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Evaluation of Land Surface Temperature and Normalized Difference Vegetation Index Relationship Using Landsat 8 Satellite Images in Mehar Taluka, Dadu

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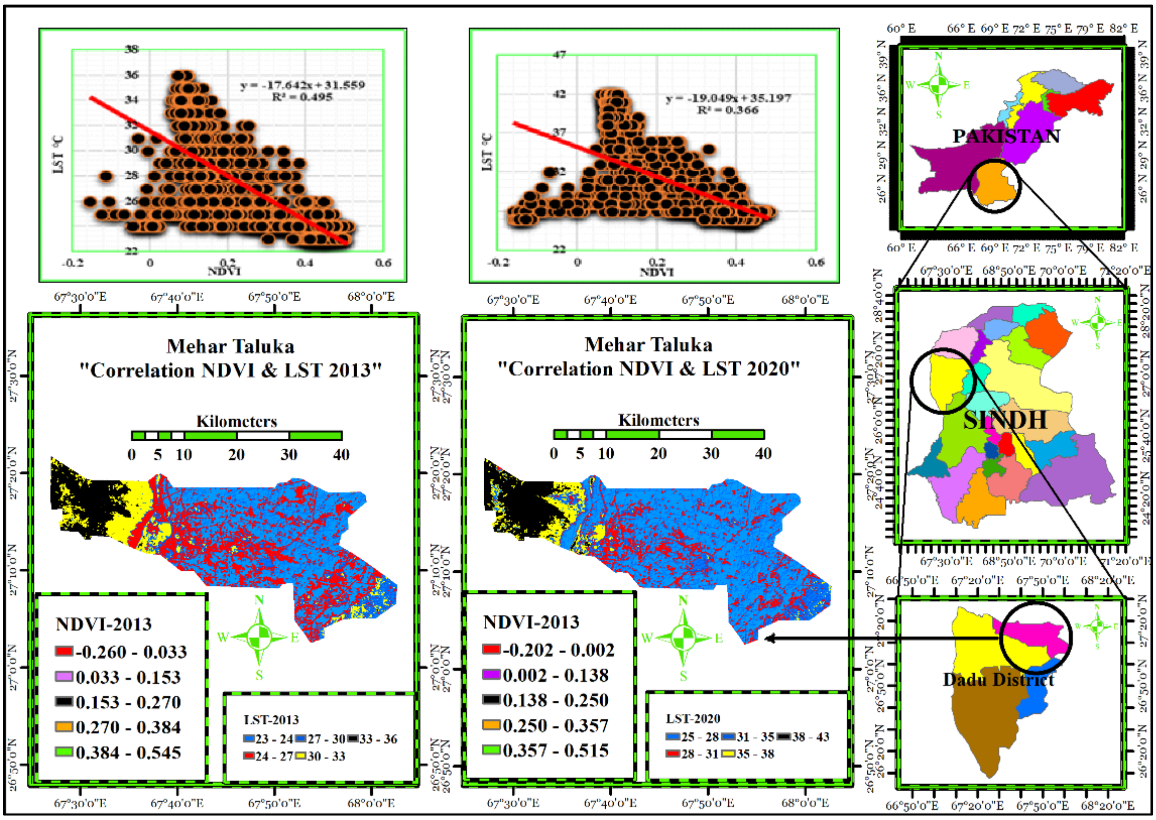
Abstract:
Mehar taluka has been undergoing a faster built-up development like other regions of Sindh province over the past decades. This expansion increased on replacement of natural surface by numerous artificial constituents which made substantial variations in Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI). The study investigates the surface temperature and vegetation index over built-up and vegetative areas from 2013-2020 in Mehar taluka. Landsat 8 imageries were acquired from the USGS web portal and processed in the ArcGIS 10.3 environment. To retrieve the LST, and to investigate the correlation, LST and NDVI were computed using equations given by USGS. The results showed that there was a linear negative correlation between both parameters. The regression coefficient value of both years was computed as (2013: R^2=0.337, and 2020: R^2= 0.2361). A strong negative correlation between LST and NDVI was found. Comparing both LST and NDVI, the results and maps exhibited that the peaks of the LST are usually the areas with no vegetation cover like built-up area and bare area. While NDVI peak is quite noticeable in the agricultural land and water body areas. Thus, it is clear from the study that remote sensing (RS) assessment is effective for determining the surface temperature and vegetation cover and also determining the relationship among LULC, LST, NDVI, UI, and NDWI for current and future scenarios on densely urban, regional and at the global level.

Keywords: NDVI, LST, Correlation analysis, Landsat 8 OLI/TIRS, Mehar taluka.

Graphical Abstract:



1.0. Introduction:

A rapid increase in population and unplanned urbanization in developing countries like Pakistan is creating a threat to socio-economic and environmental sustainability. It can be evaluated by seeing the correlation between rising temperature due to different factors i.e., global warming, decrease in vegetation cover, and built-up progress towards cities. The huge pressure of human actions, unintended urbanization, and industrialization with environmental factors heavily affect the land use and land cover. Moreover, these bring changes in surface reflectance and roughness, thereby different leading to variance in land surface temperature LST [1]. Generally, the acquisition of LST data involves direct observation via the network of local metrological stations but data is expensive and difficult to alter into surface or raster efficiency by using interpolation methods. LST provides basic statistics of Spatio-temporal changes of the surface equilibrium state [2].

Satellite imageries provide high Spatio-temporal resolution data of the earth's surface. Alterations in land cover, particularly vegetation health, have been carried out via near-infrared (NIR) as the vegetative portion reflects highly in the range. In urban and suburban regions where land cover variations from vegetation to impervious surfaces, LST studies are vital to defining thermal comfort. Satellite thermal infrared (TIR) data is straight allied to the LST through the radiative transferred equation. LST retrieval from remotely sensed TIR data and information has captivated significant attention and its history dates to the 1970s [3]. As in urban thermal environments, remote sensing RS can be useful tools for studying urban vegetation. In addition to providing measurements of radiant surface temperature, RS instruments collect measurements of reflecting energy in the red and near-infrared portions of the electromagnetic spectrum that can be used to quantify the extent and changing conditions of urban vegetation [4]. This information supports an investigation of the correlation between LST and vegetation index NDVI [5].

NDVI is mostly used in semi-arid areas for vegetation production and moisture estimation. It responds primarily in the high absorption red affected band. Vegetative indicator NDVI is generally utilized to study the relationship between LST and vegetation [6,7]. Many research studies have been conducted using NDVI to determine the correlation between vegetative indices and thermal temperature. Although using vegetative indices NDVI, higher values indicated high vegetation fraction. The correlation between LST and NDVI has been known to be negative due to evapotranspiration. It is quite complex because it is affected by many factors [8,9]. Therefore, LST and NDVI should also be studied to analyze the ecological effects of LST and address regional environmental problems. It is necessary to explore the relationship between LST and NDVI further. Currently, many scholars apply the remote sensing technique to analyze the surface temperature and vegetation index over different land use-cover dynamics and explore the relationship between LST, LULC, and NDVI [10,11]. The main thrust of this research study is to evaluate the surface temperature and vegetation index values from Landsat imageries and to determine the correlation between LST-NDVI over built-up and vegetative areas from 2013-2020 in Mehar taluka.

2.0. Materials and Methods

2.1. Study Area

The research study was conducted in Mehar taluka, district Dadu. It is located on 27° 10' 44.23''N and 67° 48' 25.34''E with an elevation of 162ft above sea level (Figure 1). The taluka is spread over an area of 1019 km² with a population of 460679. [12]. It consists of 64 villages and 15 union councils. The density per square mile is 178. The inhabitants mainly depend on agriculture. Kharif and Rabi seasons are the two main seasons for crops sowing to harvesting. Crops are categorized as major and minor crops. Wheat, cotton, rice, sugarcane is the major crops, and barely, jowar, gram, and mustard fall in minor crops. The taluka is irrigated by the Western Nara and one of its Feeders. The significant crops of taluka are jowar and rice. Mehar is intensively hot in summer and cold in winter. The temperature of the taluka, in summer is recorded between 85F to 90F. Mehar, and other talukas Khairpur Nathan Shah, and Johi of district Dadu are extremely hot belts due to the direction of sea breezes from west to east over Bagho-Thoro mountains near Lakhi Shah Saddar. The average annual rainfall in the district is about 120 mm.

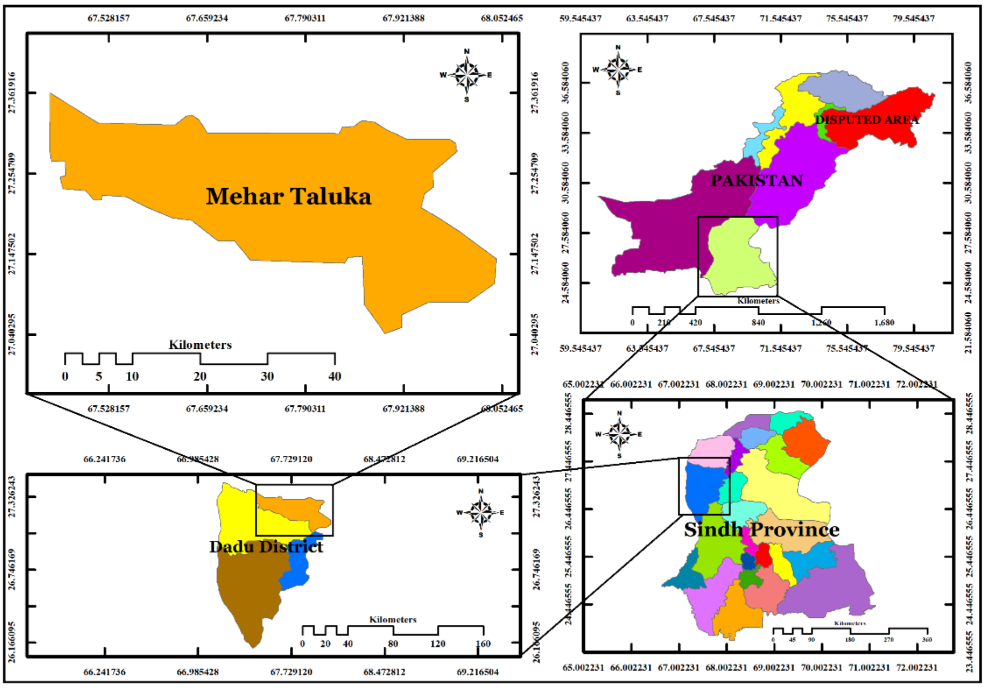


Figure 1. Location map of Mehar taluka, District Dadu, Sindh, Pakistan

2.2. Satellite Data Acquisition

Earth observation satellite data were obtained from the Landsat series covering the research area. USGS-GloVIS (https://earthexplorer.usgs.gov/) web portal was used. Two years' imageries 2013-2020 were downloaded from Landsat 8 OLI/TIRS in Tagged Image File (TIF) format with 0% cloud cover. All the satellite images were referenced to the (UTM) Universal Transverse Mercator projection system. They covered two scenes of Landsat 8 OLI/TIRS from Worldwide Reference System (WRS-2) of (path 152 rows 41, and path 153 rows 41). These imageries were freely downloaded from the web portal USGS earth explorer. (Table. 1) illustrates the downloaded Landsat 8 imageries information, and (Table. 2) shows details of 11 bands of Landsat 8.

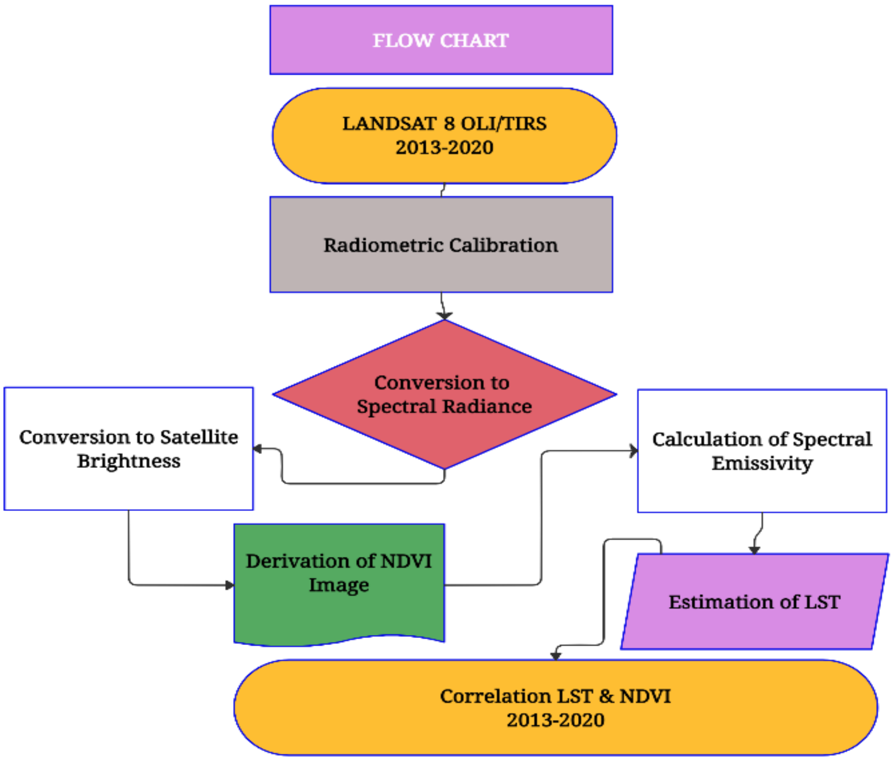


Figure 2. Represents flow chart methodology

Table 1. Illustrate Landsat 8 OLI/TIRS images information

S. No	Landsat Name	Landsat Scene ID	Path/Row	DOY	Image Acquisition Date
1	Landsat 8	LC81520412013271LGN01	152/41	270	2013-09-28
2	Landsat 8	LC81530412013262LGN01	152/41	261	2013-09-19
3	Landsat 8	LC81520412020275LGN00	152/41	274	01-08-2020
4	Landsat 8	LC81530412020282LGN00	153/41	281	08-10-2020

Table 2. Illustrate Landsat 8 OLI/TIRS bands information

Band	Wavelength (µm)	Resolution (meters)
1 (Coastal aerosol)	0.43-0.45	30
2 (Blue)	0.45-0.51	30
3 (Green)	0.53-0.59	30
4 (Red)	0.64-0.67	30
5 (Near Infrared) NIR	0.85-0.88	30
6 (SWIR 1)	1.57-1.65	30
7 (SWIR 2)	2.11-2.29	30
8 (Panchromatic)	0.50-0.68	15
9 (Cirrus)	1.36-1.38	30
10 (Thermal Infrared TIRS-1)	10.60-11.19	100
11 (Thermal Infrared TIRS-2)	11.50-12.51	100

2.3. Calculation of NDVI 2013-2020 of satellite imageries

NDVI has been one of the most commonly used vegetation indices in remote sensing since its introduction in the 1970s. With the improved accessibility of remotely sensed imagery from satellites and UAVs, researchers and scientists have come to implement the NDVI in their research activity. NDVI is an indicator of biomass and greenness [13,14]. It is used as a standard for comparing vegetation greenness between satellite images [15,16]. The value ranges of NDVI from +1 to -1. Positive values help in delineating vegetative areas, and negative values indicate non-vegetative areas [17]. In this manuscript, NDVI has been calculated for both the images 2013-2020 to check how much greenness in the area of study via using (Equation 1).

$$\text{NDVI}=\frac{\text{NIR (Band 5)}-\text{Red Band (Band 4)}}{\text{NIR (Band 5)}+\text{Red Band (Band 4)}} \quad (1)$$

Where NIR is the near-infrared band 5 value of the cell and Red is the band 4 value. The values are ranged from -1 and 1 referring to non-existence and existence, respectively [18].

2.4. Estimation of LST 2013-2020 of satellite imageries

LST is an essential factor used to estimate energy exchange and surface radiation [19]. Many scientists have implemented the thermal infrared (TIR)-Remote sensing data method. LST has been performed to estimate the temperature of the study area that refers to the air temperature of the environment. Band 10 mainly is a thermal band for LST estimation in Landsat 8 OLI/TIRS. USGS formulas, procedures, and equations were used to estimate LST values.

Step.1: Conversion to top of atmosphere TOA radiance: In this procedure using the radiance re-scaling factor, a thermal infrared digital number was converted into TOA spectral radiance by using (Equation 2).

$$\mathbf{L\lambda = ML \times Q_{cal} + AL - O_i} \quad (2)$$

Where: Lλ = TOA spectral radiance (Watts/ (m² * sr * μm), ML = Radiance multiplicative Band (No.10), AL = Radiance Add Band 10, Qcal = Quantized and calibrated standard product pixel values (DN), Oi = correction value for band 10 is 0.29.

Step.2: Conversion to Top of Atmosphere (TOA) Brightness Temperature (BT): Spectral radiance data can be converted to the top of atmosphere brightness temperature using the thermal constant Values in the Metadata file.

$$\textbf{Kelvin to Celsius BT} = \frac{K2}{Ln\left(\frac{K1}{L\lambda}+1\right)} - 273.15 \quad (3)$$

Where: BT = Top of atmosphere brightness temperature (°C), Lλ = TOA spectral radiance (Watts/ (m2 * sr * μm), K1 = K1 Constant Band (No.), K2 = K2 Constant Band (No.)

Step 3: Land Surface Emissivity (LSE): Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth calculated from NDVI values.

$$\mathbf{PV} = \{\frac{(NDVI - NDVImin)}{(NDVImax - NDVImin)}\}\mathbf{2} \quad (4)$$

Where: PV = Proportion of Vegetation, NDVI = DN values from NDVI Image, NDVI min = Minimum DN values from NDVI Image, NDVI max = Maximum DN values from NDVI Image.

$$\mathbf{E = 0.004 \times PV + 0.986} \quad (5)$$

Where: E = Land Surface Emissivity, PV = Proportion of Vegetation, 0.986 corresponds to a correction value of the equation.

Step 4: Land Surface Temperature (LST): LST is the radiative temperature calculated using Top of the atmosphere brightness temperature, the wavelength of emitted radiance, Land Surface Emissivity.

$$\mathbf{LST = BT/(1 + \left(\lambda \times \frac{BT}{C2}\right) \times Ln(E)} \quad (6)$$

Here, C2= 14388 μm K, The Values of λ for Landsat 8: For Band 10 is 10.8 and for Band 11 is 12.0. Where, BT = Top of atmosphere brightness temperature (°C), λ = Wavelength of emitted radiance, E = Land Surface Emissivity, C2= h*c/s=1.4388*10-2 mK =14388 mK, h=Planck's Constant =6.626*10-34 J s, s= Boltzmann constant =1.38*10-23 JK, c=velocity of light =2.998*108 m/s.

2.5. Correlation between NDVI and LST 2013-2020

The correlation between NDVI and LST was performed using different spatial analyst tools in ArcGIS 10.3 software. After calculating NDVI and LST for both satellite images 2013-2020, then the calculated results were prepared in an MS Excel sheet, and scatter plots were created.

3.0. Results And Discussion

3.1. Derivation of NDVI 2013-2020

NDVI calculations range from -1 to 1 depending on the relative digital number DN of NIR and red bands [20,21]. The negative values indicate the areas with the water surface, rocks, clouds, snow, bare land, an artificial structure that normally falls within the 0.1-0.2 range. 0.2-1 value corresponds to areas where plantation exists. Healthy and dense vegetation canopy always fall within 0.5 and sparse vegetation falls within 0.2-0.5. moderate vegetation tends to vary between 0.4-0.6. Anything above 0.6 values indicates the highest possible density of green leaves. NDVI value of 2013 imagery Figure 3 indicates that the maximum value of 0.54 means that the vegetation canopy over an area is highest, and the minimum value -0.26 shows the vegetation was mature. On the other hand, NDVI of 2020 imagery Figure 4 shows that the positive (maximum) value of 0.51 that the vegetation canopy over an area is healthy and highest. While the negative (minimum) value of -0.20 indicates bare land, waterbody, and built-up area. Comparing both years of NDVI, the vegetation canopy is highest in the 2013 year with full greenery on the agricultural land.

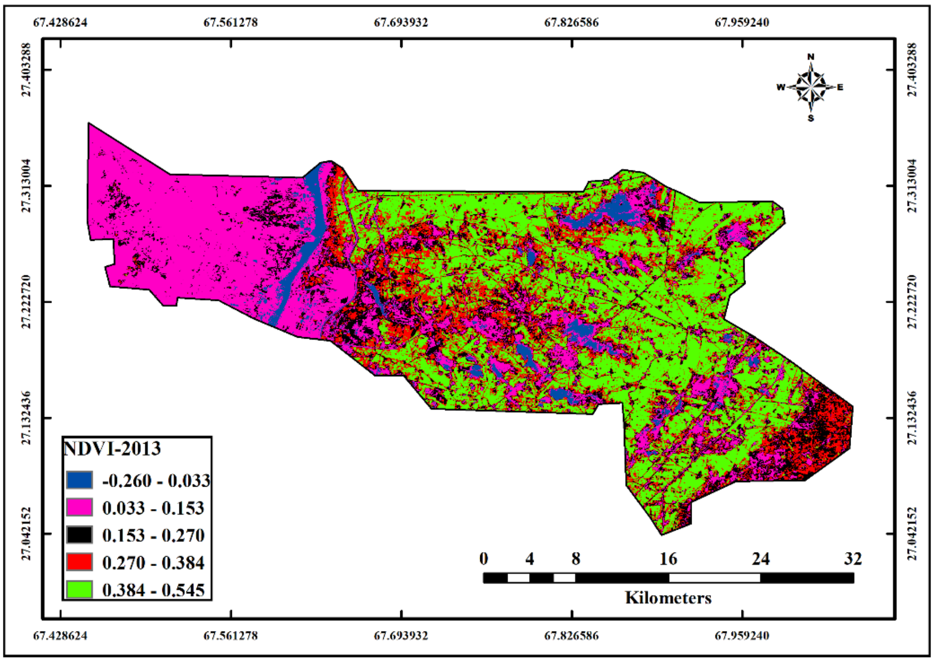


Figure 3. Represents NDVI 2013 of Mehar taluka

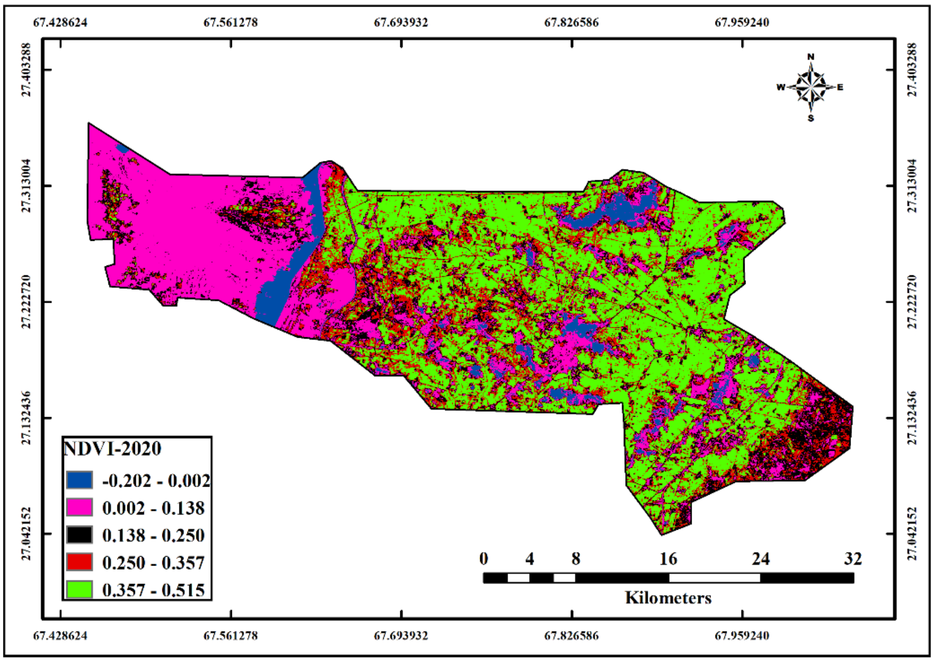


Figure 4. Represents NDVI 2020 of Mehar taluka

3.2. Derivation of LST 2013-2020

LST is one of the key parameters that is widely applied in surface energy balance, meteorology, and hydrology [22,23]. RS is a unique technique to obtain LST at the local, regional and global scale. Different LST products produced from different satellite data have been widely used in urban ecological environments, water management, and natural disasters [24]. In this manuscript, the Thermal band (Band10) of all scenes of 2013-2020 were added in ArcGIS 10.3 software after the creation of the mosaic process the Extract by mask algorithm was run and then the minimum and maximum LST was calculated using different equations followed by USGS methods. The minimum and maximum LST were 23°C and 36°C respectively in the 2013 image Figure. 5. Whereas, in the 2020 year, the minimum and maximum LST Figure. 6 was 25°C to 43°C. The difference between the seven years' temperature. There was a rise in temperature in the vegetation area i.e., the minimum temperature was increased 2°C and maximum temperature increased as 7°C between 2013-2020.

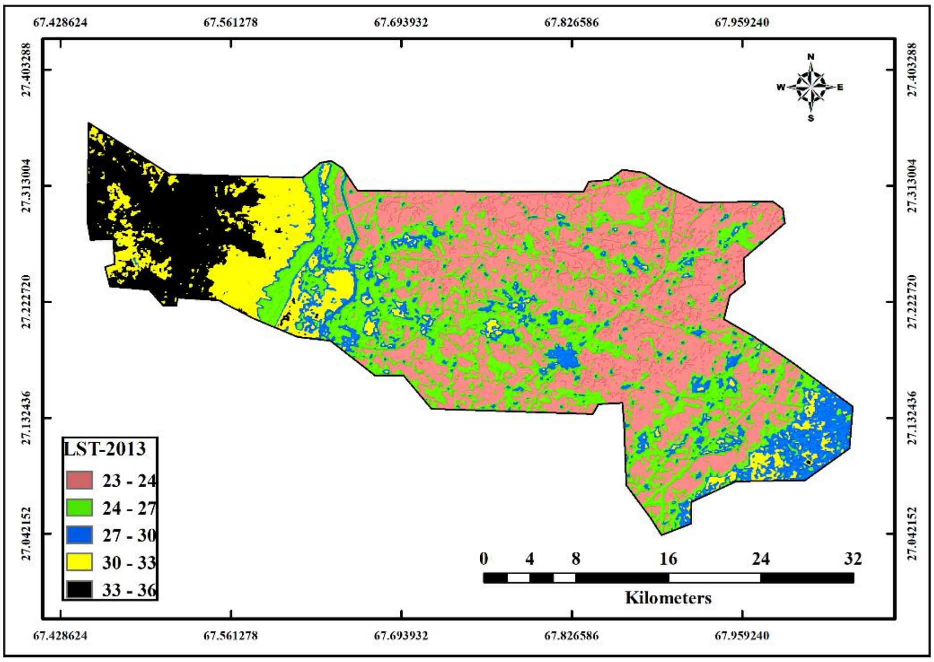


Figure 5. Represents LST 2013 in Mehar taluka

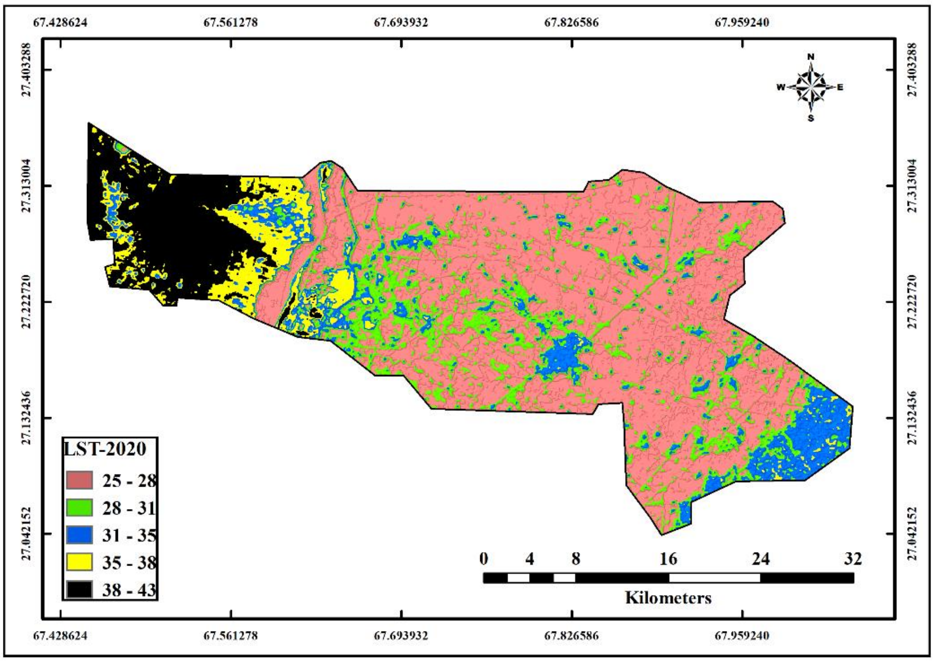


Figure 6. Represents LST 2020 in Mehar taluka

3.3. Correlation between NDVI and LST 2013

The correlation between NDVI and LST is depicted in (Figure. 7) which indicates that the NDVI is negatively correlated with LST. (Figure. 8) shows the correlation between NDVI and LST is 0.337 in 2013 imagery and defined by statistical scatter plot. It gives a clear indication that there is a linear and negative correlation between vegetation index and surface temperature. Hence, less vegetative areas experienced as high LST and full greenery areas, agricultural land, water-body have high NDVI. The correlation between NDVI and LST is depicted in (Figure. 9) which indicates that the NDVI is negatively correlated with LST. Figure 10 expressed the correlation between NDVI and LST is 0.2361 in 2020 imagery and defined by statistical scatter plot. It gives a clear indication that there is a linear and negative correlation between NDVI and LST. Hence, less vegetative areas experienced as high LST and full greenery areas, agricultural land, water-body have high NDVI.

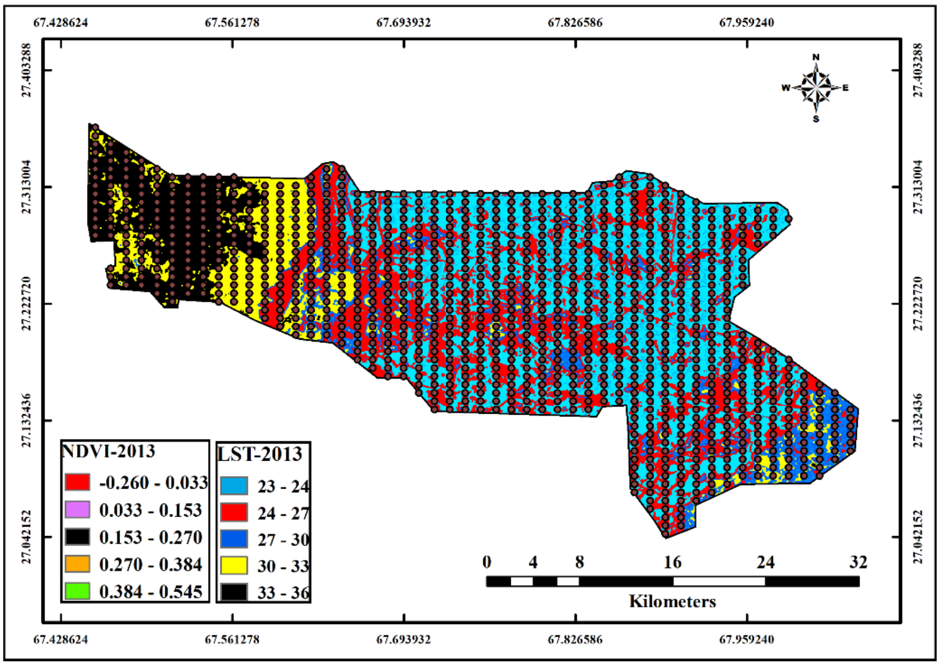


Figure 7. Correlation between NDVI & LST 2013 in Mehar taluka

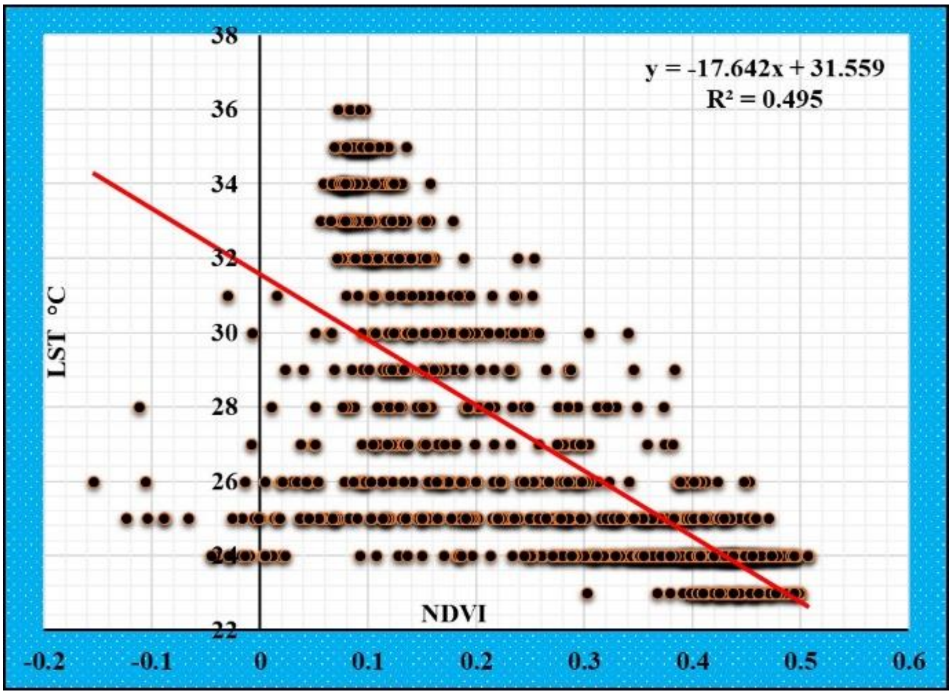


Figure 8. Scatter plot representing the correlation between NDVI & LST 2013

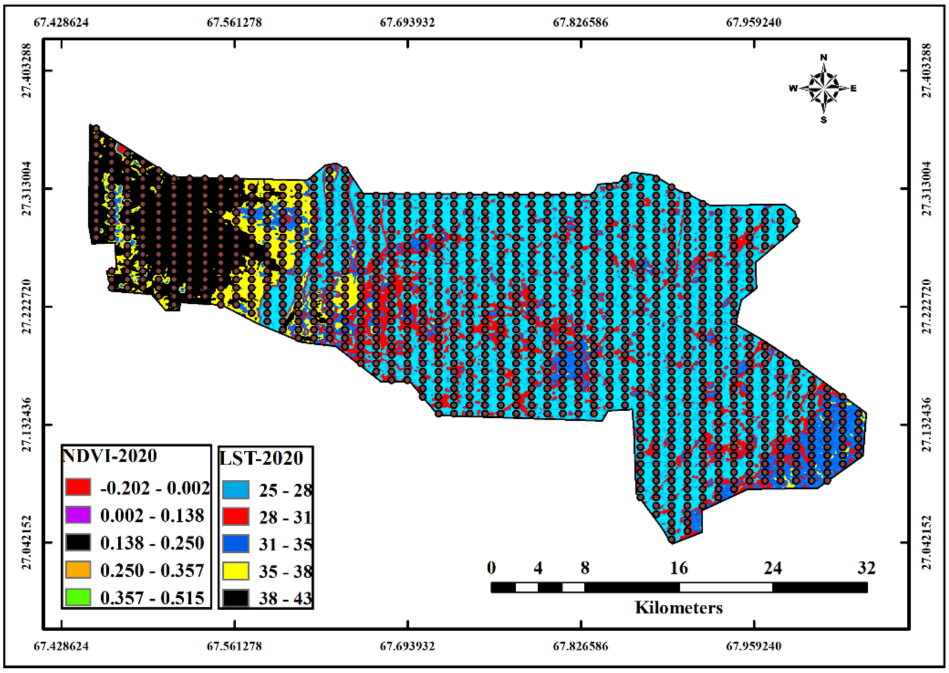


Figure 9. Correlation between NDVI & LST 2020 in Mehar taluka

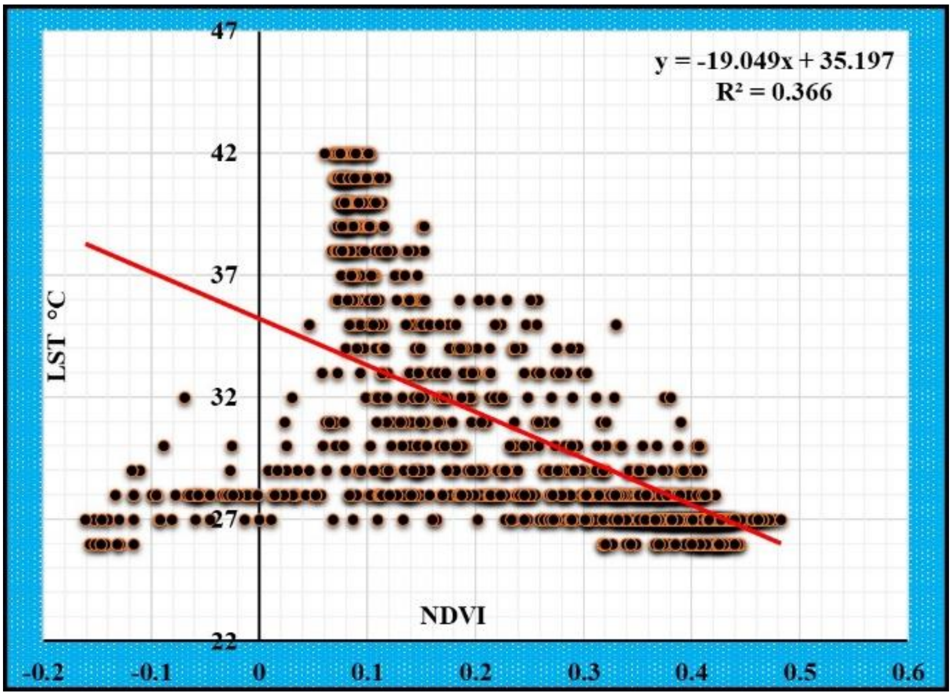


Figure 10. Scatter plot representing the correlation between NDVI & LST 2020

4.0. Discussion

The purpose of this study was to deliver a recent outlook on surface temperature and vegetation cover and also explore the correlation between NDVI and LST in Mehar taluka from 2013-2020.

- The NDVI values range is -0.26 to 0.54 in 2013 and -0.20 to 0.51 in 2020. The lowest values refer to the sub-urban of taluka Mehar with barren land and no vegetation land. In contrast, the highest values refer to the agriculture crops and vegetation cover area where the vegetation is the densest.
- LST images indicate that the highest temperature exists at sub-urban areas with bare soil and the lowest temperature exists at vegetative areas such as crops and water-body.
- (Figures 7 & 9) represent that the land-use changes have a high impact on the temperature regime of the area. However, the vegetation body has a lower temperature than the other areas, such as built-up areas. LST values are relatively higher in the built-up area or sub-urban area with no vegetation cover.
- The correlation between NDVI and LST and regression coefficient from NDVI to LST are negative, which means that where NDVI is lower has higher LST and where NDVI is higher has lower LST.

5.0. Conclusion

In this research study, a strong negative correlation between LST and vegetation is found. Comparing LST and NDVI show that the peaks of the LST are usually the areas with no vegetation cover like urban area or built-up area and bare soil area in taluka Mehar. Moreover, the Surface temperature in the study area is continuously rising day by day, while the vegetation index NDVI peak is quite noticeable especially in the agricultural land and water body areas. Increasing temperature highly affects vegetation. Therefore, this study concluded that the effective use of the RS technique is very much helpful to evaluate, monitor, and analyze the climate indicators especially for the assessment of the major variables like LST and NDVI. RS assessment is also useful for determining the relationship between LULC, LST, NDVI, urban index, moisture index, drought index, and normalized difference water index (NDWI) will be helpful to evaluate the current and future scenarios on densely built-up areas, urban, regional and at the global level.

6.0. Future Scope

Landsat imageries assessment is useful for determining the relationship between LULC, LST, NDVI, urban index, moisture index, drought index, and normalized difference water index (NDWI) will be helpful to evaluate the current and future scenarios on densely built-up areas, urban, regional and at the global level.

7.0. Acknowledgments

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8.0. Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. Besides, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication or submission, and redundancy have been completely observed by the authors.

9.0. References

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