b) Spatial resolution of 60m

3.2 Estimation of NDVI

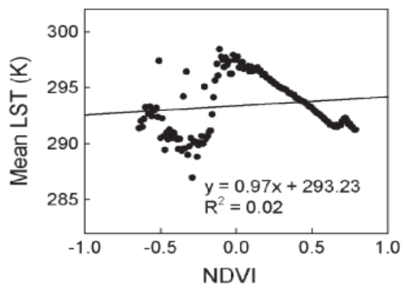
NDVI= (NIR-Red)/ (NIR+Red)

4. Results And Discussion

After applying the above equations we get the following images



Above three figures shows that Land Use/ Land Cover (LULC), Land Surface temperature(LST) and NDVI respectively. Now this paper establishes relationship between LST and NDVI through the following scatter plot *diagram*



5. Conclusion

The study investigated the relationships between the LST and NDVI in the Nagpur city. Results indicate NDVI of SUHI effects with strong linear relationships between LST and NDVI. The strong linear relationship model between the LST and NDVI suggests that impervious surface area accounts for most of the variation in land surface temperature dynamics. This implies that percentage ISA can be used as a complementary metric to the traditionally applied NDVI for analyzing LST quantitatively over the seasons for surface urban heat island studies. While we found the variations in surface temperature can be better accounted for by differences in imperviousness than by the commonly used NDVI, we also realize that the conclusion is based on only one area and four different dates. Although the overpass time and 16-day revisit interval of Landsat are not ideal for dynamic surface heat island analysis, the data nevertheless provide useful information for measuring and understanding urban heat island effects. Further studies of additional metropolitan areas and different satellite data such as MODIS are recommended.

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