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# Statistical analysis of land surface temperature–vegetation indexes relationship through thermal remote sensing

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ABSTRACT

Vegetation coverage has a significant influence on the land surface temperature (LST) distribution. In the field of urban heat islands (UHIs) based on remote sensing, vegetation indexes are widely used to estimate the LST–vegetation relationship. This paper devises two objectives. The first analyzes the correlation between vegetation parameters/indicators and LST. The subsequent computes the occurrence of vegetation parameter, which defines the distribution of LST (for quantitative analysis of urban heat island) in Kalaburagi (formerly Gulbarga) City. However, estimation work has been done on the valuation of the relationship between different vegetation indexes and LST. In addition to the correlation between LST and the normalized difference vegetation index (NDVI), the normalized difference build-up index (NDBI) is attempted to explore the impacts of the green land to the build-up land on the urban heat island by calculating the evaluation index of sub-urban areas. The results indicated that the effect of urban heat island in Kalaburagi city is mainly located in the sub-urban areas or Rurban area especially in the South-Eastern and North-Western part of the city. The correlation between LST and NDVI, indicates the negative correlation. The NDVI suggests that the green land can weaken the effect on urban heat island, while we perceived the positive correlation between LST and NDBI, which infers that the built-up land can strengthen the effect of urban heat island in our case study. Although satellite data (e.g., Landsat TM thermal bands data) has been applied to test the distribution of urban heat islands, but the method still needs to be refined with in situ measurements of LST in future studies.



## 1. Introduction

The urban air temperature is gradually rising in all cities in the world (Kolokotroni et al., 2006). One of the possible causes is the drastic reduction in the greenery area in cities. The distinguished climatic condition termed 'Urban Heat Island' (UHI) is developing in the rapidly urbanized cities (Wei et al., 2008). Kalaburagi (formerly Gulbarga) city of Karnataka is experiencing rapid urbanization that has resulted in remarkable UHI (Kumar, 2015; Shekhar, 2014). Understanding the distribution of Land Surface Temperature (LST) and its spatial variation will be helpful to decipher its mechanism and find out possible solution (Morgan et al., 1995). This study tried to investigate and identify land use types which have the most influence to the increase of ambient temperature in the city.

The vegetation parameters namely: Normalized difference vegetation index (NDVI), Ratio Vegetation Index (RVI), Greenness Vegetation Index (GVI), Soil-Adjusted Vegetation Index (SAVI) and the Normalized difference Built-up index (NDBI) are widely used to estimate the land surface temperature(LST)–vegetation relationship (Wei et al., 2008; Yue et al., 2007). Urban heat island (UHI) as an important character of urban climate change has a significant impact on the human settlements of city (Rashed and Jürgens, 2010). During past years, Urban Heat Environment (UHE) has become the focus of many scholars' research at home and abroad (Li et al., 2009). With the further research on UHI, people find that the land surface temperature (LST) and energy balance can be affected by vegetation which changes the exchange of energy and water between land surface and air. In order to investigate the driving mechanism of UHI more deeply, increasing emphases have been placed on the research of vegetation–LST relationship (Petropoulos et al., 2014; Li et al., 2009).

Recently, some investigations found the relationship between NDVI and vegetation abundance to be nonlinear. And this non-linearity suggests that NDVI may not be a competent indicator for quantitative analyses of vegetation (Wei et al., 2008; Small, 2001). At present, there are two main problems in vegetation–LST relationship for UHI research: (1) the reality of urban heat island intensity may not be acquired, because the brightness temperature that observed by remote sensor was often used to instead of LST directly in many studies; (2) NDVI as an indicator of vegetation abundance is the most widely used vegetation index in UHI

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researches which is based on remote sensing to estimate the relationship between vegetation and LST. But the nonlinearity of NDVI suggests that NDVI may not be a good indicator for quantitative analyses of vegetation to investigate the vegetation–LST relationship (Schwarz et al., 2012; Wei et al.). So the relationship between the LST and NDVI should be further calibrated. And seeking a more suitable and robust vegetation abundance indicator to supersede NDVI in Vegetation–LST relationship study should be placed more emphasis (Sobieraj, 2004). This paper contributes towards the following facets of the research:

1. The first analyzes the relationship between different vegetation indicators and LST.
2. Analyses were made to evaluate the correlations between LST and these vegetation parameters.
3. The distribution of LST with vegetation parameter describes for quantitative analysis of urban heat island in the city.

## 2. Study area and data

Kalaburagi (formerly Gulbarga) city is located in the Northern Part of Karnataka State in India. It lies in the extents between 76°.04' and 77°.42 East longitude, and 17°.12' and 17°.46' North latitude, covering an area of approximately 64 $km^2$ (Gulbarga District Website). It is situated in Deccan Plateau and the general elevation ranges from 300 to 750 m above mean sea level. This district is bounded on the West by Bijapur district and Solapur district of Maharashtra state, on the North by Bidar district and Osmanabad district of Maharashtra state, on the South by Yadgir district, and on the east by Ranga Reddy district of Telangana (formerly Andhra Pradesh) state.

Coming through a rapid development, Kalaburagi is developing as the semi-metropolitan regions. Until very recently, it was a sleepy town having very limited outskirts. The district has total area of 16174 sq kms (Gulbarga District Website). This constitutes 5.93% of the area of the state. The region is characterized by black cotton soil, expanses of flat treeless surface, a range of hills covering a surface of about 60 miles and same lower belts following the main rivers. The district is devoid of forest except in the hilly portion of Aland and Chincholi. The area under forest is 4.2% of the total area (Gulbarga District Website).

However, many environment problems, such as UHI and pollution, were brought about by the urbanization of the city. In order to understand the law of UHI development, the exploration in context to relationship between vegetation indicators and LST is worth more consideration. In this research, a Landsat Thematic Mapper image, acquired on 03rd January 2009, containing both urban and out urban areas (Rurban), was processed to retrieve the LST and vegetation parameters. The data acquisition date had a highly clear atmospheric condition. Meanwhile, the traditional meteorological data observed at the time of Landsat/TM passing by the study area by the Meteorological Station at Gulbarga was also tried to be assimilated, but no data was provided.

## 3. Methods

### 3.1. Methodology

TM data is one of the most frequently used types of remote-sensing data for environmental studies. TM data are composed of seven bands, six of which are in the visible and near-infrared regions (TM bands 1–5 (TM1–TM5) and band 7 (TM7)). Only one band, TM6, is located in the thermal infrared region. TM1 (with a central wavelength of 0.49 μm) is used for coastal water studies and vegetation classifications; TM2(0.56 μm) is used for crop identification, vegetation stage studies and water reflectance measurements; TM3 and TM4 (0.66 and 0.83 μm, respectively) are used to calculate vegetation indices, take biomass measurements and identify water borderline; TM5 and TM7 (1.65 and 2.22 μm, respectively) are used for discrimination of clouds, ice and snow; TM6, with an effective wavelength of 11.457 μm, is used for thermal radiation measurements and LST retrievals (Chen et al., 2012; Wubet, 2003).This article selected Landsat 5 images to map LST of Gulbarga city on 3rd January 2009 (autumn). The satellite passing times were at about 05:00:36.2400310Z. The path number and row number of the TM imagery were ERS path 145 and Row 48, respectively. Weather for these days was normal and there was no little cloud cover above the study area in the images. Hence, LSTs retrieved from the TM images were barely influenced by the clouds. In other words, the quality of the images was reliable.

In order to estimate land surface temperature, the satellite images acquired on the mentioned date by Landsat TM sensor mounted on Landsat-5 satellite were used (Li et al., 2012; Weng et al., 2004). Methodology includes the wide spectrum of steps comprising Thermal Image Processing (TIP) of Archived Landsat data – accessed from the Landsat Global Land Cover Facility website (www.landcover.org). Land Surface temperatures retrieval from TM band 6 (thermal infrared) by converting thermal brightness temperatures into thermodynamic (kinetic) temperatures and Urban Warming Trend Analysis were done by analyzing LST data over the period of record (Zhang et al., 1999; Li et al., 2012).

For validation of results, efforts were taken to collect the weather data measured by India Meteorological Department (also referred to as the Met Department, is an agency of the Ministry of Earth Sciences of the Government of India), still it has not been provided. This article reports the methods to retrieve the land surface temperature (LST) from thermal infrared data supplied by band 6 of the Thematic Mapper (TM) sensor onboard the Landsat 5 using multiple software's namely ERDAS 2011, Arc Desktop 10.x, and ENVI 4.8 were utilized.

### 3.2. Quantitative analysis of Landsat thermal imagery

These attempts to develop understanding of thermal imagery and presents the theoretical background of thermal remote sensing. Many multispectral systems sense radiation in the thermal infrared as well as the visible and reflected infrared portions of the spectrum. Digital numbers are manually converted to at-sensor radiances, then to brightness temperatures by extracting Information from Thermal Remote Sensing Data (Alsultan et al.; Klein). However, remote sensing of energy emitted from the Earth's surface in the thermal infrared (3–15 μm) is different from the sensing of reflected energy. Thermal energy is generally emitted rather than reflected from the Earth's surface. The break in wavelength is at about 3 μm. Shorter wavelengths are reflected solar energy, whereas longer are emitted from the Earth's surface. The Earth behaves overall as a blackbody with peak energy emission at about 9.7 μm wavelength. However, the radiant temperature of a given object depends on many thermal factors, such as emissivity, conductivity, capacity, diffusivity and inertia (Mccarville et al.). Thermal sensors essentially measure the surface temperature and thermal properties of targets.

### 3.3. Conversion of DN values to absolute radiance

Units radiance data will usually come in one of two units, W/$m^2$ SR μm or m W/$cm^2$ Sr μm.