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# Temporal Analysis of Land Surface Temperature and Land Use/ Land Cover using Remote Sensing

**Neelam Shekhawat, Ankita Pran Dadhich and Rohit Goyal***

*Dept. of Civil Engineering, Malaviya National Institute of Technology, Jaipur, 302017, India*
**rgoyal.ce@mnit.ac.in*

**Abstract—***Fast urbanization has pulled the attention of scientists from different nations and districts because of its potential effect on the earth and neighborhood atmosphere. In this study, Jaipur urban area was picked as an examination site to show the procedure of urban development and additionally the related land surface temperature change in the period 2000 to 2016 using remote sensing data. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 in 2000, 2011 and 2016 respectively were used to evaluate land surface temperature in Jaipur, the capital city of Rajasthan in India. Conversion of land use cover change (LUCC) is the main factor for change in land surface temperature. In order to analyze the relationship between UHI and land-cover changes, some indices were used in this study such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Normalized Difference Bareness Index (NDBaI). It was discovered by regression techniques that relationships between NDVI, NDBaI, NDWI, and temperature are negative.*

**Keywords***: LUCC, NDBaI, NDVI, NDWI, Regression techniques, Urbanization*

## 1. INTRODUCTION

There is lopsided urban growth, which is taking place all over the world. According to World Business Council for Sustainable Development (WBCSD), presently more than half the global population lives in cities and by 2050 it would grow to more than two-thirds [1].Being the capital city of Rajasthan state, Jaipur is also one such hub for trade-commerce, tourism, etc. and thus it is turning into a great attraction among migrants within the state. The population of the city has grown from 1.01 million in the year 1981 to 3.05 million in the year 2011 as per respective census and is approximated to be around 3.55 in the year 2016 [2].This urbanization is landing the city in a situation where population growth has started becoming a threat, resulting in its sweltering hot environment, loss of vegetation and environmental degradation. The effect of urbanization has been observed in many studies on land surface temperature [3], [4], soil, land use land cover [5], groundwater resources and air quality [6] etc.

Land Surface Temperature (LST) is the radiative skin temperature of the land derived from solar radiation [7]. LST is of prime importance in studying the urban heat islands.LST derived from remote sensing data have been used in many studies [8], [9], [10].

Urban climate studies have long been concerned about the magnitude of the difference observed in ambient air temperature [11], solar radiation, precipitation and wind speed etc. [12] between cities and their surrounding rural regions, which collectively describe the Urban Heat Island (UHI) effect. As urban areas develop, changes occur in their landscapes. Buildings, road, and other built-up area replace bare land, vegetation and forest area. These changes in the composition of the landscape are derived in various studies by computing different indices using remote sensing data. Relationship between these indices such as normalized difference vegetation index (NDVI) [13], [14], normalized difference water index (NDWI) [15], normalized difference built up index (NDBI) [16], [17], normalized difference bareness index (NDBaI) [18] and LST has been used in many studies.

This research aims to establish the relationship between LST and different indices for Jaipur urban area. The land surface temperature of thestudy area for the period of 2000-2016 was quantified using geospatial techniques and its inter-relationship with different indices has been evaluated using statistical tools. In this study, Landsat TM, ETM + and Landsat 8 data were used to derive land surface temperature for 2000, 2011 and 2016. Thereafter, LST values were correlated with different indices such as NDVI, NDWI, and NDBaI to establish decade comparative analysis and their inter-relation.

## 2. STUDY REGION

Jaipur, the capital of the North Indian State of Rajasthan, is surrounded on three sides by the rugged Aravali hills as shown In FIGURE 1. The municipal boundary of the city extends from $26^{0}46'$ N latitude to $27^{0}01'$N latitude and $75^{0}39'$E longitude to $75^{0}57'$E longitude. It falls under the semi-arid region and experiences a continental climate owing to its proximity to the desert and inland location. The mean temperature of the city is $36^{0}$C; varying from $18^{0}$C in winter

(January) to $45^0$C in summer (June).The minimum and maximum temperatures recorded vary from 5 to 48 degree Celsius.

The humidity in urban areas in comparison with rural areas can be explained by different moisture sources and by different energy balances in their respective environments. Studies reveal that urban humidity is higher than humidity in rural areas [19]. This is due to the fact that the moisture capacity of the air in the urban area is higher than the rural area because of the higher urban temperature.

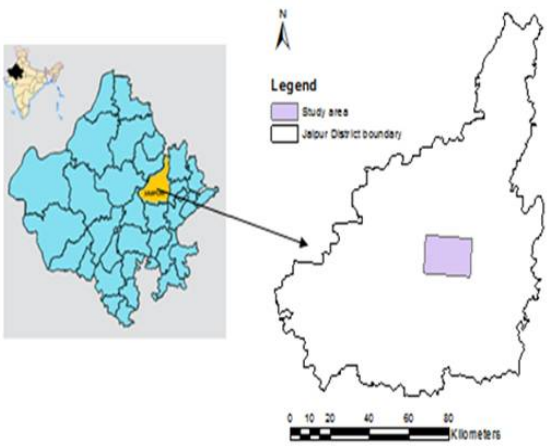



**Fig., 1: Location map of the study area**

## A. *Data used*

Landsat data are used to derive LST and other indices. In this study, Landsat data are downloaded for the years 2000, 2011 and 2016 as shown in TABLE 1. Landsat data are downloaded from USGS earth explorer [20]. ArcGIS software has been used to generate LST in Jaipur urban area for different years. Microsoft Excel software has been used to transform GIS information into an equation and graphical forms.

**Table 1: Data used for the study area**

| Year | Satellite | Sensor | Acquisition date | UTM zone/path/row | Bands | Resolution (m) |
|---|---|---|---|---|---|---|
| 2000 | Landsat 5 | TM | 14/04/2000 | UTM-43N/147/41/42 | 6 | 120*(30) |
| 2011 | Landsat 7 | ETM+ | 12/03/2011 | UTM-43N/147/41/42 | 6 | 120*(30) |
| 2016 | Landsat 8 | OLI/TIRS | 09/03/2016 | UTM-43N/147/41/42 | 10,11 | 100*(30) |

Source: (https://earthexplorer.usgs.gov/)

## 3. METHODOLOGY

To derive the change in temperature against vegetation, barren area and water bodies; images are used from Landsat data for 2000, 2011 and 2016. Spilt window algorithm [4] an approximation of land surface emissivity derived from the NDVI-based method was adopted to determine LST using following equations:

### A. *Conversion of digital number into spectral radiance*

For Landsat TM and ETM thermal band, $L_\lambda$, top of atmospheric radiance in Watts/$m^2$*srad*μm, could be calculated using equation 1.

$$L\lambda = (LMAX - LMIN) / (QCALMAX - QCALMIN) * (QCAL - QCALMIN) + LMIN \tag{1}$$

With the parameters $Q_{CALMAX}$ and $Q_{CALMIN}$ representing the highest and the lowest DN values of the range of rescaled radiance. $L_{MAX}$ and $L_{MIN}$ (watts/m2*srad*μm) each represents the top-of-atmospheric radiances, associated with $Q_{CALMAX}$ and $Q_{CALMIN}$.

For Landsat OLI thermal band, $L_\lambda$, could be calculated using equation 2.

$$L_\lambda = Mi \times Qcal + Ai \tag{2}$$

Where:

$L_\lambda$ = Top of Atmosphere (TOA) radiance in (Watts/$m^2$*srad*μm)), $M_i$= band-specific multiplicative rescaling factor, $A_i$=band-specific additive rescaling factor, $Q_{cal}$ = Quantized and calibrated standard product pixel values (DN), all are taken using Meta data.

### B. *Conversion of radiance values to at-sensor brightness temperature*

$$T = K2 / \ln (K1 / L\lambda + 1) \tag{3}$$

Where: $T$ = at-satellite brightness temperature in degrees Kelvin, $K_1$, and $K_2$ is the prelaunch calibration constants from landsat 7 handbook [21] which are shown in TABLE 2. Degree Celsius = $T$-273

**Table 2: Calibration constants for thermal band**

| | Landsat 5 | Landsat7 | Landsat8 | |
|---|---|---|---|---|
| | TM | ETM+ | Band 10 | Band 11 |
| K1 | 607.76 | 666.09 | 774.85 | 480.89 |
| K2 | 1260.56 | 1282.71 | 1321.08 | 1201.14 |

**(Source: Landsat 7 handbook)**

### C. *Land surface temperature estimation*

First NDVI values are determined using equation 4.

$$NDVI = (NIR - RED) / (NIR + RED) \tag{4}$$

Where, NIR= spectral reflectance of the near-infrared band, RED = spectral reflectance of red band. Then Land surface emissivity (e) values are estimated as follows: for those pixels with NDVI < 0.2, the emissivity was assumed as to be 0.98; whereas for those pixels with NDVI > 0.5, the emissivity was assumed as to be 0.99; for those pixels with 0.2 ≤ NDVI ≤ 0.5, the emissivity was given by equation 5.

$$e = 0.004pv + 0.986 \quad (5)$$

Where

$$pv = (NDVI - NDVImin / NDVImax - NDVImin)2$$

pv= per portion of vegetation

Now LST could be calculated using equation 6.

$$LST = BT/1 + w * (BT/p) * \ln(e) \quad (6)$$

Where, BT=at satellite temperature (T), w=wavelength of emitted radiance (11.5µm), P=h*c/s, s=Boltzmann constant ($1.38*10^{-34}$J/k), c=velocity of light ($2.998*10^{8}$m/sec), P=14380.

As the variation in maximum and minimum values of LST is high for different datasets of different years, LST was normalized [3] using the formula below:-

$$NLST = (LST - LSTmin) / (LSTmax - LSTmin) \quad (7)$$

Where, NLST is normalized LST value for a particular pixel on a particular year; LST is the LST value for that pixel for the same year; $LST_{min}$ and $LST_{max}$ are the minima and maxima of LST values, within the study area, for that year.

*The calculation of NDVI, NDWI, and NDBaI*

These indices were used to characterize the land use/cover types in the study region and to study the relationship between land use/cover types and UHI quantitatively [22]. NDVI distribution in the city symbolizes the pattern of greenness along the peripheral area [16]. Normalized Difference Bareness Index (NDBaI) represents the bare soil and differentiates between scrubs (barren land) and vegetated area [22]. NDBaI is calculated from:

$$NDBaI = (SWIR - TIR)/(SWIR + TIR) \quad (8)$$

Where, the SWIR=spectral reflectance of the shortwave infrared band, the TIR=spectral reflectance of thermal infrared.

Normalized Difference Water Index (NDWI) used to identify a change in moisture intensity of the city surface and compared to peripheral area [15].

$$NDWI = (Green - NIR)/ (Green + NIR) \quad (9)$$

Where, NIR = spectral reflectance of near-infrared band, Green = spectral reflectance of green band

## 4. RESULTS AND DISCUSSIONS

### A. *Land surface temperature*

Landsat data were used to determine the temperature of the Jaipur urban area in this study. Past three years data (2000, 2011& 2016) have been used to obtain variation between LST and land cover type as shown in FIGURE 2.

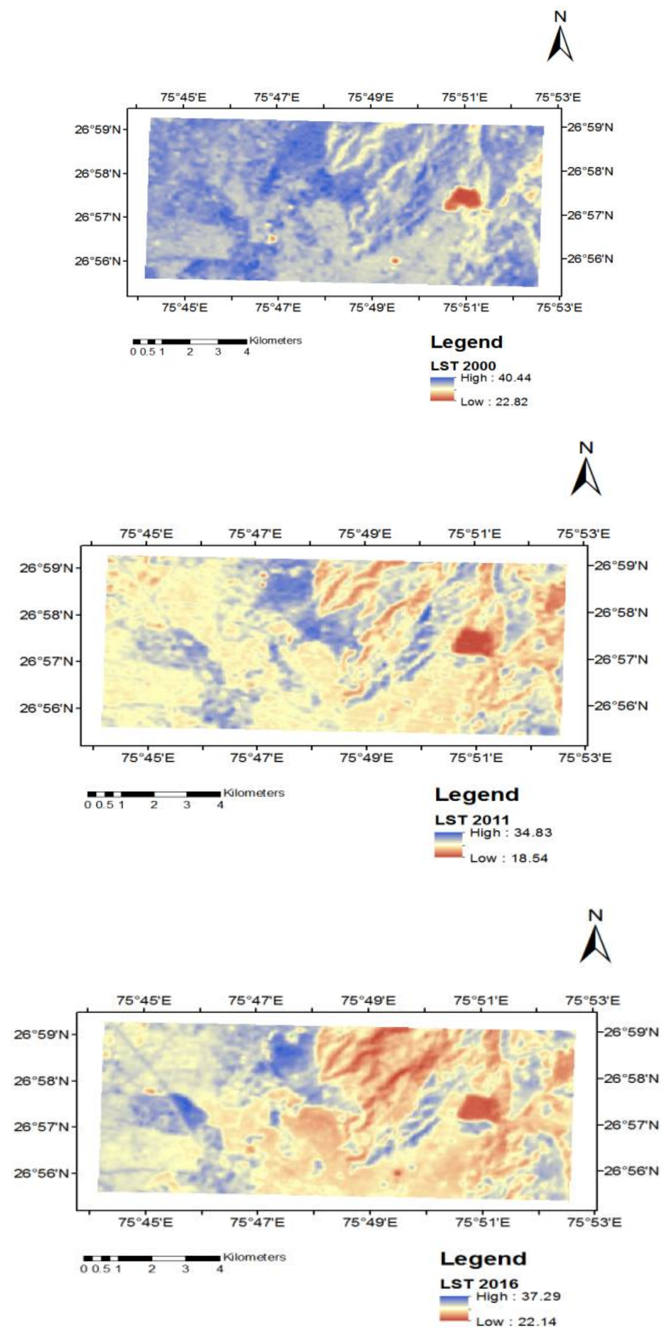



**Fig. 2: LST of the study area for different years as derived from Landsat data**

**B.** NLST and different indices with different years (2000, 2011 and 2016)

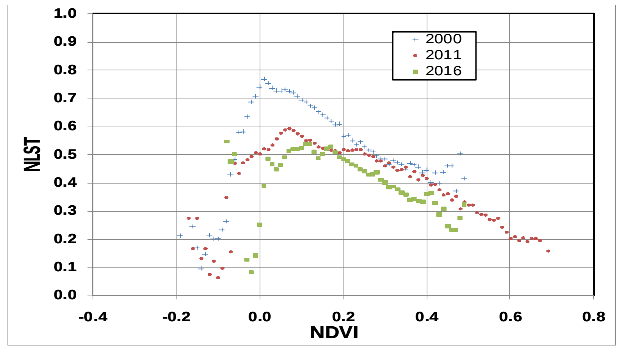
Many studies show the relation between NDVI and LST [14], [16]. In this study, three indices have been used to study the land use land cover type in Jaipur urban area. Figure 3 depicts the relationship between mean value of different indices and NLST for Jaipur urban area for different years. As can be seen from the figure, all indices almost follow the same type of trend in different years indicating not much variations from year to year. NDVI ranges are -0.18 to 0.48 in 2000,-0.17 to 0.68 in 2011 and -0.07 to 0.49 in 2016(FIGURE 3. (a), TABLE 4). This graph also shows that, at negative value NLST is less but as it comes towards 0 it starts increasing sharply and after that it again decreases. The lowest value of NDVI (< -0.1) shows water and highest value of NDVI (>0.2) shows dense vegetation (TABLE 4).Thus, high NDVI value represents low temperature whereas low NDVI value represents high temperature which can be clearly seen in FIGURE 3(a). It also predicts that water bodies on the negative side, show low temperature. As discussed, it also proves that compared to 2011, NDVI has been reduced in 2016. But as compared to 2000 NDVI value has increased in 2011. FIGURE 3(b) shows NDWI distribution against NLST in Jaipur urban area for 2000, 2011 and 2016.NDWI distribution range are -0.48 to 0.21 in 2000,-0.63 to 0.21 in 2011 and -0.43 to 0.09 in 2016.According to TABLE 4, NDWI >0.1 is categorized as water area and this clearly implies that water area is reduced in 2016 (maximum value 0.09), compared to 2000 or 2011.

Sun et al., 2012 elaborated the correlations between bareness and NLST with scatter plot. NDBaI ranges -0.07 to -0.65 in 2016, -0.85 to 0.23 in 2011 and -0.70 to 0.14 in 2000 FIGURE 3(c).When NDBaI>0, land is classified as bare land and when NDBaI<0 then as semi bare land (TABLE 4). Bare land and semi bare land both have increased in 2011 compared to 2000 but in 2016 bare land or semi-bare land has decreased in comparison to 2011and 2000.

To further investigate these relationships the graphs plotted below indices v/s NLST indicate regression coefficient of each graph, which helps to evaluate the inter-relationship. Fig 4 depicts the linear relationship between temperature and different indices in different years. All indices ranges vary between -1 to 1 and LST ranges from 0 to1. All graphs show a linear relationship between NLST against indices (TABLE 5, FIGURE 4). In this work, a strong negative correlation between NDVI and NLST can be clearly seen. It can be seen that as a result of increase in dense vegetation (NDVI>0.2) NLST decently go down. Same can be said for NDWI< -0.1 which shows dry land and increase in surface temperature. In fig 3 NDBI at open land surface decreases as compared to the built-up area or sparsely built-up area. In semi bare area (NDBaI<0), LST value linearly increases.

**Table 3: Indices value ranges for different land use/cover types**

| Index | Range | Land use/Land cover Type |
|---|---|---|
| NDVI | > 0.2 | Dense vegetation |
| | 0 to 0.2 | Sparsely vegetation |
| | -0.1 to 0 | Barren |
| | <-0.1 | Water |
| NDWI | <-0.1 | Dry |
| | -0.1 to 0.1 | Moist |
| | >0.1 | Water |
| NDBaI | >0 | Bare land |
| | <0 | Semi bare land |

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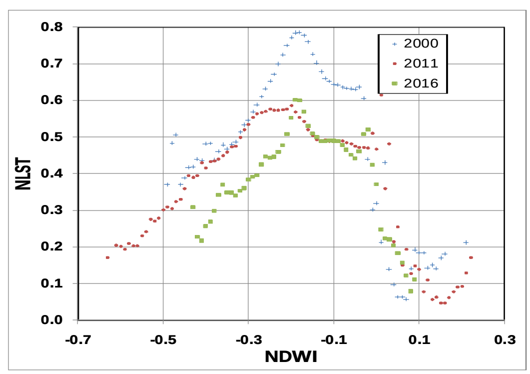


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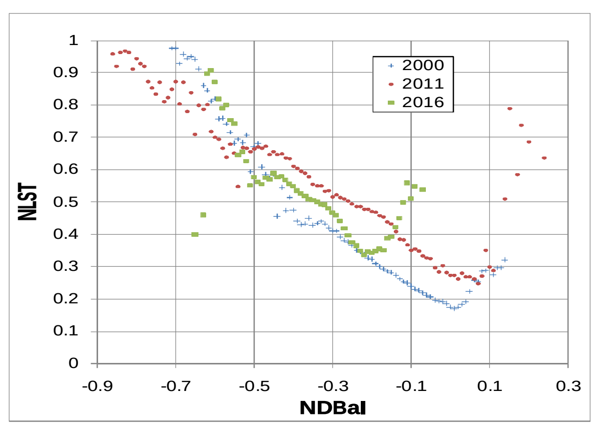
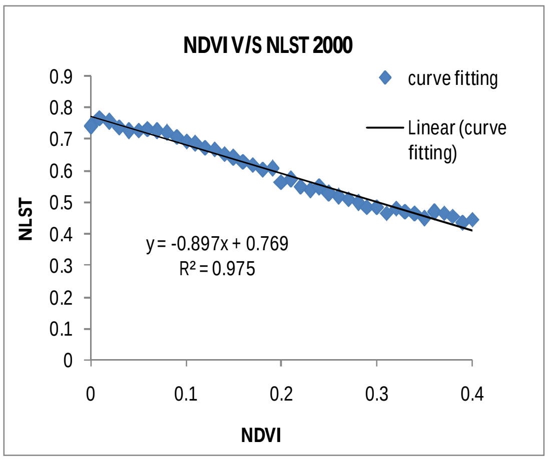


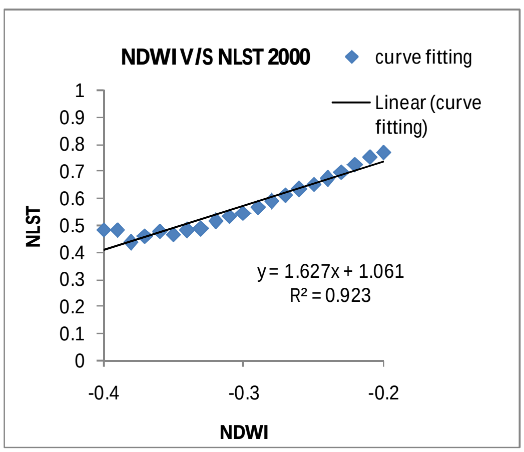

**(c)**

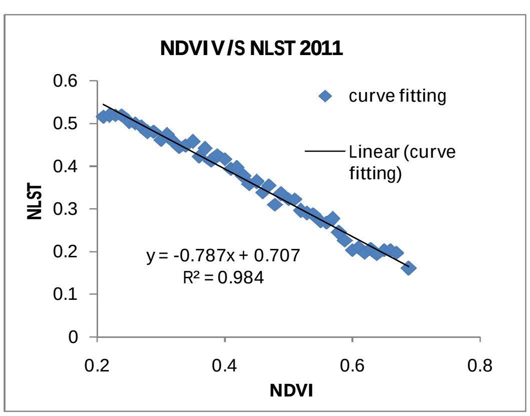
**FIG. 3: Scatterplots a.) NLST Vs NDVI (b.)NLST versus NDWI(c.)NLST versus NDBaI**

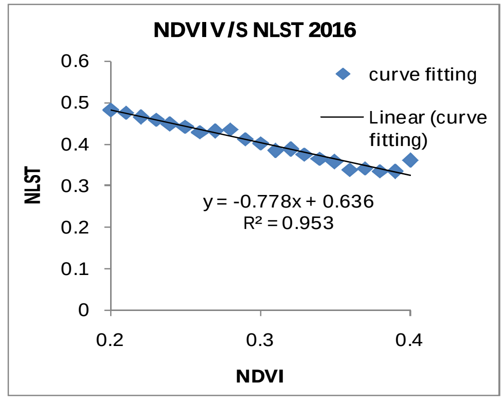
**Table 4: Regression coefficient for different indices**

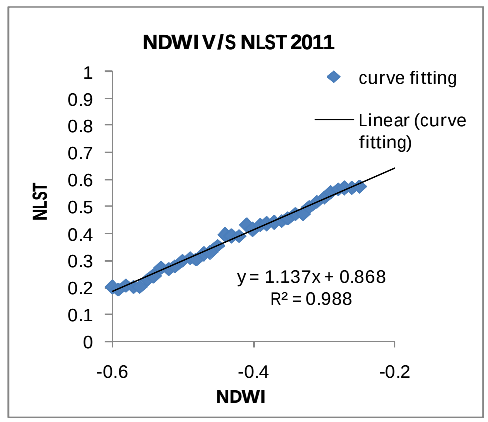
| | NDVI-NLST (NDVI>0) | NDBAI-NLST (NDBAI<0) | NDWI-NLST (NDWI<-0.2) |
|---|---|---|---|
| $R^2$(2000) | 0.975 | 0.947 | 0.925 |
| $R^2$(2011) | 0.984 | 0.987 | 0.988 |
| $R^2$(2016) | 0.953 | 0.912 | 0.927 |

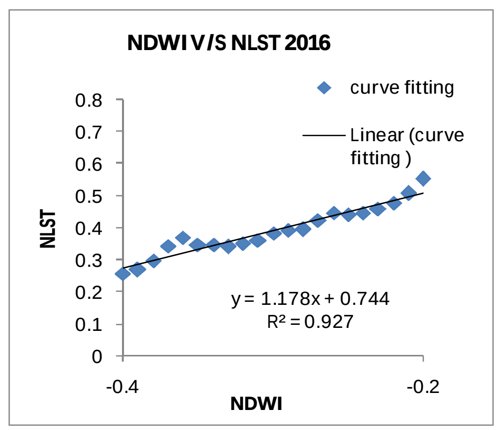


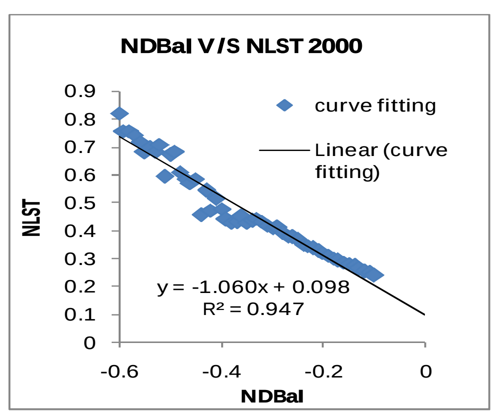



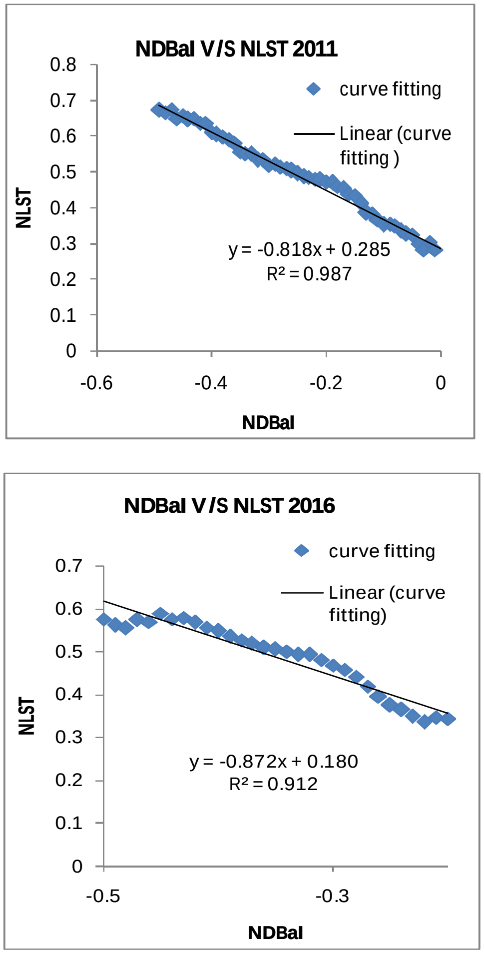
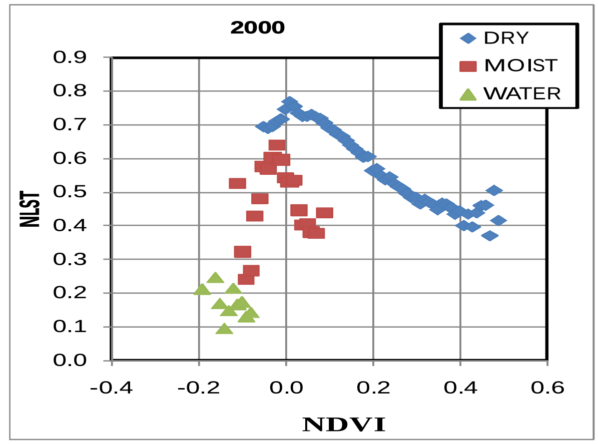



**Fig. 4: Scatter plots of different indices and LST for three years of Jaipur City**

### *C. The relationship between NDVI, NDWI, and NLST*

This study has discussed mean NDVI correlation with normalized temperature index which ranges from 0 to 1 and with other indices as NDWI. It has also been described that how their different values are related to NDVI. As FIGURE 5 (c) graph (year-2016) shows no water pixel, which represents changes occurred in the water area. Water pixel has low NDVI and low NLST. Dry or Moist pixel follow the negative trend with NLST as vegetation area increases. In 2000 and 2016 dry pixels show high land surface temperature compared to moist pixels. Thus, changing in NDWI significantly affect the relationship between NDVI-NLST.

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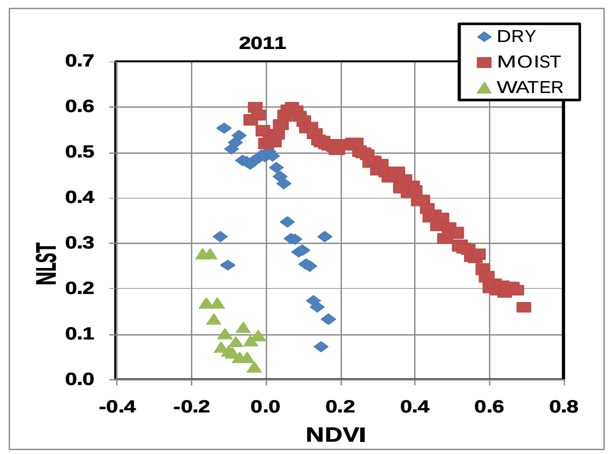


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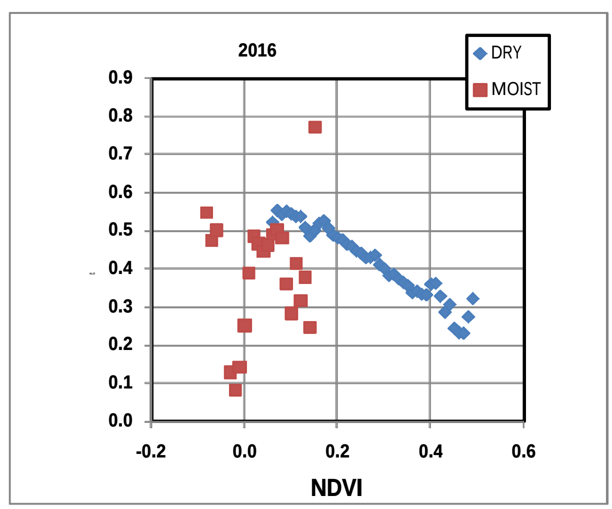


**(c)**

**Fig. 5: Compare NDVI, NDWI against NLST (a) 2000 (b) 2011 (c) 2016**

## 5. CONCLUSIONS

In this paper, subjective and quantitative investigations have been used to examine the connection amongst LUCC and UHI. The aim of this paper was to present the change in land cover against LST in 2000,2011 and 2016 using NDVI,NDWI, and NDBaI.

Utilizing NDWI for water, and NDBaI for infertile or bare land, it was discovered that the connection between NDBaI and LSTwas stronglynegative, and the connection between NDWI and LST also was negative as vegetation area increased. The numerous relapse condition was made with LST and NDVI, NDBaI, NDWI,which can be utilized to monitor the urban warm condition in view of LULC.

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