IMAPCT OF LAND USE AND LAND COVER ON LAND SURFACE TEMPERATURE ON AHMEDABAD REGION

A DISSERTATION

Submitted in partial fulfillment of the

requirements for the award of the degree of

INTEGRATED MASTER OF TECHNOLOGY

In

GEOLOGICAL TECHNOLOGY

By

NILESH TANWAR

Department of Earth Sciences

Indian Institute of Technology Roorkee

Roorkee - 247667 (India)

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Certificate

I hereby certify that the work which is being presented in the dissertation entitled "**Impact of Land Use and Land Cover on Land Surface Temperature on Ahmedabad Region**" in the partial fulfillment of the requirement for the award of the degree of Integrated Master of Technology in Geological Technology, submitted in the Department of Earth Sciences, Indian Institute of Technology Roorkee, under the supervision of **Prof. Ajanta Goswami**.

The matter presented in this dissertation has not been submitted by me for the award of any other degree of this or any other institute.

Date: **NILESH TANWAR**

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Prof. Ajanta Goswami

Department of Earth Sciences

Indian Institute of Technology Roorkee

Candidate's Declaration

I, **Nilesh Tanwar** hereby solemnly declare that the dissertation entitled "**Impact of Land Use and Land Cover on Land Surface Temperature on Ahmedabad Region**" being submitted by me towards partial fulfillment of the requirement for the award of the degree of Integrated Master of Technology in Geological Technology is a record of my own work and that I have not copied the work of any other person(s) including published literature and material from any website.

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Any accomplishment requires the effort, guidance and support of many people. This is all the more relevant in the case of students, who lack experience, insight and the knack of going about doing things. This thesis report is no different from what is mentioned above.

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Abstract

Increase in human settlement for private and residential purpose have a huge impact on land usage. Modification of vegetation and green lands into commercial areas is leading to environmental chaos and rising land surface temperature (LST). Fast built up growth can be seen in Ahmedabad region in past decades. Major amount of population of Gujarat is in Ahmedabad. It is one of the highly populated and rapidly growing city in north India. It is business capital of Gujarat. The aim of this study is to examine the effect of land use/land cover (LULC) on LST in past 18 years. This work is done by the methods of remote sensing. Total three images are use used from Landsat satellites, two from Landsat 5 and 1 from Landsat 8 for the year 2000, 2008 and 2018 respectively. Image analysis and all the processing is done in ArcGIS software. Supervised classification technique was used to calculate land classes. Five land classes: Water, Forest, Vegetation, Barren land and Urban area were defined on the basis of supervised classification technique. Land Surface Temperature maps for the year 2000, 2008 and 2018 is retrieved by mono-window algorithm. Landsat data also helped to prepare NDVI for same time period. Mean surface temperature for different land class is computed by selecting 30 random points on study area. The highest temperature can be seen in barren land and urban area i.e. 46^0C and 43^0C respectively. Low temperature can be observed in vegetation and water area in the year 2018. In this project, a strong relation between vegetation, urban and surface temperature can be seen in Ahmedabad region.

Chapter 1

INTRODUCTION

The Urban expansion in the twenty first century is high because of rapid increase in population. Human settlement causes alteration and modification in the material and structures of the land surfaces. Major cities and towns in India can be witnessed of impetuous municipal growth. Urbanization refers to the changing of natural land mass to modern land use and land cover (LULC). Buildings, roads, and other impervious land surfaces are the major part of land cover in urbanization. People from other cities prefer to shift in big cities because of better lifestyle and growth opportunities, resulting in expansion and environmental chaos. Land use in developing countries like India is expanding tremendously. From 17.35% in 1951 to 31.2% in 2011(Census, 2011), population of urban area has increased in India.

Nowadays, Remote Sensing and GIS are considered to be one the most favorable tool in measuring and analyzing the changes in Land Use and Land Cover. Remote sensing results are of great use in better planning of the city in urban and rural areas. Environmentalist and climate scientists use remote sensing tools to examine environmental and ecological changes at local, regional and global scale.

Due to high infrastructural development and settlement expansion, hectares of vegetation cover is lost annually in the major cities of India like Ahmedabad. Population of Ahmedabad in 2011 was 5.5 million which has now increased to 8.16 million in 2017(according to Census, 2011). Most of the land is covered with cement and concrete. This nonporous land results in rapid runoff and reduced evapotranspiration (Carlson, 1986), which affects the land surface temperature. At present, the most critical problem faced in urban area is increased land surface temperature (LST), caused by depleting vegetation and increase paved regions. Land Surface Temperature is the average temperature of upper radiative skin of land.

LST and emissivity data have many purposes, but they are mainly used to observe LST patterns and how they are correlated with heat fluxes and surface temperature. LST can be used to calculate surface energy and to control many biological and physical processes on land. LST retrieved from the thermal bands of Landsat 5 and Landsat 8 are used for the present study. LULC maps were generated for the year 2000, 2008 and 2018 from remote sensing data in ArcGIS software. NDVI is prepared from the near infrared bands and visible bands i.e. band 3, band 4 in Landsat 5 imagery data and band 4, band 5 in Landsat 8 data.

The aim of this study is to examine changes in Land surface temperature and vegetation cover in past eighteen years and its relation with land cover. Study area chosen is Ahmedabad, which is the biggest city of Gujarat and also one of the most prominent city in Western India. Due to its fast growth in population and pollution, many environmental changes can be seen through the help of remote sensing and gis technique. Therefore, Ahmedabad city of Gujarat, a fast changing land area, was chosen to employ the techniques of remote sensing to examine the following:

1. To analyze the change in Land Use/Land Cover and Land Surface Temperature in Ahmedabad city.

2. To examine the relationship between change in LULC and LST.

Chapter 2

LITERATURE REVIEW

Near about 50% of the world's population is residing in urban zone, It is expected to by increased to 60% in coming 10 years (Yuan and Bauer 2007). Increased trend in global urban expansion attracted many researchers to examine the potential effects of anthropogenic activities on urban thermal environment such as LST and NDVI (Dousset and Gourmelon 2003; Yuan and Bauer 2007).

Major change in land use land cover (LULC) over the past 20 years is because of continuous urban growth. (Turkoglu, 2010, Weng, 2007). Significant escalation in paved and cemented area has resulted in considerable amount of decrement in green areas, lakes, rivers and wastelands (Mosammam et al., 2017).

Urban Heat island is a new problem faced by urban areas where surface and air temperature is higher than in periphery due to urban changes resulting into bespoke thermal climate. (Voogt and Oke,2003, Oke, 1982).

LST and emissivity data is available from many satellites, and many LST related research work has been done for different regions (Aniello et al.,1995, Dousset and Gourmelon, 2003, Gallo et al., 1996, Streutker, 2003, Khandelwal et al., 2017). It is found that results by remote sensing techniques are more reliable and accurate than the one produced by ground stations. (Cheval et al. 2009). Land surface temperature is affected by modification in land surface, so it can be used to get information on various LULC types (Sinha et al., 2015). With the help of Land surface temperature, atmospheric temperature can be predicted based on the relation between mean air and surface temperature (Kawashima et al. 2000).

Due to decrease in vegetation coverage urban heat islands are getting triggered. (Feng et al., 2012). High consumption of energy, increase asphalt and concrete cover, vehicle pollution, heating fuels are the main source for man-made heat (Sailor and Lu, 2004).

Many study and research work (Zhang et al.,2013) has been carried on the major cities of the world in recent decades, but number of such type of work is very less for mid-level cities of developing nations like India. In many scenarios, balance of surface energy has been examined over vegetated and green land, although same be carried for the urban area (Zhang 1998, Chrysoulakis, 2003). In India only some study was conducted by researchers for some of the metro cities like Delhi (Mallick et al., 2008), Mumbai (Grover and singh, 2015). But not much work is done on meso level cities and small towns where urban expansion is growing rapidly with time.

Chapter 3

STUDY AREA- AHMEDABAD CITY

Total area of Ahmedabad, Gujarat will be carried out as study area covering 464/205 km². It is situated between 23° 09' 54.68"N 72° 33' 40.02"E and 22° 54' 19.90"N and 72° 39' 51.62"E with the average elevation of 53 meters.

Ahmedabad is one of the largest city of Gujarat. It was former capital of the state. It is located on the bank of Sabarmati river. It is the 7th largest metropolitan area of our country. 11% of the Gujarat's population is accommodated in Ahmedabad. Major reason for air pollution in Ahmedabad is because of the high vehicle population. Ahmedabad accounts of 1.49 million of vehicles in 2004, which has increased to 3.15 million by now. According to the master plan of the city, human settlement area has been increased from 35% to 44% from the year 1997 to 2016.

Sabarmati River divides Ahmedabad into two areas. Eastern bank area comprised of old city, bazaars and temples. Whereas western bank is much well planned. It is mainly covered by Malls, Schools, modern buildings. Two lakes are located in the city- Kankaria lake and Vastapura lake.

The variation in temperature is very high, highest and lowest temperature calculated are 47 °C and 5 °C, respectively. Climate is considered to be tropical savanna climate.

Ahmedabad has hot arid climate. During summers, weather is very hot ranging upto 43 °C maximum during the months from March to June. From months November to February climate is very dry. Monsoon hits from mid-June to mid-September resulting with an average rainfall of 932 mm. winter falls in the month of November and February with 30 °C and 15 °C maximum and minimum temperature, respectively.

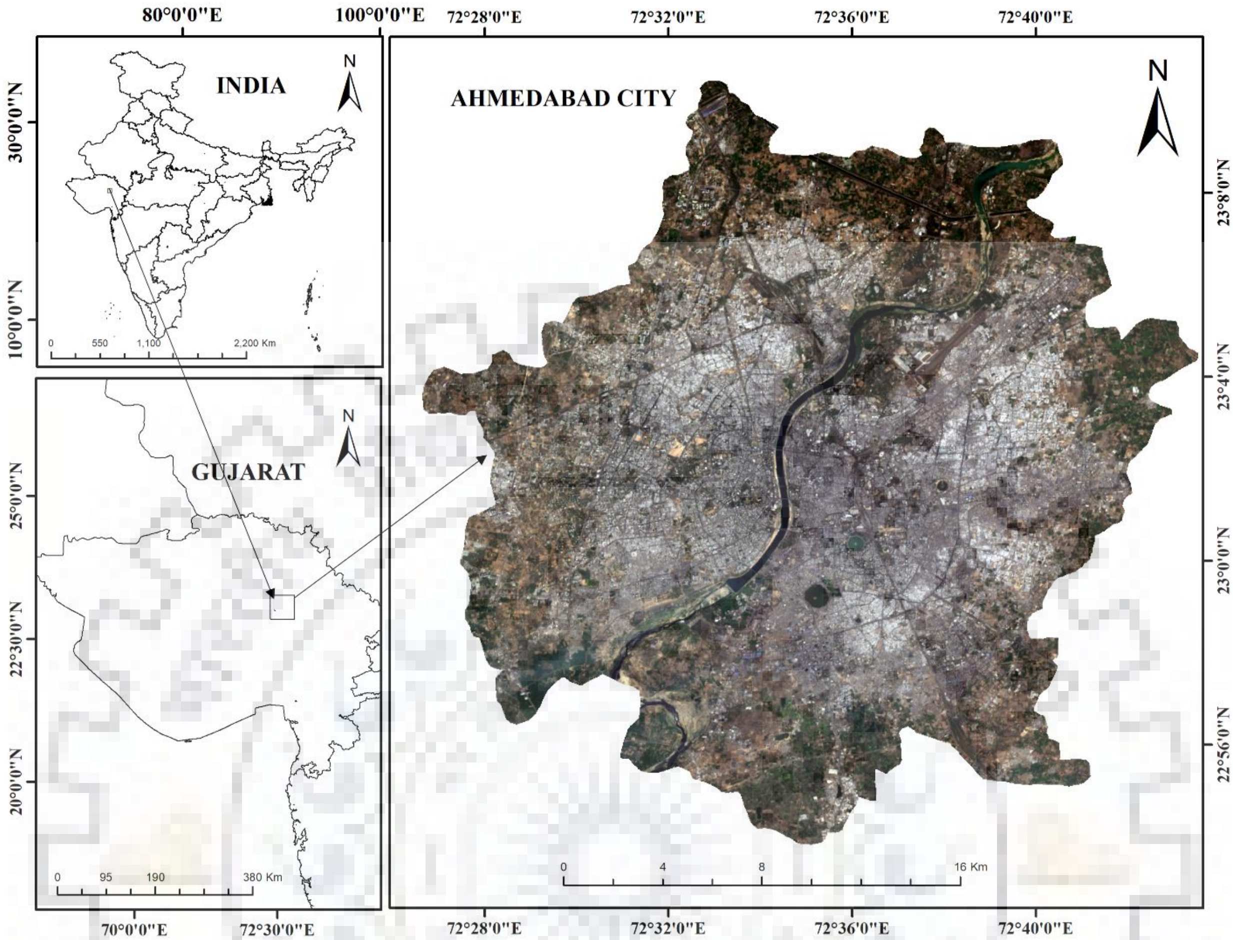

Fig. 1. Ahmedabad Study Area (True colour composite from Landsat 8)

Chapter 5

DATA

Landsat data is a reliable and longest running enterprise for getting satellite images of earth. From the first launched on July 23, 1972 to February 11, 2013 it had four more successful missions. It provides good quality multispectral data around 40 years over the globe. It became a unique source for research in land use/ land cover changes globally. This data can be collected and viewed from U.S. geological survey.

Landsat 5 and Landsat 8 data were used in this work. Data was obtained from http://earthexplorer.usgs.gov/ website for free.

Landsat 5

Landsat 5 carries two type of sensors: Multispectral Scanner (MSS) and Thematic Mapper(TM) sensors. MSS have four spectral bands which are identical to Landsat 1 and Landsat 2. In MSS Band 4 is visible green with wavelength ranging from 0.5 to 0.6 µm, Band 5 is visible red with wavelength ranging from 0.6 to 0.7 µm, Band 6 is Near-Infrared with wavelength ranging from 0.7 to 0.8 µm, Band 7 is Near-Infrared with wavelength ranging from 0.8 to 1.1 µm. Six detectors are available in MSS which provides six scanned lines for each spectral band. Pixel size i.e., interval of ground sample is 57 x 79 m.

Other type of sensor present is Thematic Mapper(TM). TM have seven spectral band among which, one is thermal band. Pixel size for thermal is 120 m and 30 m for reflective. Band 1 is visible with wavelength ranging from 0.45 to 0.52 µm, Band 2 is visible with wavelength ranging from 0.52 to 0.60 µm, Band 3 is visible with wavelength ranging from 0.63 to 0.69 µm, Band 4 is Near-Infrared with wavelength ranging from 0.76 to 0.90 µm, Band 5 is Near-Infrared with wavelength ranging from 1.55 to 1.75 µm. Band 6 is Thermal with wavelength ranging from 10.40 to 12.50 µm, Band 7 is Mid-Infrared with wavelength ranging from 2.08 to 2.35 µm.

Landsat 8

Landsat 8 have two types of sensors which gives total 11 spectral bands. Operational Land Imager (OLI) gives nine spectral bands. Band 1 is visible with wavelength ranging from 0.43 to 0.45 µm, Band 2 is visible with wavelength ranging from 0.450 to 0.51 µm, Band 3 is visible with wavelength ranging from 0.53 to 0.59 µm, Band 4 is red with wavelength ranging from 0.64 to 0.67 µm, Band 5 is near-infrared with wavelength ranging from 0.85 to 0.88 µm, Band 6 is SWIR 1 with wavelength ranging from 1.57 to 1.65 µm, Band 7 is SWIR 2 with wavelength ranging from 2.11 to 2.29 µm, Band 8 is panchromatic with wavelength ranging from 0.50 to 0.68 µm, Band 9 is cirrus with wavelength ranging from 1.36 to 1.38 µm. Products like TOA can be produced through the data provided in meta data file(MTL).

Another type of sensors in Landsat 8 are Thermal Infrared Sensors (TIRS). It gives us two spectral bands. Band 1 is TIRS 1 with wavelength ranging from 10.6 to 11.19 µm, Band 2 is TIRS 2 with wavelength ranging from 11.5 to 12.51 µm.

Chapter 6

Methodology

In this project several processing on remote sensing data were used to get the final results. Software used for processing was ArcGIS (version 10.2.0.3348).

1. Data Pre Processing

Pre-processing is an important step to get proper image data from raw data. It has an impact on the quality of final result. LANDSAT 5 data for 2000 and 2008, whereas LANDSAT 8 data for the year 2018 was obtained from USGS website. Clear weather conditions were observed in the month of April month. So images from this particular month was processed for the Ahmedabad region. Ahmedabad region is situated in between 2 Landsat scenes. So it took 2 images to cover the extent of study area. So we mosaicked two satellite images according to their band number.

2. Image Classification

On the basis of spectral characterization, image classification gives land use/land cover class to each pixel of the image.

It is one of the most useful method of image analysis but also very complicated, because of the factors which need to be taken in consideration. Primary step includes selection of required classification technique, choosing training samples.

Supervised and Unsupervised are two major classification systems.

Unsupervised classification is automated in which training data samples are not required. It tests all the pixels of the image and distribute them according to the class defined.

Supervised image classification was used to find the changes in land use. Approximately 30 training sample for each class has been collected from all the three images to detect land cover properly for each class. Five different land use classes like Urban cover, Vegetation, Forest, Water and Barren land were obtained by maximum likelihood method.

3. Land Surface Temperature (LST)

LST in Landsat 5 data and Landsat 8 data is calculated from different methods, algorithms and different bands.

TM sensor on LANDSAT 5 gives us image with 7 different bands.

Total 6 bands are ranging from 0.5µm to 2.5µm in electromagnetic spectrum which are visible and shortwave infrared. One band ranging from 10.4µm to 12.5µm is thermal infrared, i.e. emissive part of electromagnetic spectrum.

Steps taken to retrieve LST are taken from Landsat Data Users Handbook published by USGS (Landsat 7, 2011; Landsat 8, 2015).

3.1 For Landsat 5 data.

Firstly added the thermal band to ArcGIS, i.e. band number 6 for Landsat 5.

3.1.1 Spectral radiance

Value of pixels are converted to radiance using the metadata files of Landsat image.

$$L\lambda = \text{"gain"} \times QCAL + \text{"offset"}$$

Lλ= spectral radiance;

Gain= rescaled gain;

Offset=rescaled bias;

3.1.2. Emissivity

After conversion of digital numbers to spectral radiance from the above step. We implemented plank’s law with calibrating constants K1 and K2 with an assumption that emissivity is still the same.

$$T_B = \frac{K_2}{\ln(\frac{K_1}{L_\lambda} + 1)}$$

K1=607.76;

K2=1260.56;

T=degrees (Kelvin);

At end converted degree Kelvin into degree Celsius by the formula

C=K-273.15

3.2 For LANDSAT 8 data

Used thermal band (band 10) and metadata to retrieve land surface temperature for the year 2018.

3.2.1 Spectral Radiance

Converted band data to spectral radiance using the rescaling factors provided in MTL file.

$$L_\lambda = M_L Q_{cal} + A_L$$

L_λ=TOA spectral radiance;

M_L=Radiance Mult Band;

A_L=Radiance Add Band;

Q_{cal}=Quantized and calibrated standard product pixel value;

3.2.2 Atmosphere brightness temperature

In next step, converted spectral radiance to top of atmosphere brightness temperature with the help of constants provided.

$$T_B = \frac{K_2}{\ln(\frac{K_1}{L_\lambda} + 1)}$$

Kelvin(K) to Celsius(C) degrees.

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

T_B=Atmosphere brightness temperature;

L_λ=TOA spectral radiance;

K1=K1 constant band (thermal conversion constant);

K2=K2 constant band (thermal conversion constant);

3.2.3 NDVI

For LST study, we use NDVI parameters because it does not get affected by changed atmospheric condition. NDVI is standardized index. It is calculated by using band 4 and band 5 which are near infrared and red bands, respectively.

NDVI=(NIR-RED)/(NIR+RED)

Land surface emissivity is mean emissivity

This is the formula to calculate land surface emissivity (LSE). It is the mean emissivity calculated from NDVI value which is going to give us proportion of vegetation.

$$Pv = ((NDVI - NDVI_{min})/(NDVI_{max} - NDVI_{min}))^2$$

3.2.4 Emissivity

By using this result in the below formula we finally get the land surface emissivity.

e=0.004*Pv + 0.986

This emissivity will be required to calculate the land surface temperature from the given formula:

T=$T_B/[1 + (\lambda * c2) * \ln(e)]$

Where:

λ=wavelength of emitted radiance;

c2=14388 µm K;

h=Plank's constant;

s=Boltzmann constant;

c=velocity of light;

Value of λ for Landsat 8 satellite for Band 10 is 10.8 µm.

Chapter 7

RESULT and Discussion

LULC maps, LST distribution maps and the NDVI maps of the Ahmedabad region is prepared in ARCGIS.

1. Land Use /Land cover classification

LULC maps of the year 2000, 2008 and 2018 are prepared by maximum likelihood classification technique in ArcGIS with good accuracy. Significant amount of change can be seen in the urban area and vegetation cover due to high urban growth and coverage in past 18 years.

Table 1 shows that the urban area has increased by significantly from the year 2000 to 2008, while a little less from the year 2008 to 2018. A total of 119 Km^2 has increased from the year 2000 to 2018.

Vegetation area got significantly decreased from the year 2000 to 2008, while less in between 2008 and 2018. Because of increase in urban area and decrease in vegetation area covering barren land got increased in those years. While land coverage by water and forest got decreased from the year 2000 to 2018.

Major reason behind this change is growth in population and other socio-economic factors. High growth rate can be seen in the outskirts of city because of its business and economic growth. Many new factories and industries got setup in those past 18 years. Many alterations are done in old city. Many people from nearby areas got shifted because of good job opportunity, good education and better living conditions.

Table 1. Area covered by different LULC class in the year 2000, 2008 and 2018.

Class	Area (km2)		
	2000	**2008**	**2018**
Water	17	12	8
Urban	160	253	279
Vegetation	144	49	31
Barren land	164	205	205
Sand	19		
Forest	23	9	5

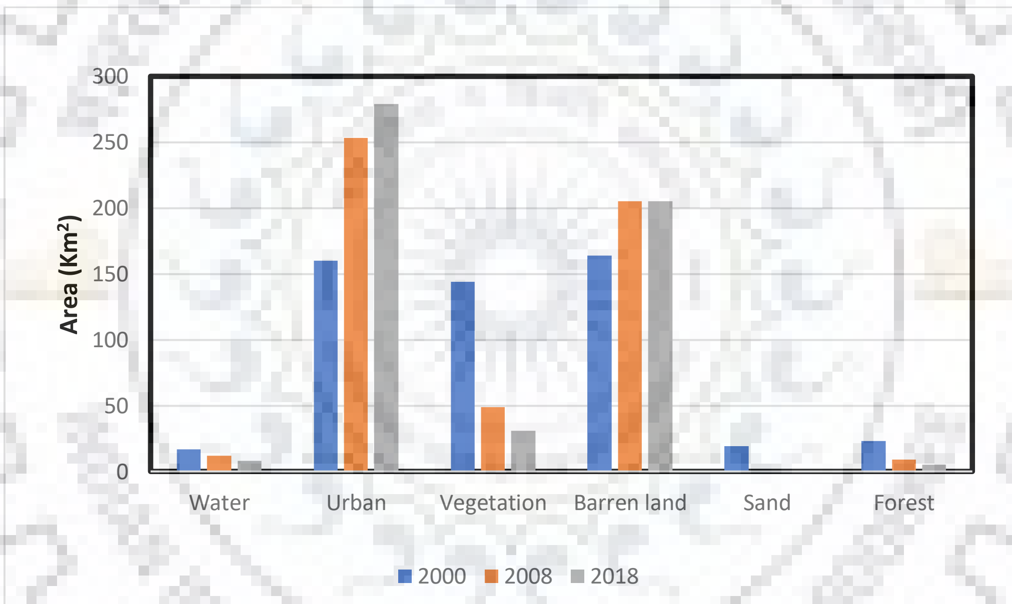

Fig. 2. Histogram showing variation in area with LULC classes in the year 2000, 2008 and 2018.

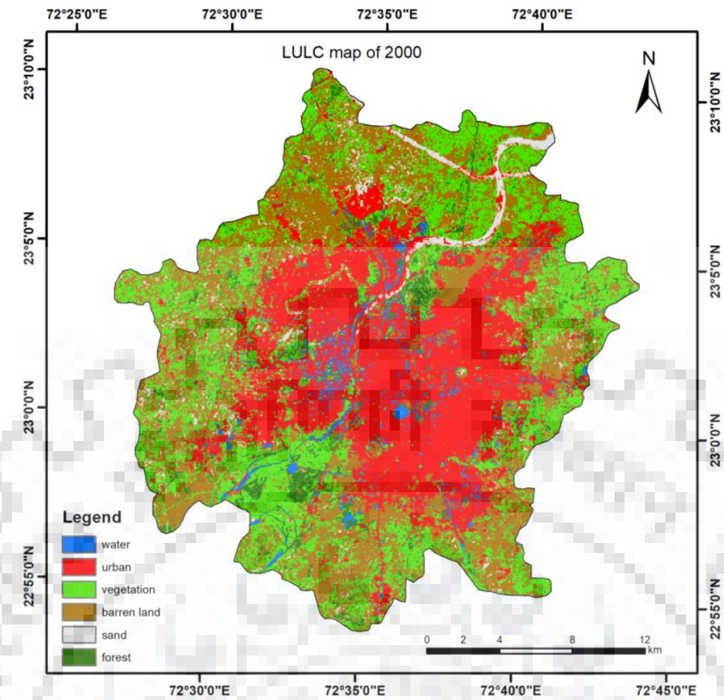

Fig. 3. LULC map of the year 2000.

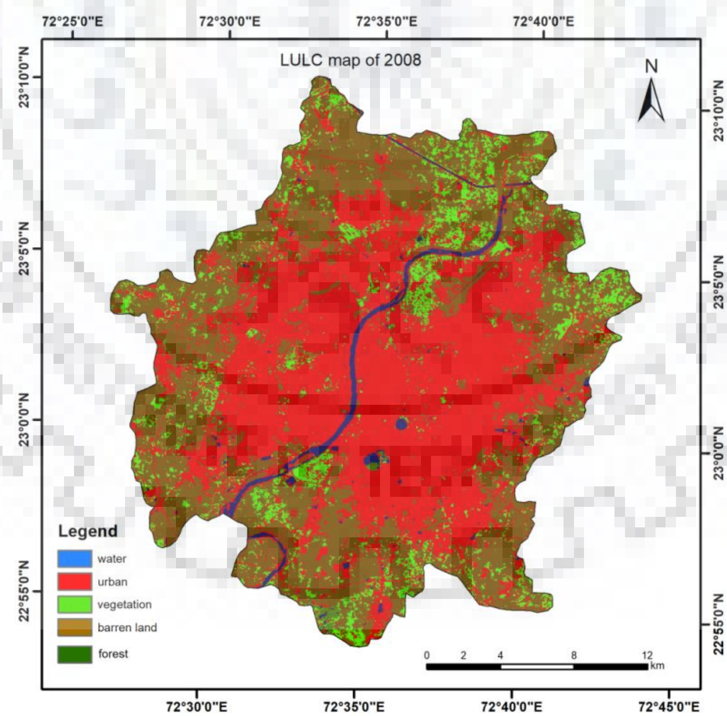

Fig. 4. LULC map of the year 2008

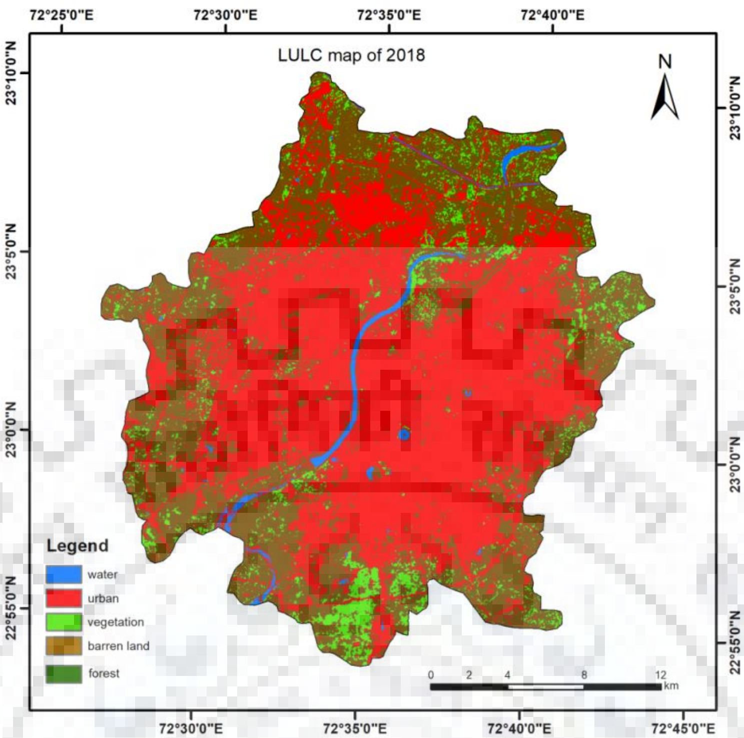

Fig. 5. LULC map of the year 2018.

2. Analysis of Land Surface Temperature

Land surface temperature maps of the year 2000, 2008 and 2018 are prepared for the study area. LST values showed ranges between 28-47 °C, 26-53 °C, and 30-51 °C respectively. Significant amount of difference can be observed in minimum and maximum temperature. All the three maps were produced for the month of April. From the year 2000 to 2018 minimum surface temperature has increased by 2.4 °C. Whereas maximum temperature by 4.33 °C. Mean temperature for all the three years grows in a linear behavior.

Table 2. Variation of LST in the year 2000, 2008 and 2018

Year	Min	Max	Mean	STD
2000	28.35	47.40	39.09	2.43
2008	26.67	53.82	40.51	2.52
2018	30.75	51.73	41.24	2.54

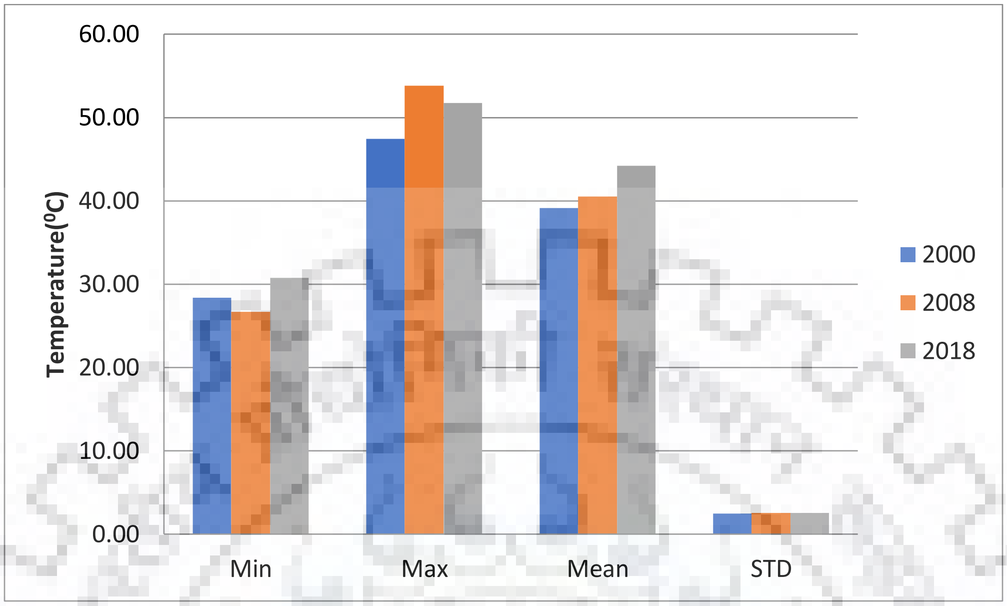

Fig. 6. Histogram showing variation in minimum, maximum, mean and standard deviation with temperature, for the year 2000, 2008 and 2018.

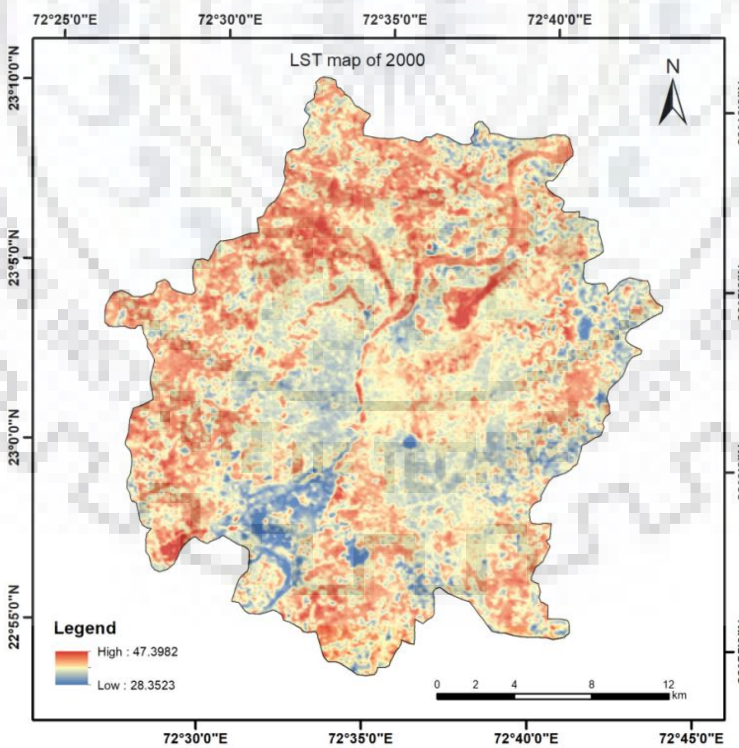

Fig. 7. LST map of the year 2000.

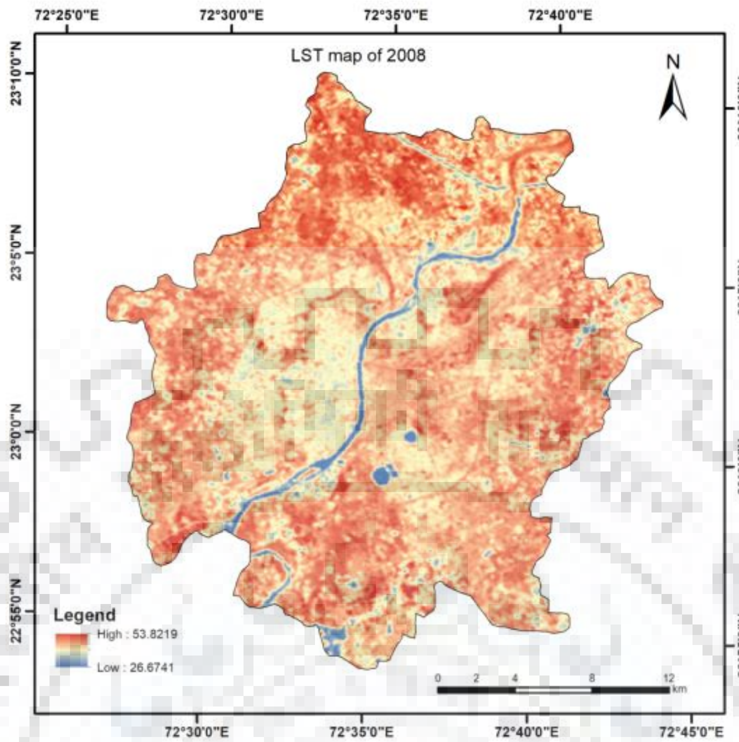

Fig. 8. LST map of the year 2008

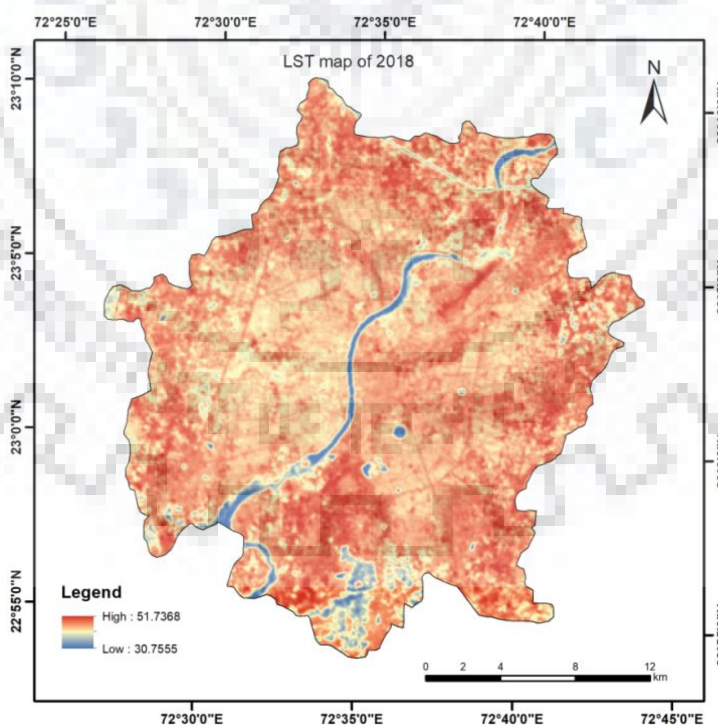

Fig. 9. LST map of the year 2018.

3. Normalized Difference Vegetation Index (NDVI)

Value of NDVI ranges from -1 to 1. Minimum and maximum value ranges from -0.328-0.644, -0.573-0.654 and -0.213 to 0.497 for the year 2000,2008 and 2018 respectively. Linear behaviour can be observed for the mean values of NDVI.

Table 3. Variation of NDVI, in the year 2000, 2008 and 2018.

Year	Min	Max	Mean	STD
2000	-0.328	0.644	0.094	0.102
2008	-0.573	0.654	0.105	0.112
2018	-0.213	0.497	0.112	0.078

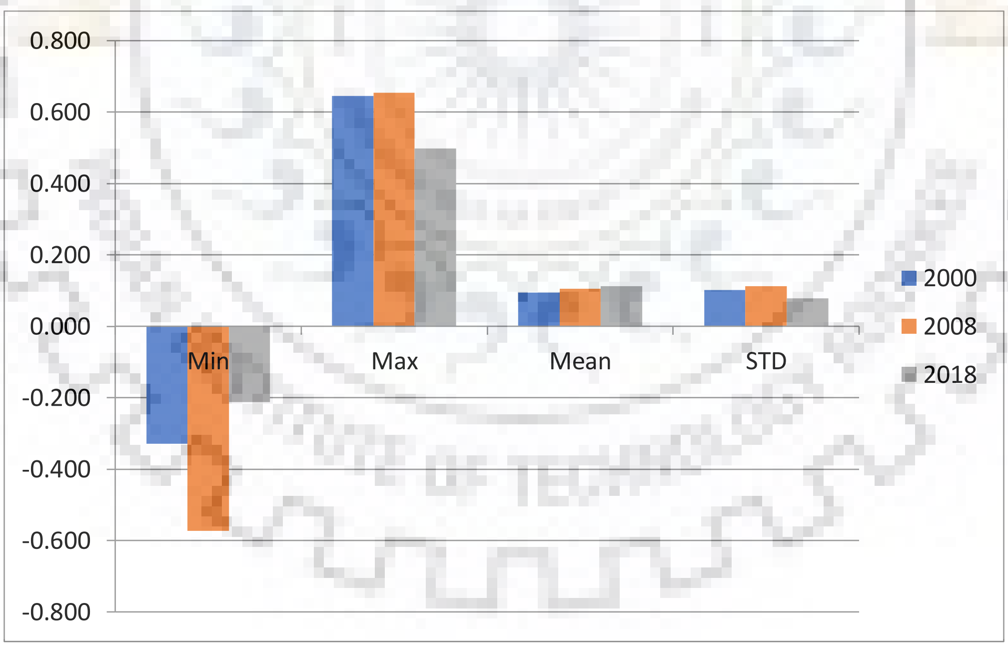

Fig. 10. Histogram showing variation in minimum, maximum, mean and standard deviation with NDVI value for the year 2000, 2008 and 2018.

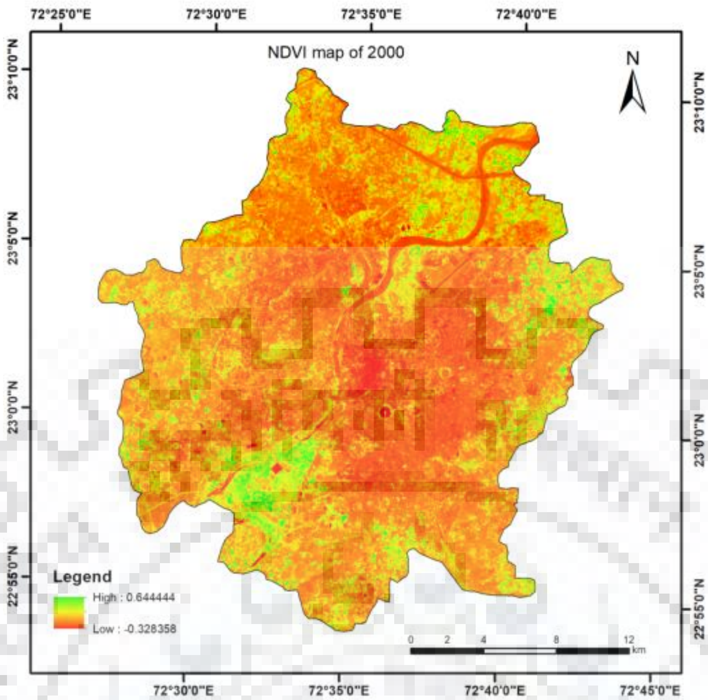

Fig. 11. NDVI map of the year 2000.

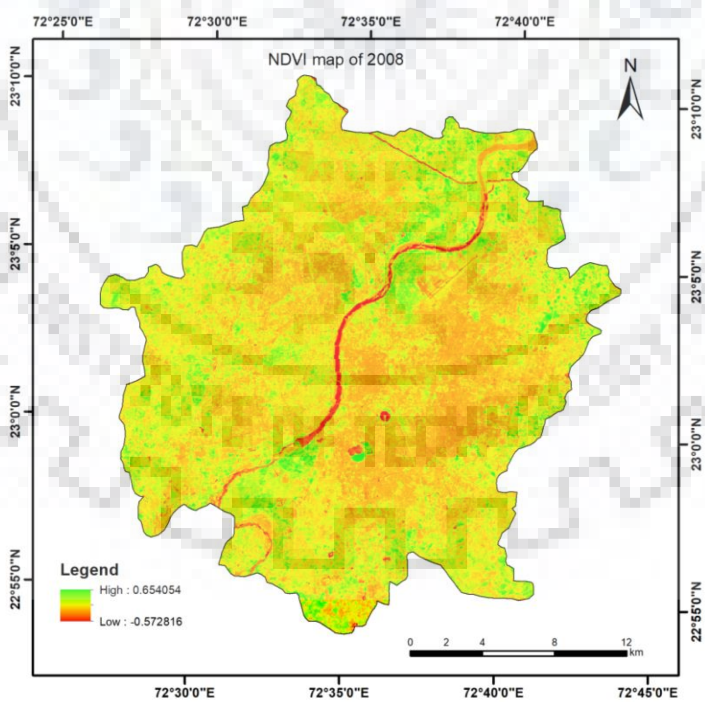

Fig. 12. NDVI map of the year 2008.

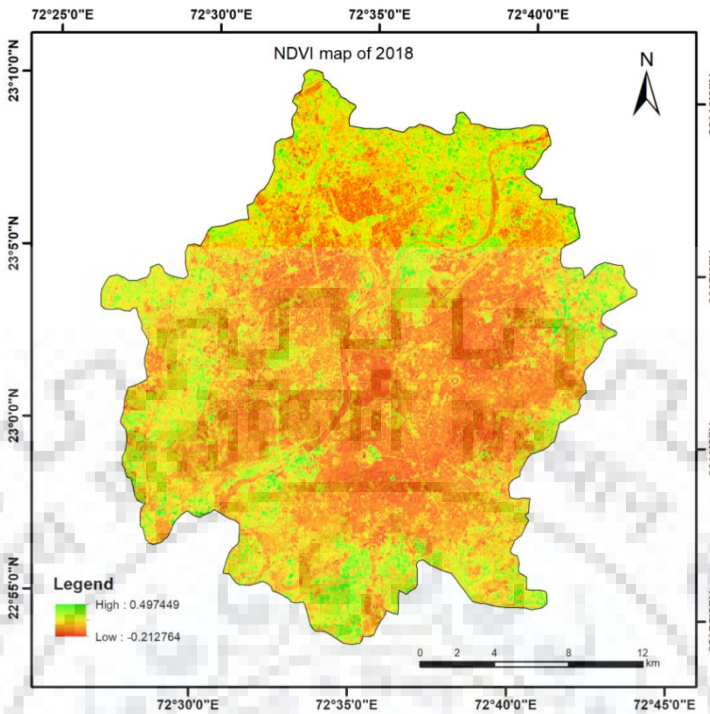

Fig. 13. NDVI map of the year 2018.

4. Relationship between LST and LULC

To find the effect of increasing growth of Land cover on surface temperature in past 18 years, 30 random points were selected in study area of different class. Average land surface temperature was calculated according to LULC class. Different relations can be analyzed from the plot between LST and LULC. Highest difference in the mean temperature was seen in urban area and least in area covered by water.

Continuous decrement in land surface temperature can be seen in water, vegetation and forest area. Whereas in urban and Barren land surface temperature is opposite. From the year 2000 to 2018, LST decreased by 1.3 in water area, 1.85 in vegetation area, 4.71 in forest area. On the other hand LST increases by 5.43 ^{0}C in urban area and 4.21 ^{0}C in Barren lands.

Table 4. Average temperature of LULC classes in the year 2000, 2008 and 2018.

LULC class	LST (°C)		
	2000	**2008**	**2018**
Water	33.26	32.46	31.96
Urban	38.55	39.51	43.98
Vegetation	37.81	36.23	35.96
Barren land	41.95	42.35	46.16
Forest	41.83	39.42	37.12

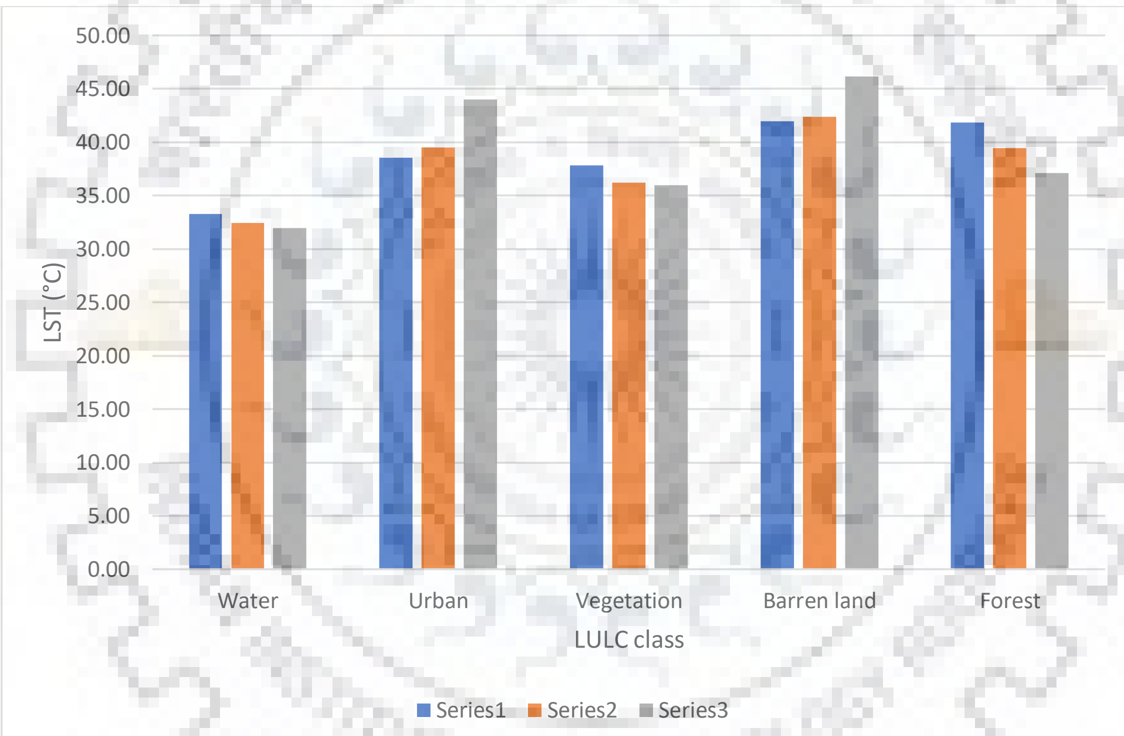

Fig. 14. Histogram showing variation in LST (^{0} C) with LULC class in the year 2000, 2008 and 2018.

Chapter 8

Conclusion

Quality of the environment in particular region is highly affected by the type of land cover. The correlation is observed between five land class of green vegetation, impervious land, barren land, Forest area and water with surface temperature. This project gives an idea of how LU/LC change can affect the environment and related factors. Land cover of the urban region and barren land has grown up to 22% and 7% respectively. While vegetation and forest land has decreased by 21% and 1% due to many factors. A strong connection can be observed in the land surface temperature and LULC. LST increased in a linear way on the points taken randomly on the study are for urban areas. High temperature can be observed at major city area in the year 2018 as compared to 2000. Mean temperature for water, Forest and vegetation area decreased. Whereas it increased for barren land and urban area. With urban expansion and change in land cover, depletion of vegetation near urban area can be observed. A negative relation can be seen in the LST and green area (NDVI). The LST of this region is highly influenced by land use and modification.

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