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Assessment of diurnal change in land surface temperature of the Union Territory (UT) of Jammu and Kashmir, India

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Abstract: Land Surface Temperature refers back to the calculation of ground temperature that is made with extraordinary factors. Due to changes in the land surface temperature of the area, the climate and vegetation are also affected. The Normalized Difference Vegetation Index (NDVI) serves as an indicator of vegetation abundance to estimate the land surface temperature (LST) vegetation relationship. Landsat 7 ETM$^+$ and Landsat 8 OLI TIRS images for four years (2005, 2010, 2015, and 2020) are used to study the LST changes in the research area (Jammu & Kashmir). Correlations between NDVI and LST are calculated. Through the study, it is clear that the Normalized Difference Vegetation Index plays a major role in the calculation of land surface temperature. In this study, the change in the higher temperature noted in the year 2005 was 20^{0}C, and in the year 2020, the highest temperature was 25^{0}C. If we talk about the lower temperature, the change is 1^{0}C. Both Jammu and Kashmir have semi-deciduous vegetation that includes subtropical pine forests.
Keywords: LST, climate change, local climate, remote sensing, GIS, band ratio

Procjena dnevne promjene temperature površine tla u Jamuu i Kašmiru, Indija

Sažetak: Temperatura površine tla odnosi se na izračun temperature tla koji se vrši s posebnim faktorima. Promjena temperature površine tla u području utječe i na klimu i vegetaciju. Vegetacijski indeks normalizirane razlike (NDVI) služi kao pokazatelj bujnosti vegetacije za procjenu vegetacijskog odnosa temperature površine tla (LST). Za proučavanje promjena LST-a u području istraživanja (Jamu i Kašmir) koriste se slike Landsat 7 ETM+ i Landsat 8 OLI TIRS za četiri godine (2005., 2010., 2015. i 2020.). Izračunavaju se korelacije između NDVI i LST. Kroz studiju je jasno da vegetacijski indeks normalizirane razlike ima glavnu ulogu u izračunu temperature površine tla. U ovom istraživanju, zabilježena promjena više temperature 2005. godine je bila 20°C, a 2020. godine najviša temperatura je bila 25°C. Ako govorimo o nižoj temperaturi, promjena je 1°C. I Jamu i Kašmir imaju polulistopadnu vegetaciju koja uključuje suptropske borove šume.
Ključne riječi: LST, klimatske promjene, lokalna klima, daljinsko ispitivanje, GIS, omjer pojasa

1. INTRODUCTION

The Earth's system is a complicated cycle with a lot of interconnected components, like the Earth's surface and its interior. The earth's surface is naturally covered by different land cover types, which are mainly distributed based on climate patterns. Adding more people and their needs to this well-balanced system will cause a lot of problems because of how we change how land is used to meet our needs, regardless of how it affects the environment.

Climate change is one of the most important and demanding situations that the arena faces. Previous research has pronounced that weather extrude has a substantial impact on the land floor temperature and its different parameters. The growth of city regions is taken into consideration as a substantial element in the increase in land use and land floor temperature. Previous research has shown that, in China, city boom and weather extrude, together with temperature extrude, are severe troubles as a result of financial and social development. Therefore, it's essential to analyse methods expected to extrude inland floor temperature (LST) extrude. Land surface temperature (LST) is the temperature of the land's skin surface, as determined by satellite data or direct measurements. LST is a precise indicator of the energy exchange balance between the Earth and the atmosphere [1]. The spatial heterogeneity of LST is quite great. Land surface features, which are heavily impacted by elevation, slope, and aspect, exert a direct effect on incoming solar radiation, affecting the degree of LST [2]. Furthermore, the topography is one of the characteristics that influence soil moisture distribution, which has an impact on land surface temperature. Seasonality, time of day, sea breeze, surface air temperature, humidity, wind speed, and land use can all affect LST [3,4].

Land surface temperature (LST) is a crucial issue in worldwide weather alternate research, for estimating radiation in warmness stability research and as a managing factor for weather alternate models. The expertise in floor temperature is crucial to a variety of problems and issues in earth sciences, weather, and human interactions with the environment. Land Surface Temperature is the first thing that is used to figure out how the weather and the glacial region have changed. This is the subject of the study. The land surface temperature is the temperature at the Earth's surface. This is the warm temperature that comes up from the ground of the landscape. LST is described as the temperature felt while there may be changes in long-wave radiation and turbulent warmness fluxes in the floor-ecosystem interface [5]. The LST is being used an increasing number of times to assess the weather modifications in city zones. Satellite images are used as re-assets of statistics for floor temperature tendencies and variability.

In remote sensing language, LST is the surface radiometric temperature radiated by land surfaces and detected by sensors at immediate viewing angles. LST is derived from different platforms, e.g. Terra/Aqua-MODIS, Terra-ASTER, NOAA-AVHRR, and Meteosat-MVIRI. Surface temperatures on mountain glaciers are an immediate mirrored image of the warm temperature at the glacier floor, which controls the degree of ablation. Information about floor temperatures is consequently vital in simulating the evolution of mountain glaciers and in knowing the glaciers' reactions to weather change. In situ observations imply that once the existence attitude equals 75°, relative to the nadir attitude, the emissivity version at λ = 12.5 μm in naked ice is as good a deal as 0.24. However, studies concerning the far-off-sensing-retrieval of mountain glacier floor temperatures do not usually keep in mind the topography (i.e., the existence attitude), and the validation of far-off sensing strategies through the use of surficial weather measurements on mountain glaciers is lacking. Globally, 2011–15 was the warmest 5-year period on record. In the past several decades, remote sensing technology has contributed well to the study of land surface temperature. One of the earliest applications of space borne measurements was surface temperature and its relationship to the urban heat island effect and climate. Since then, remote sensing has become vital in the field of land surface temperature studies, including the study of climate. [6-7] used satellite-derived measurements of surface temperature to investigate the relationship between urban land use and heating patterns. During the years 2006 to 2010 and 2011 to 2015, global mean annual air temperatures were 0.5 and 0.57°C above the 1961–90 average. Global air temperature increases are enhanced at high latitudes. The objectives of the present study are to include estimating the land surface temperature during the period of 2005 to 2020 and analysing the impact of land surface temperature on the local climate. Remote sensing data has been used to validate LST data with actual on-the-ground temperature readings, specifically to aid in modelling surface temperatures. Depending on the number of bands used, thermal infrared (TIR) sensors can acquire quantitative, high-quality surface temperature data for evapotranspiration, climate change, hydrological cycle, vegetation monitoring, urban climate, and environmental studies using single-infrared channel or split window methods [8]. It is now possible to monitor global climate change and its effects on the cryosphere on both continental and global scales using high-resolution satellite data, which is difficult to do using in situ measurements. Several studies have been conducted, and various ways to obtain LSTs using satellite TIR data have been proposed [9-11]. Satellite observations are better than results that come from interpolating temperature data from a small number of meteorological observatories.

2. STUDY AREA

The UT of Jammu and Kashmir are located in India's far north-western corner. It is located between 32°17' and 37°05' north latitude and 72°31' and 80°20' east longitude. The Pir panjal Range, the Karakoram Range, and the Himalayan Ranges cover Kashmir's higher portions. The state's forests are dispersed throughout three large geo-climatic zones, covering the Jammu, Kashmir, and Ladakh areas. The Kashmir valley is a longitudinal depression in the great north-western complex of the Himalayan ranges. It is a significant relief feature with enormous geographic significance. The valley, which was carved out tectonically, has a strong genetic tie with the Himalayan complex, which has a profound influence on its geographic entity. It occupies the interior of the state of Jammu and Kashmir. Jammu and Kashmir's vegetation and climate can be divided into sub-tropical, temperate, and alpine zones, with a vast range of wildlife and plants (Figure 1).

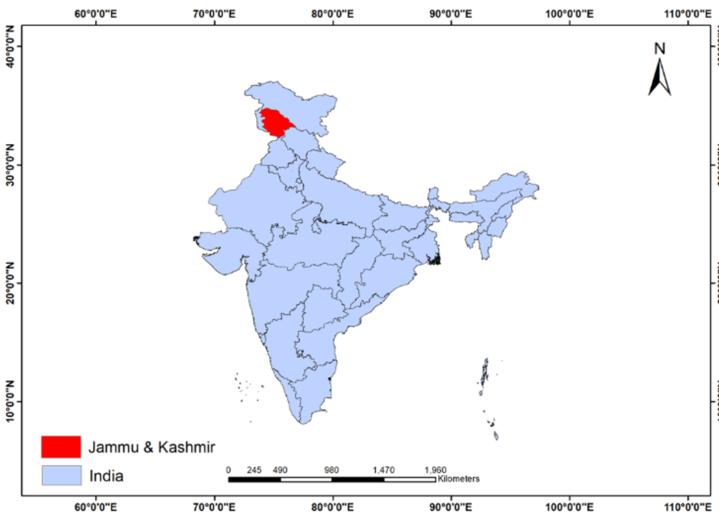


Figure 1. Study area map. Red filled area is the UT of Jammu and Kashmir

3. MATERIALS AND METHODS

The enhanced availability of images from remote sensing platforms with adequate spatial and temporal accuracy, comparable to global coverage and low financial costs, allows the estimation of glacier parameters to be extended over broader regions and longer periods of time. In the visible (VIS) and near-infrared (NIR) bands of the electromagnetic spectrum (0.35–2.5 mm) and the radiation emitted by the surface in the thermal infrared (TIR) (8–14 mm) measured as the sensor brightness temperature, optical sensors detect the solar radiation absorbed by the surface of the Earth [12 – 19]

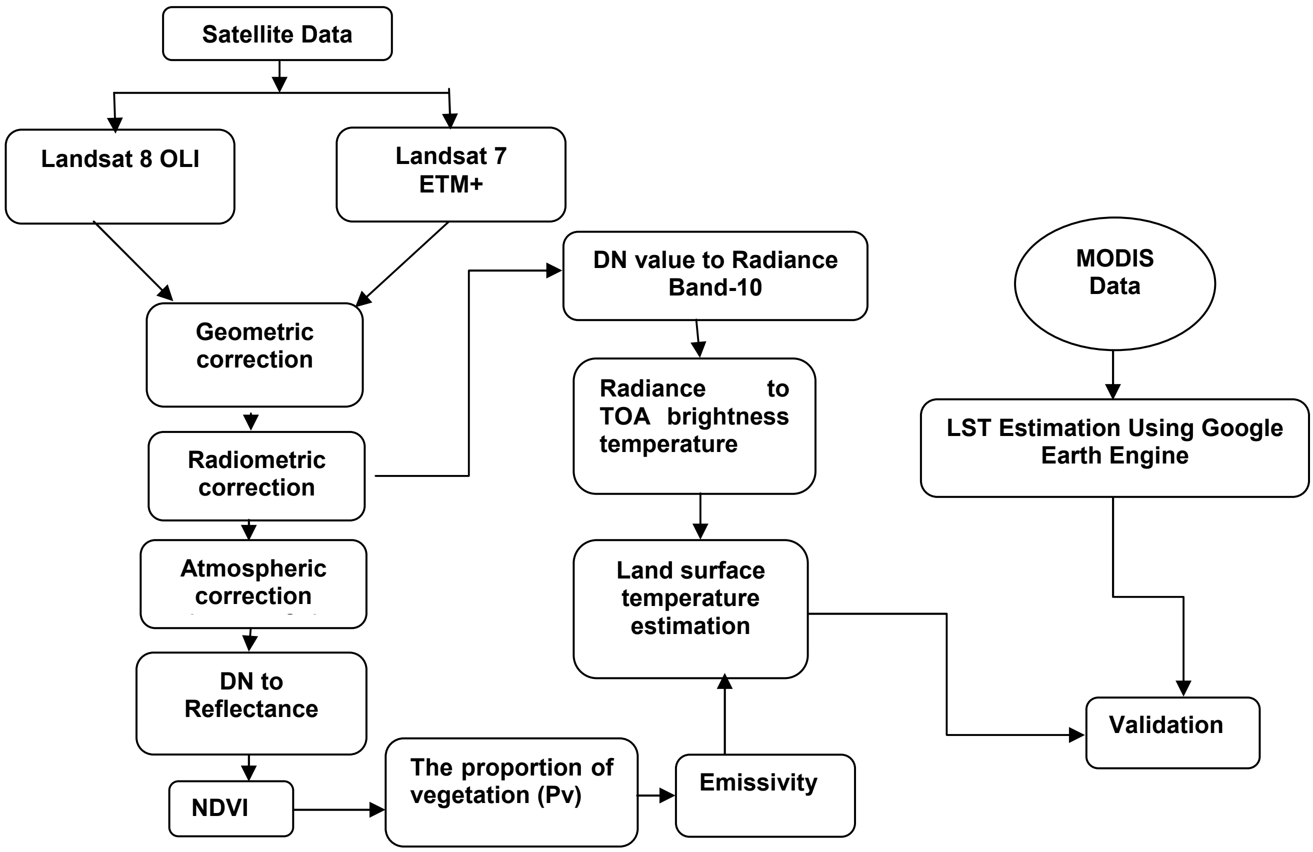


Figure 2. Flowchart - the study's methodology

For the present study, multi-sensor, remote sensing data from Landsat-8 (OLI) and Landsat-7 ETM+ were used. The thermal infrared band will be used for temperature calculation. Landsat-8–TIRS has two bands, but we use band 10, whose spectral resolution is 10.60 m to 11.19 m. The spectral property of band 10 avoids the natural absorption of the atmospheric property, so the Landsat-8 images were downloaded from the US Geological Survey, which is free of cost (https://glovis.usgs.gov). At various wavelengths of the electromagnetic spectrum, Landsat sensors record reflected and emitted energy from Earth. From microscopic gamma rays and x-rays to massive radio waves, the electromagnetic spectrum encompasses all kinds of transmitted energy [20, 21]. The visible wavelengths of this spectrum are visible to the human eye.

The LANDSAT programme is a constellation of optical and infrared remote sensing satellites designed to monitor land. The National Aeronautics and Space Administration (NASA) began the programme in 1972, and after it became operational, it was handed over to the National Oceanic and Atmospheric Administration (NOAA). Since 1984, a commercial business called EOSAT has been in charge of satellite operations and data management [22]. On the other hand, data older than two years goes into the "public domain." This data comes from the US Geological Survey's Earth Resource Observation System (EROS) Data Centre. The first satellite in the series, LANDSAT-1 (formerly known as the Earth Resource Technology Satellite ERTS-1) was launched on July 23, 1972. The satellite was supposed to last a year, but it didn't stop working until January 1978. LANDSAT-2 was launched on January 22, 1975, followed by three more LANDSAT spacecraft in 1978, 1982, and 1984. (LANDSAT-3, 4, and 5 respectively). The LANDSAT-6 satellite was launched in October 1993, but it never made it into orbit. LANDSAT-7, a new satellite, was launched on April 15, 1999. On February 11, 2013, the LANDSAT 8 satellite sensor was successfully launched from Space Launch Complex-3 at Vandenberg Air Force Base in California and will join the LANDSAT orbit constellation.

4. RESULTS AND DISCUSSION

There are various algorithms available to estimate the land surface temperature (LST) using satellite data such as Split Window Algorithm, Mono Window Algorithm, Single Channel Algorithm, and Radiative Transfer Equation. In this paper, we used two different algorithms to estimate the LST, the split window algorithm on Landsat 8 (OLI) for the years 2015 and 2020 and the Mono Window algorithm on Landsat 7 ETM+ for the years 2005 and 2010. The split Window Algorithm requires the brightness temperature value of both band 10 (TIR 1) and band 11 (TIR 2) as well as emissivity. The most used technique for obtaining land surface temperature (LST) from satellite data is the split-window approach [23]. In order to solve the radiative transfer equation (RTE) set, it is necessary to first simplify Planck's function, which is a crucial step in the development of the SWA. This allows us to directly connect the radiance to the temperature [24]. As well as to estimate the LST for the years 2005 and 2010 Mono Window algorithm has been used on Landsat ETM+ data. The suggested algorithm directly considers the effects of the atmosphere and the emitted ground on the thermal radiance transmission of the ground and calls for the retrieval of three key parameters: emissivity, transmittance, and atmospheric average temperature. According to validation, the algorithm's accuracy is high up to 0.4°C for the estimate of the crucial parameters with no mistakes and 1.1°C for the estimate with substantial errors. The technique is known as a mono window approach because it has been used with remote sensing data that only has one thermal band.

Validation is an important issue to acceptance and uncertainty of remote sensing data which are produced after the examination or observation. In this study, MODIS daily thermal data has been estimated using Google Earth Engine shown in Figure 3c, 4c, 5c and 6c. The MODIS LST has been used to compare with Landsat calculated thermal data. Validation shows that the temperature has been slightly different between MODIS daily temperature data and the calculated temperature data sets.

The process of calculating Land Surface Temperature comprises six steps which include the Calculation of DN radiance, Radiance temperature, NDVI, Proportion of vegetation and Land Surface Temperature (Figure 3-6):

Step 1.
For the analysis and calculation of the LST, only Band 10 and Band 11 are needed. The values in the downloaded raw Landsat images are the so-called Digital Numbers of the sensor. First, these have to be converted to TOA reflectance values using the following equation:

$$R_{TOA} = \frac{\pi * L}{\frac{1}{d^2} * I_{Sun} * cos\theta_{Sun}} \quad (1)$$

Where:
L = upward radiance
d = Earth – Sun distance
I_{Sun} = mean extraterrestrial solar irradiance
Θ_{Sun} = solar zenith angle

Conversion to TOA Radiance:
Landsat data can be converted to TOA spectral radiance using radiance rescaling factors provided in the metadata file:

$$\mathbf{L\_\lambda = M\_L * Qcal + A\_L} \quad (2)$$

Where:
L_λ = Spectral radiance
M_L = Radiance multiplicative scaling factor for the band (RADIANCE_MULT_BAND_n from the metadata)
A_L = Radiance additive scaling factor for the band (RADIANCE_ADD_BAND_n from the metadata).
Qcal = L1 pixel value in DN
Step 2.
Conversion of TOA to Brightness Temperature

$$\boldsymbol{BT = (K2 / (ln\,(K1 / L) + 1)) - 273.15} \quad (3)$$

where:
K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_**x**, where x is the thermal band number).
K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_**x**, where x is the thermal band number).
$\boldsymbol{L_\lambda}$ = TOA
Therefore, to obtain the results in Celsius, the radiant temperature is adjusted by adding the absolute zero (approx. -273.15°C).
Step 3.
To Calculate the NDVI (Normalised Difference Vegetation Index)

$$\boldsymbol{NDVI = (Band\,5 - Band\,4)/(Band\,5 + Band\,4)} \quad (4)$$

Step 4.
To Calculate the Proportion of vegetation P_v

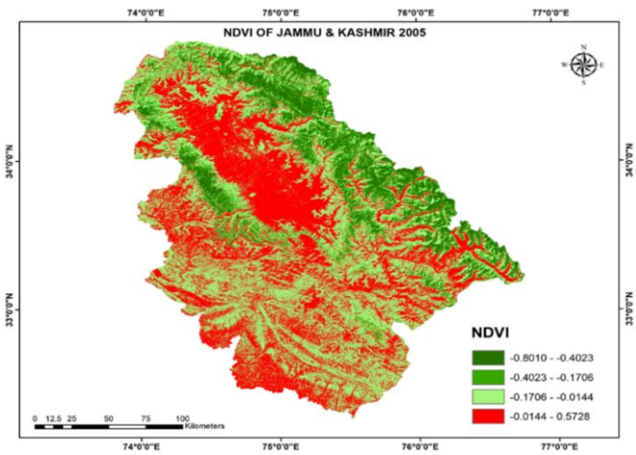
$$\boldsymbol{Pv = Square\,((NDVI - NDVImin) / (NDVImax - NDVImin))} \quad (5)$$

the minimum and maximum values of NDVI image can be displayed in the image (both in ArcGIS, QGIS, ENVI, Erdas Imagine), or you can open the properties of the raster to get those values.
Step 5.
To Calculate Emissivity **ε**

$$\varepsilon = 0.004 * Pv + 0.986 \quad (6)$$

If the equitation is applied in the raster calculator, the value of 0.986 corresponds to a correction value of the equation.
Step 6.
To Calculate the Land Surface Temperature

$$LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(\varepsilon))) \quad (7)$$



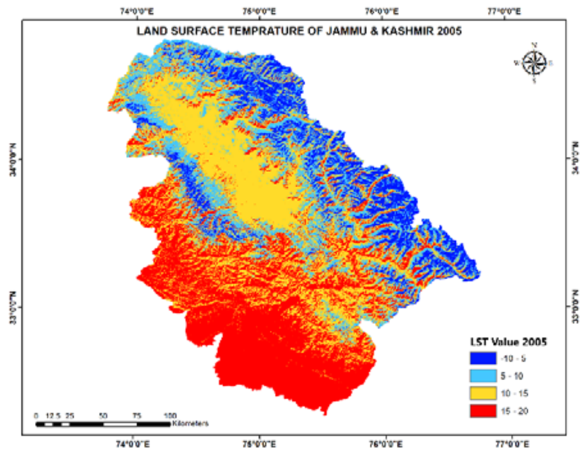
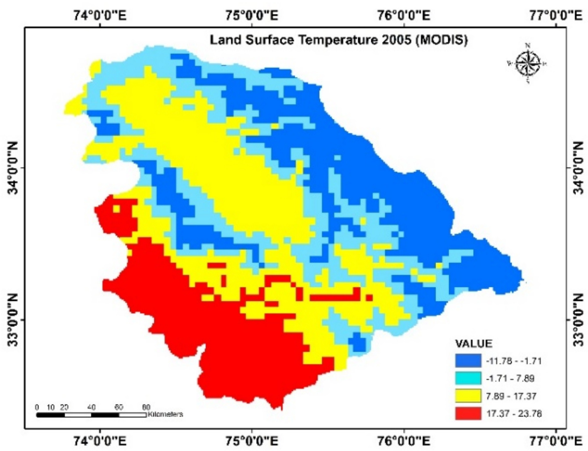
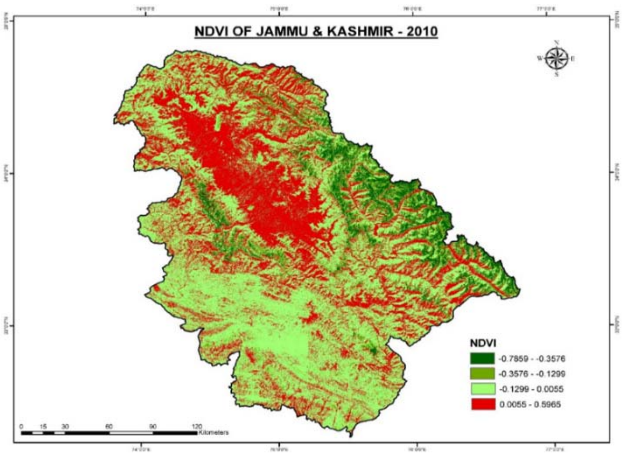


Figure 3. (a) NDVI 2005 (b) LST 2005



(c) MODIS LST 2005



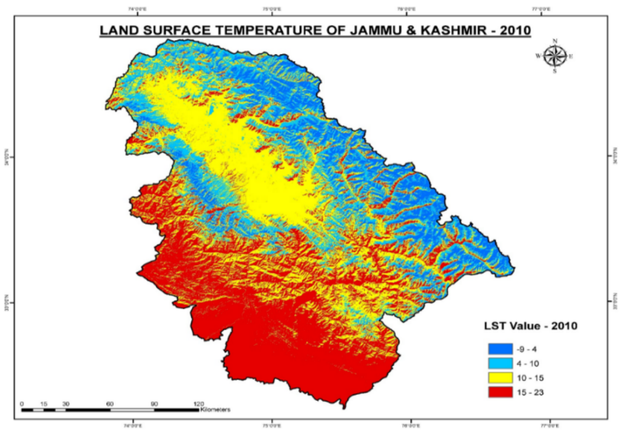
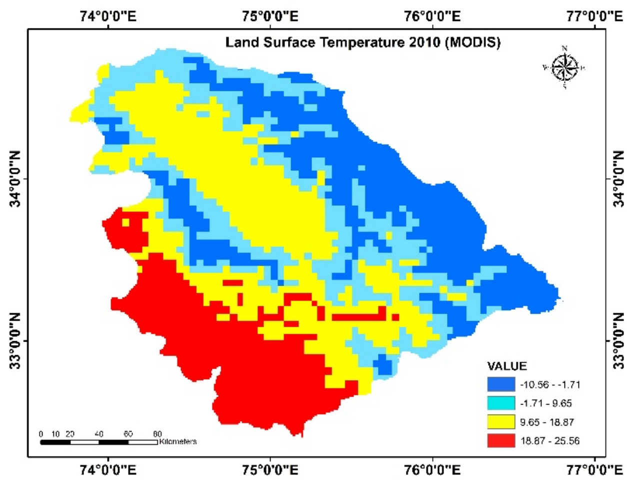
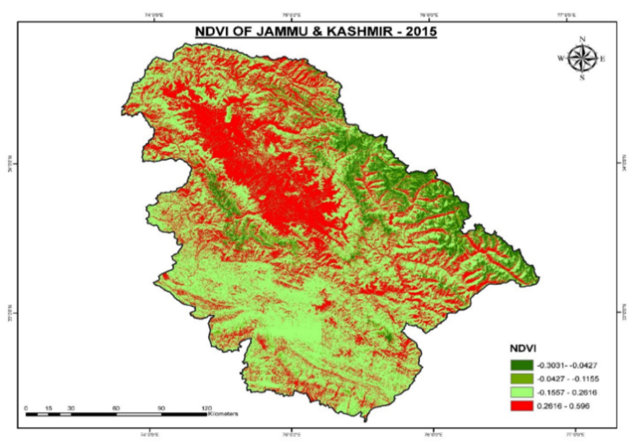


Figure 4. (a) NDVI 2010 (b) LST 2010



(c) MODIS LST 2010



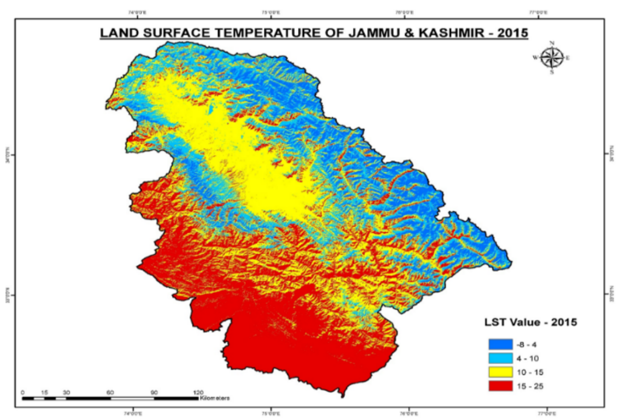
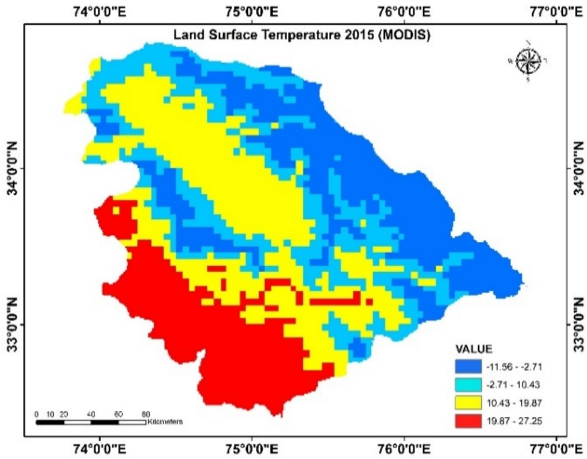
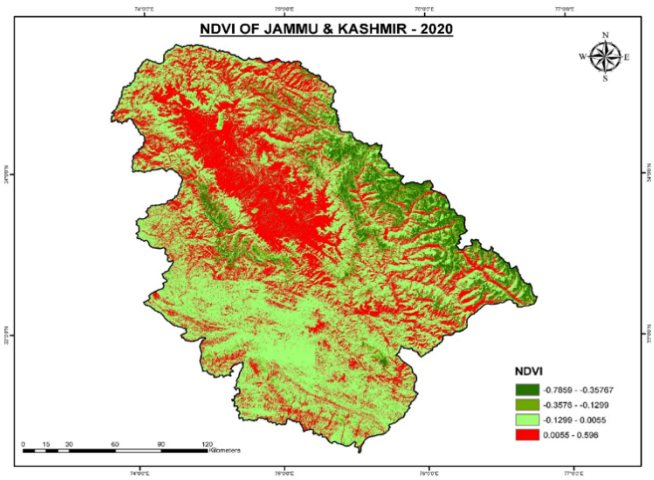


Figure 5. (a) NDVI 2015 (b) LST 2015



(c) MODIS LST 2015



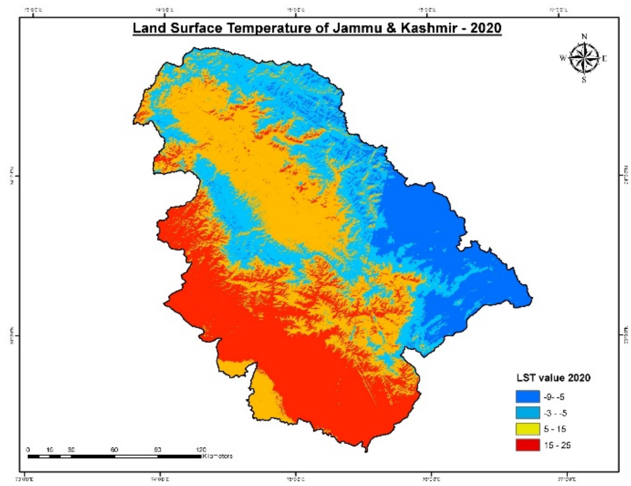
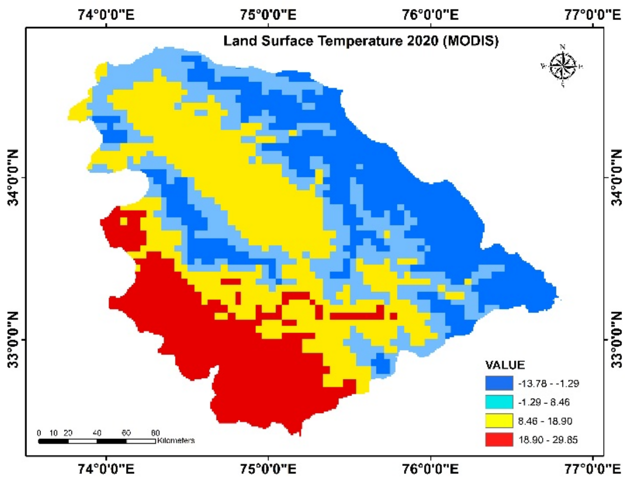


Figure 6. (a) NDVI 2020 (b) LST 2020



(c) MODIS LST 2020

5. CONCLUSION

Remote sensing and GIS are useful tools for deriving information about land surface temperature and the Normalized Difference Vegetation Index. Application of Landsat TM thermal infrared data and Landsat OLI data to the study of land surface temperatures Remote sensing-based LST is determined from thermal emission at wavelengths in the infrared band. In the research, the potential of remote sensing to study the land surface temperature (LST) in Jammu and Kashmir is presented by estimating the spatial distribution. The study is related to the changing characteristics of land surface temperature on a temporal as well as spatial scale. The picture that arises from the study indicates that there is variation in the LST values over the four years. The values have slightly changed in the last 20 years. For urban heat island studies, LST plays a vital role. In 2005, the highest recorded temperature was 20^0C. In 2020, the highest recorded temperature was 25^0C, with slightly less variation in the lower temperature. Climate factors such as wind speed and precipitation all have an impact on land surface temperature. Increases in LST serve as indicators of greenhouse gases and an increase in land surface temperature leads to changes in vegetation and glacier area. Increasing urbanisation is one of the factors behind the increase in LST. Land Surface Temperature can be used for predicting the climate or making climatic models. Along with land surface temperature, land surface emissivity also plays a major role in detecting earth surface characteristics. Land Surface Temperature is used for supervising vegetation and monitoring global warming.

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