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Vegetation Change Analysis using Normalized Difference Vegetation Index and Land Surface Temperature in Greater Gir Landscape

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Abstract: **Vegetation indices and Temperature datasets are very crucial in remote sensing to identify the differences over the period of time on the particular landscape. Remotely sensed multi-spectral data from Landsat-8 is highly useful in vegetation change analysis based on which remote sensing indices and temperature parameters. NDVI (Normalized Difference Vegetation Index)-LST (Land Surface Temperature) relation is important to understand the climatological effects on vegetation on regional scales. Threshold based classification have been used to understand vegetation change in multi-temporal studies. Similarly, in this study NDVI based classification have been applied in order to understand change in the area covered by vegetation and waterbodies. Overall, there is weak negative correlation (r = - 0.232) found between NDVI-LST. It is observed that our results based on correlation analysis reaffirms other findings previously done for LST-NDVI relations in semi-arid regions.**

Index Terms: **NDVI, LST, Vegetation Cover, GIS, Remote Sensing.**

I. INTRODUCTION

Vegetation phenology change studies have been carried out using NDVI (Normalized Difference Vegetation Index) even on regional scales. It is essential for understanding climatological and environmental effects on inter and intra-annual differences in vegetation cover (Fensholt et al., 2009).

NDVI and LST (Land Surface Temperature) are used to analyze vegetation condition in semi-arid and arid regions (e.g. drought conditions) because these are directly related to vegetation health and moisture present in soil. However, the relationship between NDVI and LST is subject to seasonal variation i.e. strong but negative correlation found in the summer months whereas positive correlation found in winter months (Sun & Kafatos, 2007). In order to understand the detrimental effects of desertification on vegetation cover, multi-temporal analysis based on NDVI and LST are preferred as the combined use of both these would allow better understanding of changes in vegetation especially in different regions for instance a) In arid regions NDVI values will be steadier and almost unvarying b) Semi-arid regions witness higher NDVI when temperature is lower c) In tropical regions there is changing NDVI values according to the season however it doesn't change that much in dense vegetation areas especially in tropical rainforests d) And in temperate and high latitude regions the NDVI reaches maximum especially in summer (Julien et al., 2011).

Furthermore, direct parametrization of albedo can be used to identify variations among different cover types. Similarly, NDVI has also been used for preparing land cover classifications at continental level as well as global level because reliable results can be obtained if these classifications are done using multi-temporal NDVI data based on seasonal and interannual variations. This is because these variations can be observed due to climatic variability or actual change in land covers (Defries & Townshend, 1994). In addition, changes in vegetation cover can be directly observed by NDVI as the correlation between vegetation cover and NDVI has been found to be very high. Even moderate resolution satellite imagery is effective for understanding and monitoring vegetation cover dynamics and therefore, a multi-temporal analysis based on NDVI can be useful for identifying vegetation cover degradation due to anthropic pressures over the years given that rainfall distribution and other climatic parameters remain constant and evenly distributed spatially (Jacquin et al., 2010). In semi-arid regions, the NDVI and LST varies both spatial and temporally such that NDVI is minimum in advent of the

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significantly lower-than-average precipitation annually, seasonally drops to lowest in the dry summer and also spatially the NDVI has variations e.g. NDVI tends to be higher in rural area. Whereas, LST-NDVI relations vary seasonally but overall, it has weak and negative relationship however, in winters NDVI rises with LST. Also, one important observation is that the daytime LSTs are found to be lower in dense built-up areas in all three seasons in the semi-arid climatic category i.e. summer, winter and autumn (Rasul et al., 2016).

In semi-arid climates, the relationship between precipitation and average yearly NDVI have found to be in positive correlation especially in growing season. Soit is infered that precipitation can be the main driving factor in decreasing NDVI as recurring droughts and climate variability have caused annual reduction in NDVI especially in shrublands and croplands. Although, precipitation is an important factor, shifts in temperatures can affect the vegetation directly as strong negative correlations in growing season between temperature and NDVI have been found in these type of regions (Measho et al., 2019).

Additionally, the change in land use - land cover can also affect the LSTs e.g. if irrigated cropland and forest covers change to built-up areas over the years it can increase both air and land surface temperature whereas if Bare soil cover changes to Urban area the mean LST of that area can decrease, thus it can be said that vegetation and urbanization can also reduce LSTs on local scale as vegetation has cooling effect through transpiration, shade and retention of rainwater whereas urbanized areas can play this role because of the surface and type of material that makes convection more efficient comapared to other areas such as bare soil or rocky areas (Rasul et al., 2017). In this analysis, a bi-temporal NDVI and LST vegetation cover change and regression comparison using QGIS Open Source Environment in Greater Gir landscape is performed. Also, this timeframe was chosen in order to observe the post scenario of Asiatic Lion census 2015 which occurred in pre-monsoon period of 2015 in the region. We hypothesize that higher LSTs have drastic effects on the vegetation cover, and also the LST variations and its effect on different vegetation cover types will be discussed in this study keeping in mind different conservation areas, urban settlements, water bodies and other land surface features.

II. Methodology

A. Study Area

The Study area consists of frequent wildlife movement area under two districts of Amreli and Bhavnagar in Gujarat, India with the geographic extent between 20° 45'and 22° 7' N lat. and 71° 5 'and 72° 22'E long. It has a total area of 9409.74 km². The climate of this region is classified as Hot Semi-arid climate (Bsh) with hot dry summers and mild winters as per Köppen-Geiger climate classification map (Peel et al., 2007)Furthermore, this area comes under the Agro-ecological region no. 7 which broadly includes Malwa Plateau, Gujarat Plains and Kathiawar Peninsula. It is categorized by a hot-semi arid region with moderately deep black soils (Mandal et al., 2016). Additionally, this study area falls over three major Agro-climatic zones viz. i) North Saurashtra, ii) South Saurashtra and iii) Bhal and Coastal Area mostly characterized by a Dry sub-humid Climate (National Dairy Development Board, 2013).The vegetation of the region is classified under Tropical thorn forest and patches of Dry deciduous forest (Champion & Seth, 1968).

The Average Annual Precipitation is 561.8 mm for Amreli and 655.9 mm for Bhavnagar. Average Daily Max. air temp. for Amreli is 34.3 °C and for Bhavnagar is 33.9 °C whereas Average Daily Min. air temp. for Amreli is 20.1 °C and for Bhavnagar is 21.7 °C. Also, the relative humidity of Amreli is 39% and of Bhavnagar is 44% (Indian Meteorological Department, 2010).

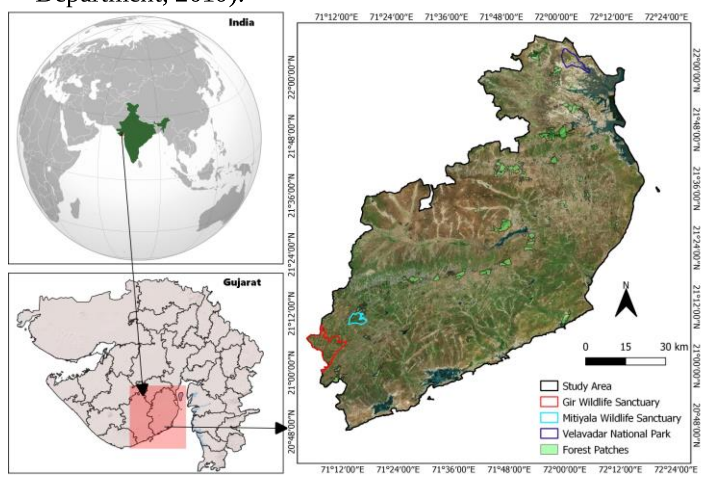

Fig. 1 Study area map (includes Amreli and Bhavnagar districts)

B. Datasets and Methodology

1) Datasets

The datasets used in this paper were USGS Landsat satellite Level-1 Data Product consisting of raster images of multi-spectral image data in the form Digital Numbers (DN) i.e. pixel values which has 9 Bands Optical Spectral Bands from OLI (Operational Land Imager) and 2 Thermal Bands from TIRS (Thermal Infrared Sensor) for the November month of the years 2015 and 2019 for a bi-temporal comparison.

In this analysis, Band 4 (Red), Band 5 (Near-Infrared) and Band 10 (Thermal Infrared 1) were used for generating NDVI and LST maps. The spatial resolution of Bands 4 and 5 was 30 m while the resolution of Band 10 was 100 m. Required georectification, mosaicing and subsetting was done on all raster images used in this analysis by using the vector boundary of the two districts mentioned earlier.

2) NDVI computation

Band 4 and Band 5 are used for generating NDVI as the ratio of these bands is used. NDVI is a dimensionless quantity which provides the values between +1 and -1. From 0 to 1 it represents from sparse vegetation to dense vegetation whereas values less 0 represent complete absence of vegetation indicating water or ice. It is computed using Eq. 1.

$$NDVI = \frac{Band5 - Band\,4}{Band\;5 + Band\,4} \quad (1)$$

Band RS-GIS Plugin was used to compute instant NDVI raster images as it converts the DN values to Reflectance for Band 4 and Band 5 in order to obtain NDVI.

3) *LST computation*

In order to compute LST, there are few steps of processing to be performed on the Level-1 data of TIRS i.e. Band 10. However, all these steps are carried out instantly in RS-GIS Plugin in QGIS.

a) DN to TOA (Top of the Atmosphere) radiance

First step is to convert raw DN into TOA radiance (L_λ) as shown in Eq. 2.

$$L_\lambda = ML_\lambda \times Q_{cal} + AL_\lambda \quad (2)$$

Where, ML_λ is the radiance multiplicative scaling factor for respective spectral band, AL_λ is the radiance additive scaling factor for respective spectral band, and Q_{cal} is the pixel value i.e. DN.

b) TOA Radiance to At-satellite brightness temperature (T_λ)

The next step would render is illustrated by Eq.3.

$$T_\lambda = \frac{K_2}{\ln\frac{K_1}{(L_\lambda + 1)}} - 273.15 \quad (3)$$

Where, L_λ is the radiance, K_1 and K_2 are prelaunch calibration constants (U.S. Geological Survey, 2016).

c) Emissivity calculation before final LST computation

Author In order to compute LST it is required to calculate emissivity (e) as shown in Eq. 4.

$$e = 0.004Pv + 0.986 \quad (4)$$

Where, Pv is the vegetation proportion and is calculated with the help of scaled NDVI (by using the NDVI obtained earlier) as shown in Eq. 5.

$$Pv = \left[\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right]^2 \quad (5)$$

Where, the NDVI which is computed earlier per pixel. While, $NDVI_{min}$ and $NDVI_{max}$ are the minimum and maximum NDVI respectively. The equation portion in the squared brackets is also called 'scaled NDVI' (Carlson & Ripley, 1997).

d) LST Calculation

Finally, LST is calculated as per Eq. 6.

$$LST = \frac{T_\lambda}{1 + \left(\frac{\lambda \times T_\lambda}{\rho}\right) \ln e} \quad (6)$$

Where, T_λ is the at-satellite brightness temperature, λ is the wavelength of the emitted radiance, ρ = h×c/j (h is Planck's constant i.e. 6.62607015×10^{-34} Js , c is velocity of light i.e. 2.99 x 10^8 m/s and j is the Boltzmann constant i.e. 1.380649×10^{-23} J K^{-1}) and as mentioned earlier the emissivity (e) computed using Eq. 4 will be further used to calculate the final LST (Artis & Carnahan, 1982).

4) *NDVI-derived Vegetation Cover*

The vegetation cover maps are prepared by thresholding NDVI values. The threshold values of the cover types are approximately based on the reference studies as mentioned in Table 1. Bare Soil threshold was based on 2 studies, one directly and the other indirectly based on minimum threshold value of crop. Similarly, Sparse vegetation threshold was indirectly based on the minimum threshold values of crops.

Table 1. NDVI threshold values of different cover types

Cover Type	**NDVI Value Threshold**	**Reference**
Water	-0.046	(Bisrat & Berhanu, 2018), (Dalezios et al., 2001)
Bare Soil	0.25	(Ding et al., 2016) (Thorat et al., 2015)
Sparse vegetation	0.35	((Thorat et al., 2015))
Moderate vegetation	0.5	(Bisrat & Berhanu, 2018), (Dalezios et al., 2001)
Dense vegetation	1	(Dalezios et al., 2001)

III. Results and Discussion

As shown in Fig.1 and Fig.2 it is confirmed clearly that the 2015 NDVI values are significantly lower than 2019 NDVI values as the mean NDVI value for 2015 was found to be 0.34 (±0.17 SD) in contrast to 2019 mean NDVI value which was 0.44 (±0.22 SD). For 2015, the minimum and maximum NDVI values were -0.75 and 0.79 respectively. For 2019, the minimum and maximum NDVI values were – 0.97 and 0.87 respectively.

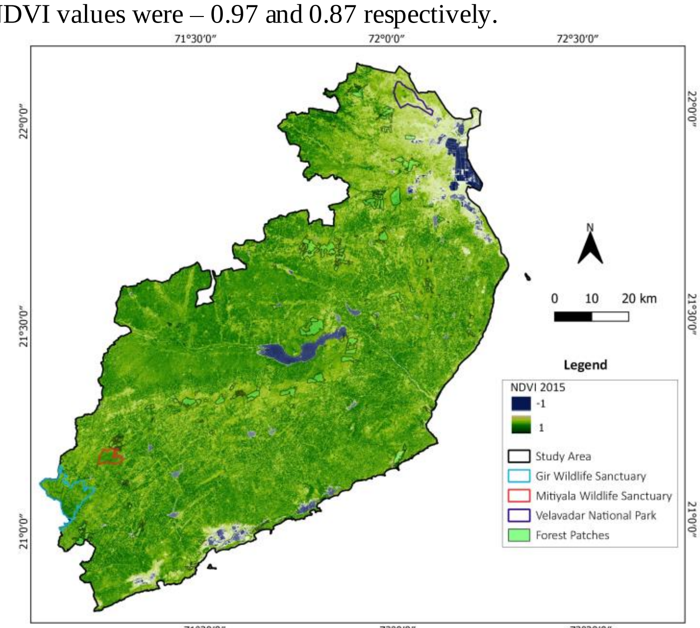

Fig. 2. NDVI map of the study area for 2015

In the central part of the study area where the Shetrunji River Basin lies, there was clear difference of NDVI which suggests the significantly varying vegetation cover while comparing the two years.

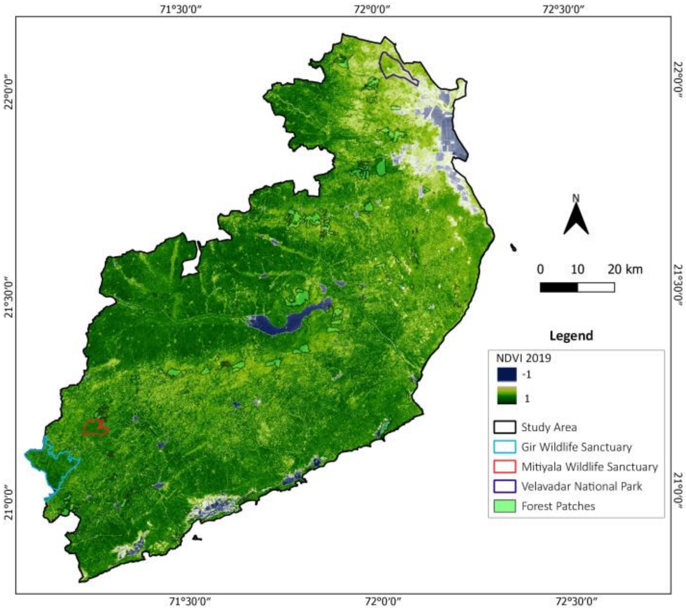

Fig. 3. NDVI map of the study area for 2019

Also, the LST maps as shown in Fig. 3 and Fig. 4 reveal that there is a significant difference in LSTs while comparing the two years. In 2015, the mean LST of the entire area was 32.1 °C (±2.1 SD) whereas for 2019, the mean LST was 30.4 °C (±2.2 SD). This clearly suggests 2015 year must have higher temperatures even in the month of November as it is almost the onset of winter in this region.

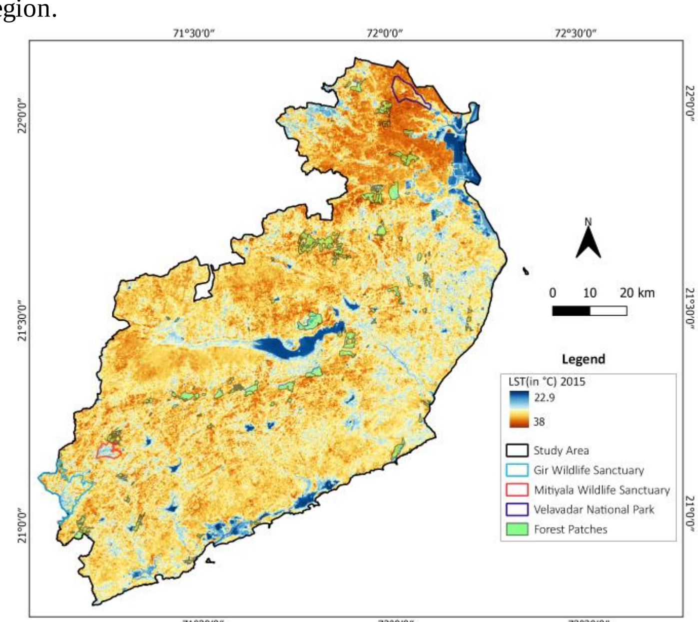

Fig. 4. LST map of the study area for 2015

In comparison, 2015 witnessed a stark difference of LSTs between different land cover types e.g. water bodies and barren areas in the north, in contrast to 2019 where the southern-central part had higher temperatures compared to the north and temperature differences were not as big as 2015 LSTs.

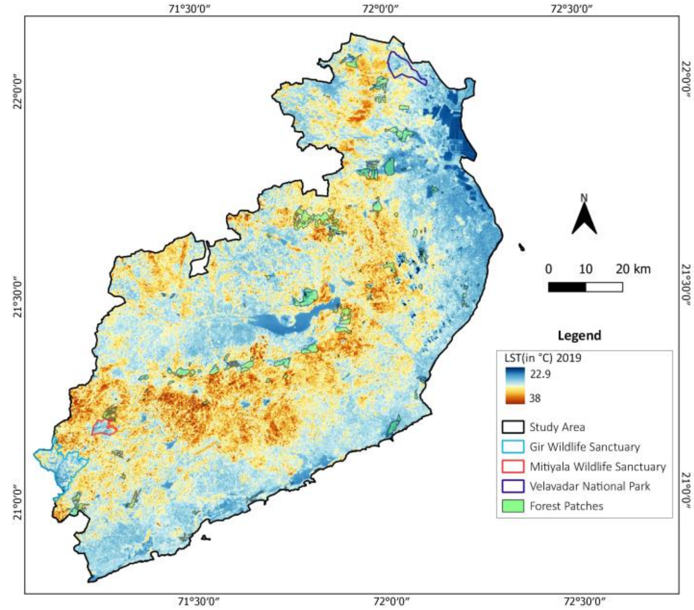

Fig. 5. LST map of the study area for 2019

Our results are in agreement with a study, which imply that strong negative correlations between LST and NDVI are only witnessed in the warm months including summer, and when approaching the onset of winter (i.e. November in our study area) the change from negative to positive correlation starts (Sun & Kafatos, 2007).

As shown in Fig. 5. There is overall weak negative correlation (r = -0.232) found for both the years. In addition, there was even weaker negative correlation (-0.069) found in 2019 between LST-NDVI values compared to 2015 where although it was weak negative (-0.171), it was still stronger than 2019.

Moreover, as shown in Fig.5 density plot the NDVI values in 2015 are almost normally distributed compared to 2019 which shows slight negatively skewed which shows it has relatively lower negative NDVI values compared to 2015. This also confirms with the result of 2019 LSTs which shows cooler temperature compared to 2015.

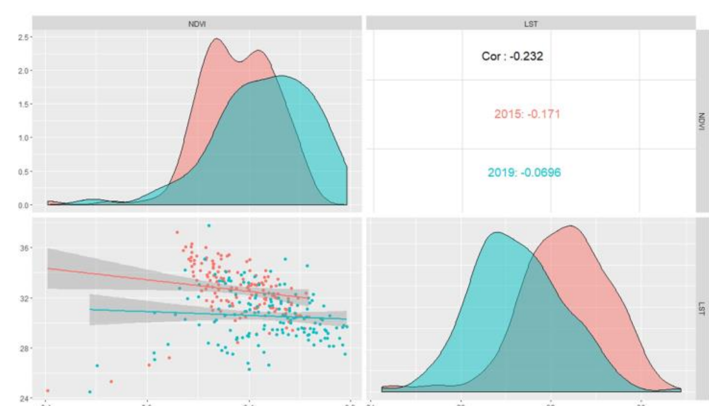

Fig. 6. LST-NDVI Scatterplot and Density plots for comparing 2015 and 2019 values

While comparing Fig.6 and Fig. 7, again the difference in vegetation cover types specifically in dense vegetation class is huge. Sparse and Moderate vegetation covers more area in 2015 than in 2019. Dense vegetation patches are few in 2015 vegetation cover map.

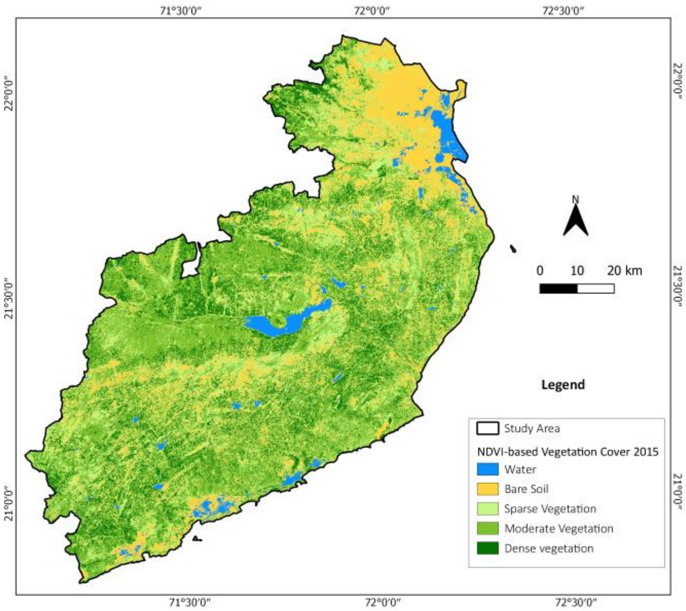

Fig. 7. Vegetation Cover Map of the study area for 2015

Most importantly, dense vegetation cover patches are almost absent in 2015 in Shetrunji River Basin area and in the southern areas near the coast.

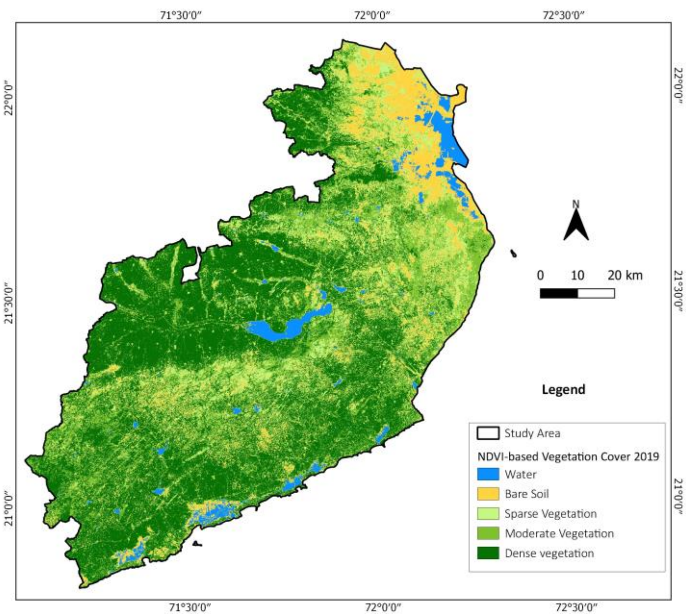

Fig. 8. Vegetation Cover Map of the study area for 2019

The area statistics are provided in Table 2 for comparison. As per the Table 2, the Dense vegetation cover in 2019 was almost 30% higher than 2015 which also can be because the LSTs in 2015 were higher than 2019 and higher LSTs can be due to dry or drought-like condition in the that year and therefore 2015 has less dense vegetation cover than 2019. Water cover was lower by almost 5000 hectares (0.5%) in 2015 than 2019. Additionally, Bare soil area had been reduced from 2015 to 2019 by more than 7%. This clearly shows marked differences in vegetation covers between the compared years.

Table 2. Area (in hectares) and Percent Area by vegetation cover types

Cover Type	2015 Area in hectares (%)	2019 Area in hectares (%)
Water	28,607 (3.04)	33,561 (3.57)
Bare Soil	185,155 (19.68)	113,907 (12.11)
Sparse Vegetation	232,662 (24.73)	129,790 (13.79)
Moderate Vegetation	342,299 (36.38)	236,075 (25.09)
Dense Vegetation	152,251 (16.18)	427,641 (45.45)
Total	940,974 (100%)	

CONCLUSION

Our findings reaffirm that strong negative correlations between LST and NDVI are observed in the warmer months i.e. mainly in summer, and only in winter positive correlations occur especially in our climatic zone but can be also in other zones globally. Another important observation is the waterbodies percentage were significantly lower in 2015 compared to 2019 which also suggests that lower precipitation also have an effect on NDVI values as it may affect irrigation in semi-arid regions like our study area. Therefore, to address the limitations of LST-NDVI relation for vegetation change analysis precipitation and irrigation scenario can be included to understand the correlation with NDVI. Also, we suggest the usage of other indices such as Enhanced Vegetation Index (EVI) or Perpendicular Vegetation Index (PVI) for similar threshold-based vegetation cover classification.

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