

# Remote Sensing and GIS-based Analysis of Land Surface Temperature Dynamics and Land Use Changes in Vijayawada, India

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## Abstract

*The alteration of land use/land cover (LULC) has significant environmental consequences since it is strongly linked to long-lasting land degradation and leads to diverse environmental alterations. It is crucial to monitor the locations and distributions of changes in land use and land cover (LULC) to comprehend the connections between government actions, policy choices, and resulting LULC activities. Modern systems for protecting the environment and managing natural resources now depend heavily on changes in land use and cover. Variations in land surface temperature are also explained by this phenomenon. Using the Normalised Difference Vegetation Index (NDVI) and Land Surface Temperature (LST), this study examines the various effects of land conversion on the environment. The information gathered from the Landsat 8 OLI sensor in Vijayawada city is used to accomplish this.*

**Keywords:** Land use/Land cover (LULC), land surface temperature (LST), normalized vegetation index (NDVI), remote sensing

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## INTRODUCTION

Because of the alterations that humans have brought about, the climate system is continually evolving. The degradation of the environment and human well-being is a pressing issue in metropolitan areas since it is caused by both natural and human-induced environmental changes. The Global Environment strongly depends on Land use and Land cover changes [1]. Land cover changes increase energy exchanges between the atmosphere and surface thus have an impact on the local climate [2].

Nearly 14% of the existing forest area was lost between 2019 and 2020 in India and the forest cover has been reduced to 46% worldwide [3]. If this trend continues, the Earth will be at a huge risk and no one can save our mother Earth. Thus it is really important to analyse the land use/land cover change and planning and management should be done accordingly [4].

The phrases "land usage" and "land cover" are distinct and can be used interchangeably. Land

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cover is the cover of the land i.e., grasslands, pastures, forests, etc., and Land use is how we use the land cover i.e., built-up, agricultural areas, and others [5]. Traditional methods have many complexities which make analyzing LULC changes hard. Therefore, emerging technologies such as Remote Sensing and Geographical Information Systems (GIS) may be used to examine Land Use and Land Cover (LULC) alterations. [6]. Using these new technologies will make the analyses easy and accurate.

The investigation of changes in land use and cover (LULC) and the computation of the Normalised Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) are the main objectives of the present research. NDVI gives the changes in Vegetation [7]. LST gives information about the change in the Surface Temperature of the Earth [8].

The protection that wetlands, forests, impassable obstacles, residential areas, and bodies of water provide for the Earth's surface is referred to as land cover. The term "land use" describes how people make use of the Earth's surface's physical characteristics to improve and preserve its lifetime [9]. The future environmental state will be significantly impacted by human activity, particularly due to the exponential growth of the population [10].

The expansion of urban areas, unintentional colonization, and the resulting fast increase in population have significant negative impacts on the surrounding territory [11]. These abrupt changes in the local, regional, and global ecology have prompted serious warnings to people [12]. Thus, information needed for environmental effect analysis is specified by combining data from Geographic Information Systems (GIS) and Remote Sensing (RS) at a desired spatial and spectral resolution [13].

The main objective of this paper is to analyze the LST of Vijayawada City in response to LULC changes using NDVI.

## LITERATURE SURVEY

Schaofeng Yuan et al. Atmospheric correction was processed using the quick atmospheric correction in EIVVI53. The patches of low-temperature landscape exhibited low fragmentation. Whereas that of the high-temperature one exhibited low complexity [1].

John Wiley Sons et al. Normalized Difference Vegetation Index (NDVI) was derived from the surface reflectance. Future climate change exerts a larger impact on the concentration of pollutants than the potential impact of land use change [2].

Guha Subhanil et al. Landsat image manipulation involves resampling, radiometric modification, and geometric rectification. TIR bands were used to calculate LST. Given that mean LST performs both above and below mean LST, it was deemed an important metric for this investigation [3].

Wei Sun et al. Data Processing, Interpretation, and Accuracy Evaluation. Urban expansion is significantly constrained by elevation, whereby cities with lower elevation or flat terrain are subject to enhanced urban spatial expansion and development relative to cities located in hilly or mountainous areas [4].

Pei Liu et al. LULC and UST maps are depicted with the help of SVM, MWA algorithms, and the CA-Markov model. Analysing and discussing spatial distribution and temporal change of LULC and UST concerning expansion intensity and buffer zone analysis. The result is observed that there is the strongest urban growth. The thermal environment change process is relatively complicated and the dynamics of spatial-temporal change are dramatic [5].

P.S. Kafer et al. NDVI Threshold method is used to estimate LSE and LST is calculated. Obtained relation between LST-NDVI and surface albedo-LST in natural grasslands. The LST-NDVI relation varies with the season [6].

Yongjie Zheng et al. The Fully Constrained Least Square(FCLS). Spectral unmixing and several derived spectral indices are used for the generation of the LULC maps and radioactive Transfer (RTE). The temperature inversion method is for the estimation of the LST [7].

Jovish John et al. Remotely sensed satellite, LISS-3 satellite. The overall Vegetation cover increased to a certain extent in the study area. There is an increase in vegetation associated with a decrease in surface temperature [8].

Fatemi Mehran and others. The Method of Supervised Classification The findings indicated that the quality of the vegetation cover deteriorated as the area covered by it shrank [9].

Narendra Singh et al. Radiometric rescaling calibrated coefficient and the quantization range of band-6, MODIS spectral radiance data, Knowledge-based hybrid LSE model, TOA spectral radiance. A decrease in Vegetation has led to higher thermal temperatures. Temperature has been increasing at a very rapid rate [10].

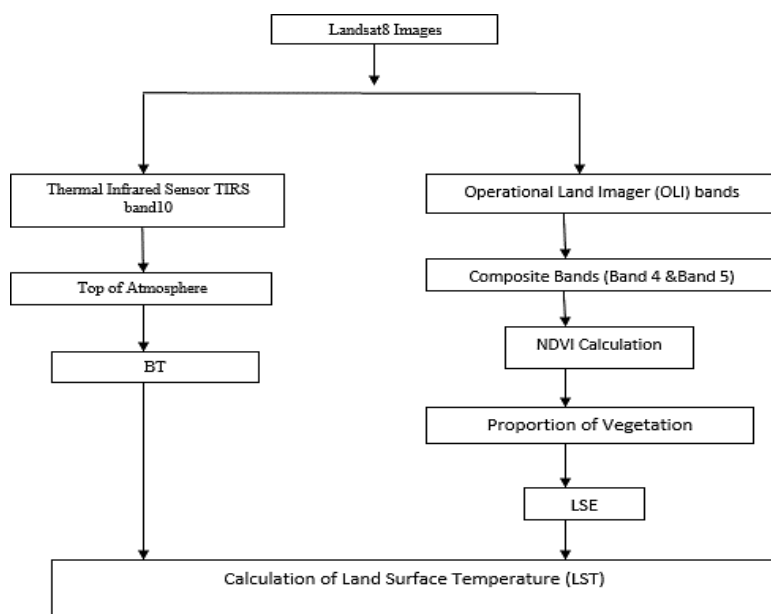
Kanchan Lakra et al. Satellite Imagery of Landsat 5TM Landsat 8OLI and TIRS were used for the retrieval of LST and the Generation of a LULC map of the study area LULC observed in the study area is dependent on both socio- economic and natural climatic conditions prevailing in the region during the time the image was taken by the satellite [11].

Ankush Agarwal et al. A cloud and IoT based approach. In this study, we have applied the IoT concept to extract the result form two different sensors which results in a little variation [12].

Swades Pal et al. Geometric Correction of the images was done using Ground Control Points(GCP) collected through GPS. Ancillary data from Topographic maps and Google Earth images. Surface Temperature has been rising over advancing phases in all seasons. The primary factor causing modifications to land cover and the ensuing rise in LST is urbanization [13].

## METHODS AND MATERIALS

The United States Geological Survey (USGS) is used to download the necessary study area photos. One place where one may get satellite images is USGS. Afterwards, the LST in the study region was calculated using the MW method. The ArcGIS 10.8 software platform. A detailed description of the methodology is outlined in Figure 1



**Figure 1.** Methodology adopted in this work

### Obtaining and Pre-Processing Images

Readjusting the photos to WGS-1984-UTM-Zone\_13N was done. Subsequently, the digital number (DN) was translated into a physical measurement of the satellite brightness temperature (TB) and the top of atmospheric (TOA) radiance. Afterward, the Landsat 8 picture collection provided a file with the extension " MTL," which contains the thermal constants needed to transform TIRS data using the satellite TB. Lastly, thermal constants depicted in the metadata file shown in Tables 1 and 2 were processed using TIRS band data to alter the spectral radiance to TB.

**Table 1.** Landsat 8 Metadata of the study area.

Sensor	No. of Bands	Resolution (m)	Path/Row	Date of acquisition
OLITIRS	9	30	032/031	1st May,2020
	2	100		

The numerical mechanisms of alternate detection become exploited in this research. Each satellite picture is classified in the alternative detection technique. The resulting land use and land cover (LULC) maps obtained after the process are compared to a pixel-by-pixel representation using a change detection matrix.

**Table 2.** Empirical constant for Landsat8 images.

Thermal constant	Band10
K1	774.8853
K2	1321.0789
M <sub>L</sub>	0.0003342
A <sub>L</sub>	0.1

## RESULTS AND DISCUSSIONS

### Generation of LULC maps of the study area

The LULC thematic maps of Vijayawada for the year 2020 were derived using time series Landsat satellite data from the Operational Land Imager (OLI). The green, red, and near-infrared (NIR) bands with a resolution of 30 m were used for this purpose. The images were georeferenced and classified using Interactive supervised classification using 100 reference and classified data points for each LULC class observed in the study area. The overall accuracy of the generated maps is calculated.

### Calculation of LST:

LST was calculated for the year 2020. LST can be calculated using (1) radiative transfer model (RTM), (2) mono-window (MW), and (3) split-window (SW). The photos have previously been adjusted to WGS-1984-UTM-Zone\_16N. The next step is to convert DN to ToA spectral radiance through the application of the radiance rescaling factor TIR. Then, utilising thermal constant values in a data file, spectral radiance data can be translated to top-of-atmosphere brightness temperature. Afterwards, the thermal constants required to transform TIRS data using the satellite TB were sent in a file with the extension ". MTL" that was included in the Landsat 8 image set. Lastly, thermal constants from the metadata file were processed using TIRS band data to convert spectral radiance to TB. The detailed, step-by-step procedure for calculating LST is provided below.

#### Step-1

Converted Digital Numbers (DN) i.e., pixels of the image into Top of Atmosphere (ToA) Radiance. The formula to convert into ToA is

$$L_{\lambda} = ML * Q_{cal} + AL - O_i \quad (1) L_{\lambda} \text{-TOA spectral radiance}$$

ML – Band-specific multiplicative rescaling factor from the Metadata (Radiance\_mult\_Band\_X, where X is the band number 10)

AL – Band-specific additive rescaling factor from the metadata (Radiance\_add\_Band\_10)

Q cal – Quantised and calibrated standard product pixelvalue (DN)

O<sub>i</sub> – Correction value of Band 10 which is 0.29.

**Step-2**

Spectral radiance data can be converted to top-of-atmosphere brightness Temperature using thermal constant values in a data file. The conversion formula is given as

$$BT = (K2 / (\ln(K1/L\lambda) + 1)) - 273.15 \quad (2)$$

Lλ – TOA spectral radiance calculated in the above step

K1, K2 – Band specific thermal conversion from metadata (K1 – Constant\_Band\_10, K2 – Constant\_Band\_10)

273.15 = Convert Kelvin to 0Celsius. Step-3

Estimated land surface emissivity (LSE) using the given equation.

$$E = 0.004PV + 0.986 \quad (3)$$

E = Emissivity

PV = Proportion of vegetation that is calculated using the NDVI value

NDVI = Normalised difference vegetation index

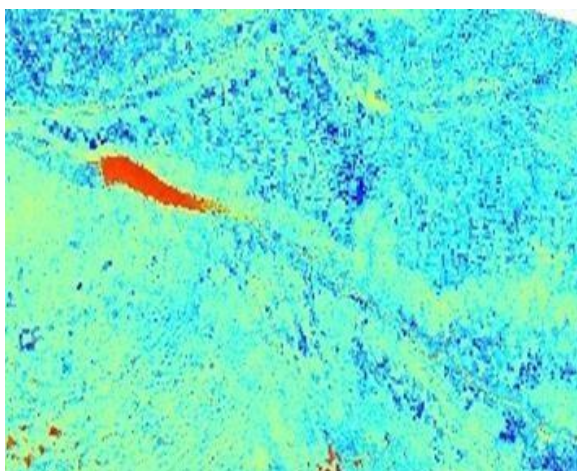
NDVI can be calculated in ArcGIS by applying the given formula.

$$NDVI = \text{Float}((\text{Band5} - \text{Band4}) / (\text{Band5} + \text{Band4})) \quad (4) \text{ where,}$$

Band5 = Near-infrared (NIR - 0.85–0.88 μm) Band,

Band4 = Red Band (0.64–0.67 μm) wavelengths

from the NDVI result, The NDVI<sub>min</sub> 11044 value was and the NDVI<sub>max</sub> value was 86636 (Figure 2). We substituted these values in Equation 5 and derived the proportion of vegetation (PV).



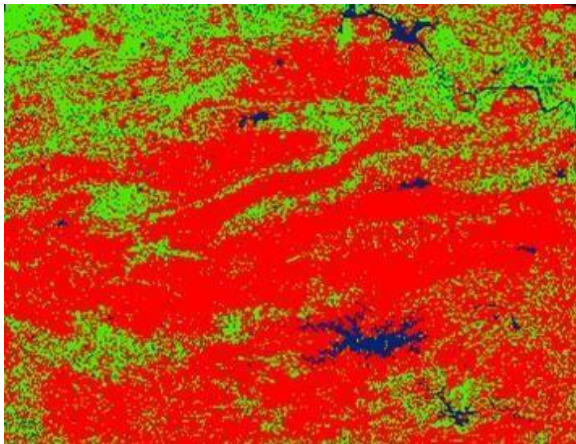
**Figure 2.** NDVI map of the study area.

PV can be calculated using the below formula.

$$PV = \text{Square}((NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min})) \quad (5)$$

$$E = 0.004 * PV + 0.986 \quad (6)$$

the overall accuracy of the map and the accuracy for each class in the map. The percentage of overall accuracy was calculated using the following formula:



**Figure 3.** LULC image of Vijayawada.

$$\text{Overall Accuracy} = (\text{Total correctly classified pixels}) / (\text{Total number of pixels}) \quad (8)$$

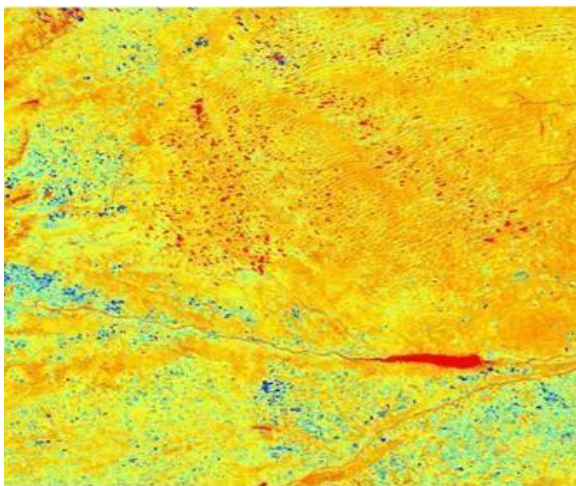
The land is classified into four classes water, Dense Vegetation, Vegetation, and Built-up.

**Table 3.** Values of different parameters calculated.

Parameter	Value
NDVI <sub>max</sub>	86636
NDVI <sub>min</sub>	11044
LST <sub>max</sub>	-74.8475
LST <sub>min</sub>	-75.0734
Overall accuracy	91%

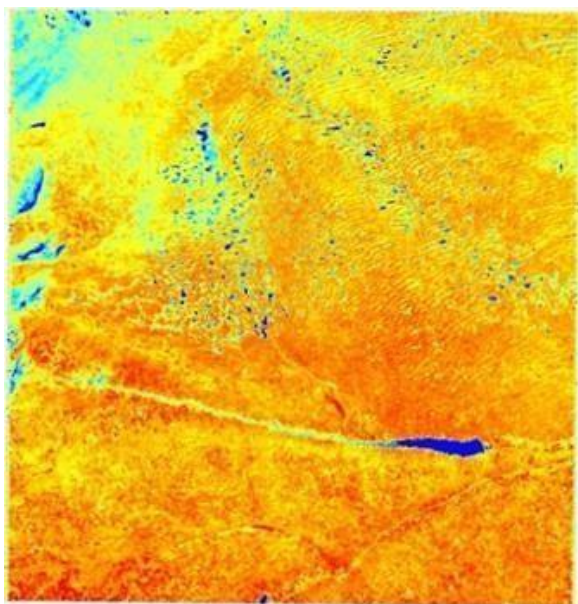
## CONCLUSION

This paper focuses on LULC changes in an urban area. The temporal changes in LULC and LST of Vijayawada, Andhra Pradesh from South India are analyzed for the year 2020 using remote sensing data and GIS technology. The findings of our study unequivocally demonstrated that there were substantial land use and land cover (LULC) changes that occurred in the year 2020. This research has shown that the incorporation of Geographic Information Systems (GIS) with remote sensing technologies is a very efficient tool for urban planning and management. The measurement of land use and land cover (LULC) varies in Vijayawada is very useful for environmental management groups, policy makers, and for public to better understand the surroundings.



**Figure 4.** LSE image Step-4.

LST was estimated using the following Equation  $LST=BT/(1+(\lambda*BT/C2) *ln(E))$  (7)



**Figure 5.** LST image.

### **LULC Accuracy Assessment**

For the accuracy assessment, the classified results are compared with available reference datasets, which is assumed to be correct for defining a classification. The ultimate classification products provide an impression of the major LULC features of Vijayawada city. The result of an accuracy assessment typically provides the users with an

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