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TEMPORAL LAND SURFACE TEMPERATURE AND ITS EFFECTS ON BUILT-UP AREAS USING RS AND GIS

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Abstract - *Land Surface Temperature (LST) is the temperature of the top of the surface of the earth which is in direct contact with the measuring instrument. Urban built-up consists of areas or lands which are covered with small or large buildings. The temperature of several land covers vary differently. The LANDSAT 8 imagery is used to find LST using thermal bands (Band 10 and Band 11) present in it. The study area is Bhopal city, capital of Madhya Pradesh. Built-up area is extracted using the Google Earth imagery to analyze the LST in those regions. In this study, temporal LST is developed for the month of May in the years 2014, 2016 and 2018 for the built-up areas extracted from Google earth imagery of the year 2014 captured on different dates in the months of November and December. The graphs are used to interpolate the various ranges of temperature for the respective years and the relative variations in the LST of the years 2014, 2016 and 2018. It is observed that the temperature is rising with the passing years. The Temporal images developed for LST of built-ups is then used to find the spots or areas which are Urban Heat Island of the built-up regions. There were 9 such built-up areas observed, which were spotted as a buffer zone around the point of 500 m. Hence the study concludes that the urban built-up does not have uniform temperature ranges and UHIs exist only in certain areas of the city.*

***Key Words*: LST, Urban Heat Island, Built-up, NDVI, Remote Sensing, GIS**

1. INTRODUCTION

The urbanization is generally the process of increasing of urban population. With the rise in population, the need and demand for other vicinities also rise, like food, water and shelters, the common most requirements. Thus, to meet these requirements of rising population, the resources are being consumed a little more every year. The water table is falling year by year, which is directly or indirectly affecting the environmental conditions, or is itself affected by some environmental conditions. The various meteorological parameters are having dynamic impacts on them because of changing environmental conditions. Urbanization, known as a process of developing villages into towns and then towns into cities and further small cities into large ones, and so on. It is studied that the urban settlement is increasing on even a faster rate than the population. The main parameter to quantify the urban trend of change is Built-up. Not only the infrastructure, but also the environment is getting affected by this irregular settlement. Various environmental consequences of increasing urbanization are directly linked to meteorological parameters. Meteorological term is related to the process and phenomenon of the atmosphere which can be directly or indirectly used to forecast the weather. Various meteorological parameters are humidity, wind, haze, rainfall, temperature, solar radiations, and so on. These parameters are somehow inter-related to each other. Thus, one such parameter is temperature of the land surface, which is also known as Land Surface Temperature. Landsat 8 imagery has two thermal bands which help in developing the temperature image of any area. And there is definitely a relation between this temperature rise and urbanization. built up is the key factor to spot the urbanization.

The land previously covered with greenery are now covered with concrete and bricks. This will for sure, result in the tremendous change in the environmental conditions. Also the temperature is varying year by year, whether it be the hottest one or the coolest one. This study is thus, to understand the pattern of effects of these built ups on the rising temperature of the city of Bhopal, situated in Madhya Pradesh state. With the passing years, the temperature is changing, it is expected to keep changing in coming years also. We can't exactly predict the temperature, but we can analyze the trend of change in temperature.

The UHI is an urban area or area of a city where the temperature of the surface is significantly higher than the temperature of the surrounding areas. The reason for the same might be various human activities which may affect the temperature of the area. The quality of air as well as water of UHI are lower as compared to the nearby rural areas. This is due to presence of more pollutants in urban areas due to more population, vehicles and industries. The quality of water also degrades in nearby streams because of the hot water evaporated from UHIs and thus the water which has adapted to life in a cooler environment. In summers, the urban areas require more energy for running various electronic devices like AC, coolers, etc. This strains the energy resources in urban areas in summers, thus more radiations released and thus, more chances of spotting UHI.

1.1 Study Area

The study area consist of the city of Bhopal. It lies in central state of Madhya Pradesh and is its capital, having geographical extents of latitudes 23o21'45.15" N to 23o6'16.67" N and longitudes of 77o13'39.87" E to 77o31'49.59" E and approximately 527m above MSL (Mean Sea Level). The census data of 2011 submitted by census of India reported the population of Bhopal to be around 1,798,218. It is 17th most populous city in the country.

It lies just north of Vindhya mountain upper ranges. The terrain of the city is irregular. Somewhere it has flat terrain and somewhere hilly. Because of this irregular terrain, the ground properties also vary. The elevations of the city vary, somewhere small hills are found at the boundaries of the city. Some significant hills in the city are Arera hills in central part, Shyamala hills and Idgah hills in northern region. Bhopal is known as the City of Lakes for its various natural as well as artificial lakes and is also one of the greenest cities in India. It is the 17th largest city in the country and 131st in the world.

1.2 Software and Data Used

ArcGIS: ArcGIS is a Geographic Information System (GIS) for working with maps and geographic information. It is utilized for making and utilizing maps, incorporating geographic data, analyzing mapped information, sharing and finding geographic information, utilizing maps and geographic information in a scope of utilizations, and overseeing geographic information in a database. The version used in the study is ArcMap 10.2.

Google Earth: Google Earth is a computer software or application that renders a 3D portrayal of Earth based on satellite imagery. The program maps the Earth by superimposing satellite images, aerial photography, and GIS information onto a 3D globe, empowering clients to see urban regions and scenes from various focuses. Clients can investigate the globe by entering locations and coordinates, or by utilizing a console or mouse. The program can likewise be downloaded on a cell phone or tablet, utilizing a touch screen or stylus to explore.

MS EXCEL: It is used to prepare the charts and tables of the data collected by the ArcGIS software.

Landsat 8: Landsat 8 Imagery is used to find the LST imagery. Landsat 8 was launched on Feburary 11, 2013. This is sun-synchronous satellite and orbits around earth in near-polar orbit. It is at an altitude of 705 km and inclination angle of 98.2o. The temporal resolution of the satellite is 16 days. The Landsat 8 has OLI (operational Land Imager) and TIRS (Thermal Infrared Sensor) sensors.

Table -1:

Different bands of Landsat 8, their wavelengths and spatial resolution		
LANDSAT 8 Bands	Wavelength (micro meters)	Spatial Resolution (meters)
Band 1 - Ultra Blue	0.435 - 0.451	30
Band 2 - Blue	0.452 - 0.512	30
Band 3 - Green	0.533 - 0.590	30
Band 4 - Red	0.636 - 0.673	30
Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
Band 8 - Panchromatic	0.503 - 0.676	15
Band 9 - Cirrus	1.363 - 1.384	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	30
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	30

Table -2:

Metadata values used in calculations	
TYPE OF METADATA	VALUE
Radiance Add Band 10	0.10000
Radiance Add Band 11	0.10000
Radiance Mult Band_10	0.0003342
Radiance Mult Band_11	0.0003342
K1 Constant band 10	774.8853
K2 Constant Band 10	1321.0789
K1 Constant Band 11	480.8883
K2 Constant Band 11	1201.1442

2. METHODOLOGY

1. Data Download: Download Landsat 8 Imageries of the study area which falls in Path 145 and row 44. The images are

downloaded for may 2014, 2016 and 2018. The source of downloading is from USGS site.

2. Band Composite and Normalised Differential Vegetation Index ,NDVI : Band composites are formed which will be used later to generate NDVI of the images. Thus, bands 2,3,4 and 5 are to be selected while forming band composites. Then, NDVI can be formed by using red and Infra-red bands of the imagery.

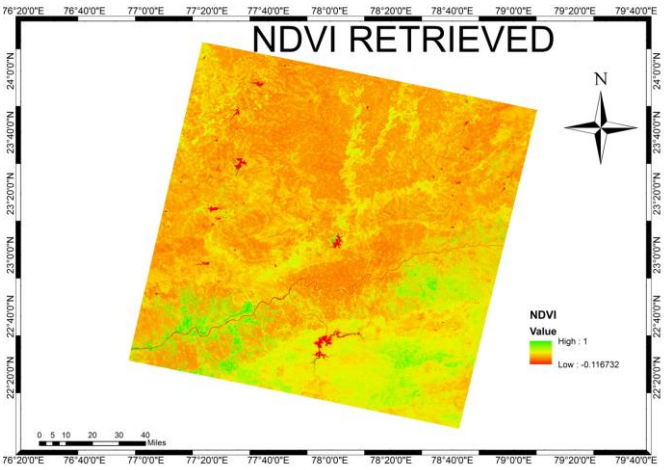

Fig -1: NDVI retrieved for the Image

NDVI=(NIR-RED)/(NIR+RED).....Eq 1

NIR: Digital Number values in Near Infrared Band

RED: Digital Number values in RED band

The value of NDVI ranges from -1 to +1. The values are used to signify the amount of vegetation present, as the name signifies Normalized Difference Vegetation Index. This derives its value from the green color of the chlorophyll contents present.

3. Calculating Proportion of Vegetation:

$P_v=((NDVI-NDVI_{min})/(NDVI_{max}-NDVI_{min}))^2$.....Eq 2

P_v: proportion of vegetation

$NDVI_{min}$: Minimum Value of NDVI from NDVI Image

$NDVI_{max}$: Maximum Value of NDVI from NDVI Image

NDVI: NDVI value from NDVI image

4. Calculating Land Surface Emissivity: It is a ratio of emitted energy from any surface for which emissivity has to be calculated to the energy that is emitted by a black body under same conditions. It varies with the nature of surface, like the rough surface will absorb more energy, so it will have high emissivity and smooth surface will have lower emissivity.

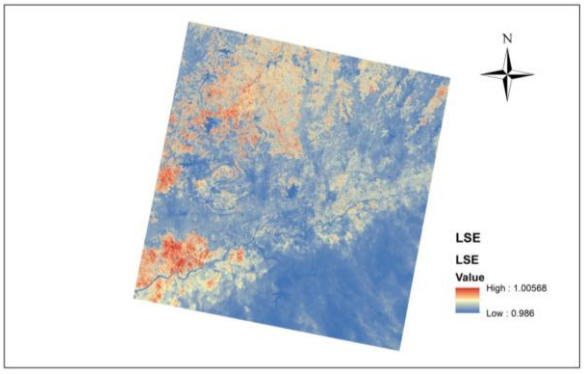

Fig -2: Land Surface Emissivity calculated

E = 0.004 * PV + 0.986.....Eq 3

E: Land Surface Emissivity

5. Calculating Top Of Atmosphere Radiance: The Thermal bands are Band 10 and band 11. Thus the values which these bands represent are the digital numbers. These digital numbers are converted to radiance, called as Top of Atmosphere radiance (TOA radiance)using the formula given in Eq 4

$L\lambda = ML * Qcal + AL$.....Eq 4

$L\lambda$: Top Of Atmosphere Radiance (Watts/ (m^2 * sr * µm))

ML: Radiance of multiplicative Band

Qcal: pixel values of Quantized and calibrated standard product or digital no.

AL: Radiance of Add Band

6. Calculating Satellite Temperature: It is the temperature calculated from satellite imagery at certain altitude, which could then be transferred to the ground level to depict the surface temperature.

BT = K2 / ln (k1 / Lλ + 1) - 272.15.....Eq 5
BT: Top of Atmosphere Brightness Temperature
K2: band constant
K1: band constant

7. Built-Up Extraction: Here for extraction of built-up, we have used Google earth pro software and plotted the areas covered by urban built-up by zooming in the imagery on google earth. The various built-up areas are covered by forming polygons in google earth. And have added placemarks for around all the varieties of settlements, with more number of placemarks in densely settled areas and lesser in other areas.

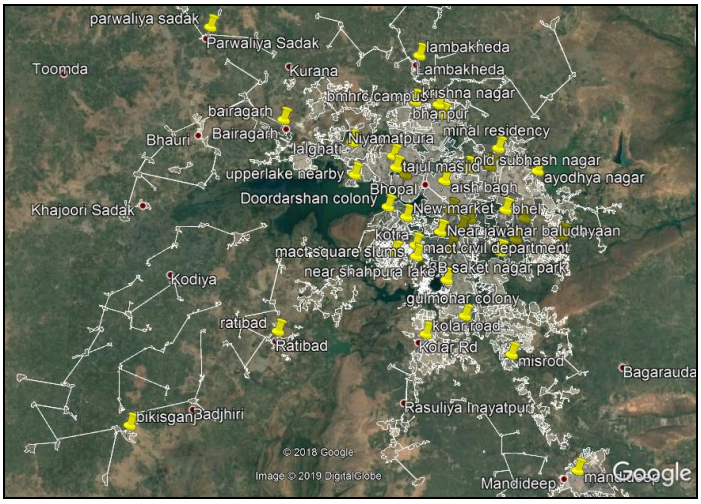

Fig -3: Google Earth Imagery having marked the built-up areas

8. Importing Polygons to ArcGIS: Now all these polygons extracted for built-up and placemark locations are now exported to ArcGIS so that the study area could be set up properly.

9. Extracting Temperature of Selected Areas and Points: Now the LST generated and the polygons extracted are overlayed and the temperature for only the built-up areas is extracted. The place marks will now be the study points, about them the temperature will be extracted. The same procedure will be adopted to generate the LST of the images of other years and extracting LST for urban built-up.

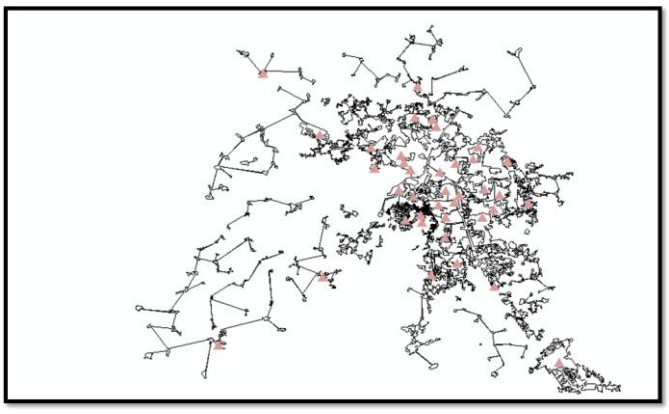

Fig -4: Study points marked

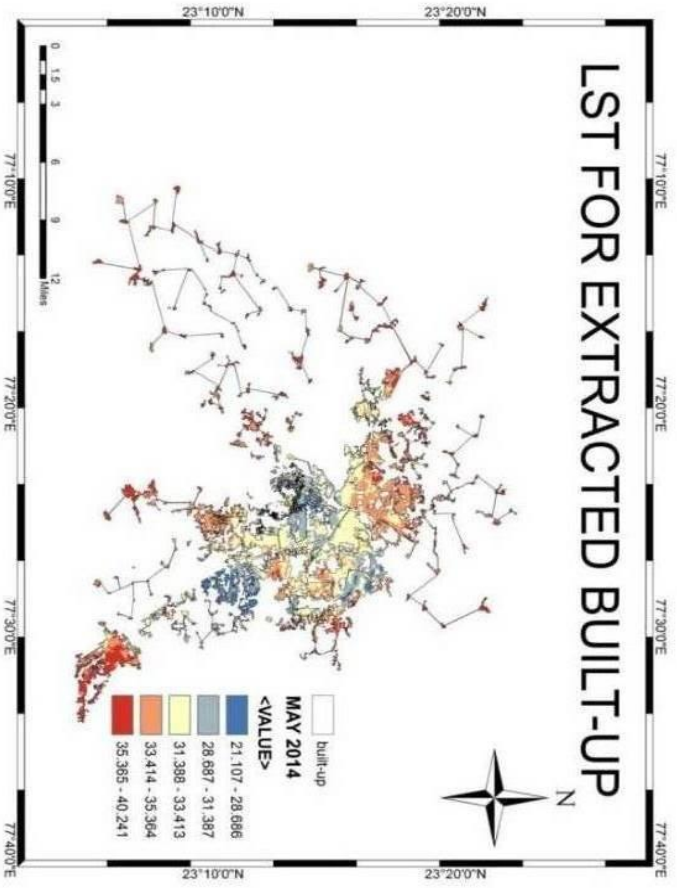

Fig -5: LST image of May 2014

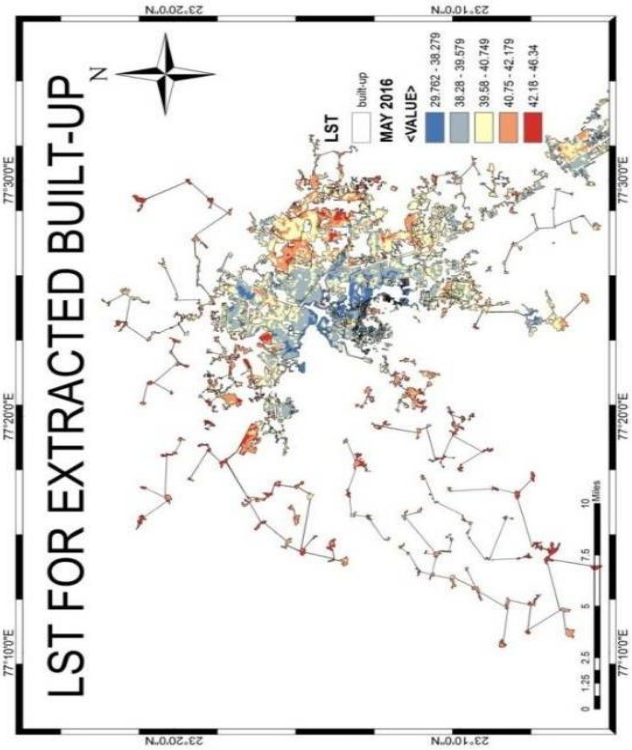

Fig -6: LST image of May 2016

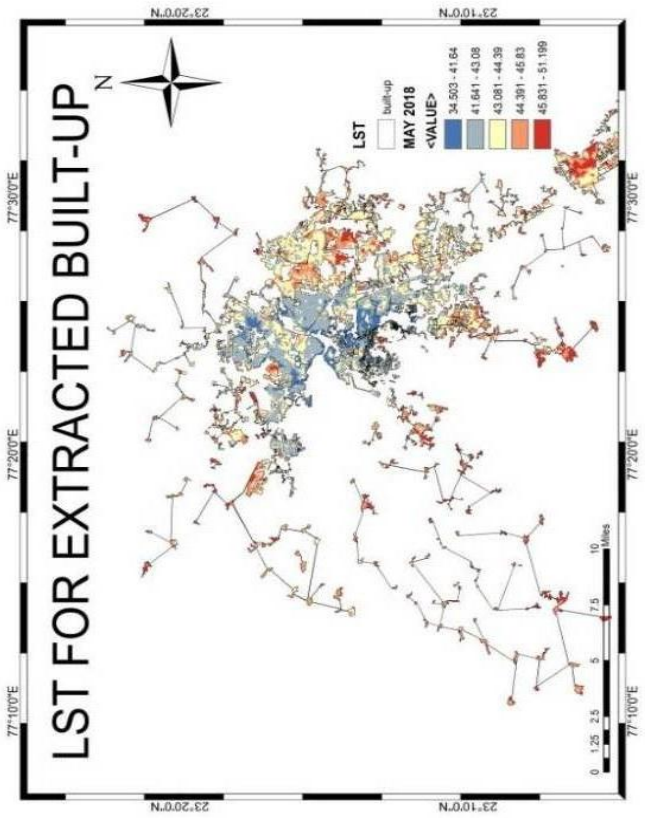

Fig -7: LST image of May 2018

10. Spotting Built-Up Regions Turning to UHI: The images of LST developed for several years can then be used to spot the areas which have higher temperature than nearby areas and are a sort of Urban heat islands in the built-up areas of the city. There will be certain areas on the imagery which will have higher temperature than the nearby areas, and this will be repeated for the further years. These areas have to be first selected out and then the buffer of 500 m around the points selected in these higher temperature areas is generated. There will be some limited number of such heat Islands.

2.1 Results

The temperature changes year per year. Now we have taken the base year of 2014 and studied the change in the temperature of Built-up with the passing years. This can be studied by Figures given below and implicated observations can be recorded.

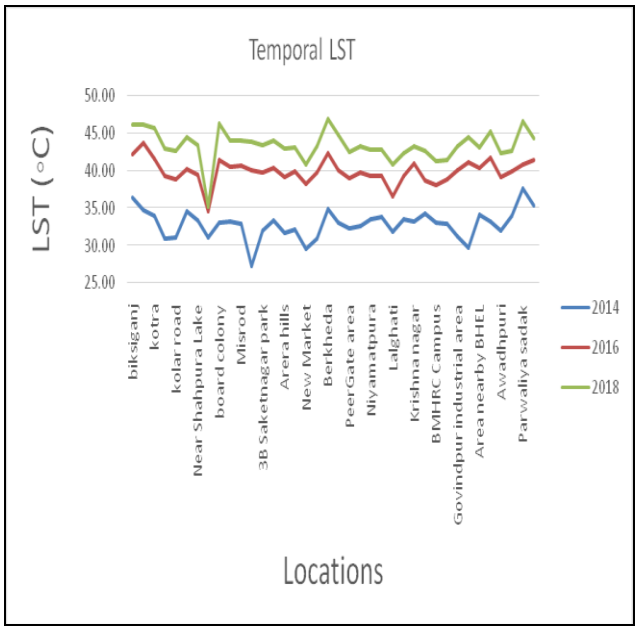

Chart -1: Graph showing relation of LST with Time

Minimum temperature of Built-up in the year of 2014 is 21°C, in the year of 2016 is 29°C, and in the year of 2018 is 34°C. This is not the minimum temperature of the year, it the minimum temperature of the built-up in January months of various years in general. The minimum temperature for the given years might have went even below these ranges. But it can be clearly observed that the minimum temperature is increasing with the coming years, but the incremental increase is decreasing.

Maximum ranges of temperature for the recorded years are 40°C, 46°C and 51°C for years 2014, 2016 and 2018 respectively for the month of may. The maximum temperature is also increasing with the passing years.

As mentioned for minimum temperature, the maximum temperature is also not the overall maximum temperature of the Built-up, it might be the temperature of any few pixels, or some areas only. But, still this maximum value for trending years has shown a significant increase.

One more and very important observation done is that the areas which have lower temperature in 2014 are having lower temperature in 2016 and lower temperature in 2018 as compared to other areas of the respective years. Similarly the areas having moderate temperatures have moderate temperatures in every year, so is with the higher temperature areas. Still some areas or small sectors are exception. This can help to identify the areas which are having high chances of converting to urban heat islands in the coming years if no step for precautions taken.

BUILT-UP URBAN HEAT ISLANDS

UHI are areas having more temperature than the surrounding areas and thus forms an island of heat surrounded by cooler areas. Such areas in the built-up region for the city of Bhopal are spotted in Fig-6.

These areas are having high temperatures in the image of every recorded year, and with the years trending, the temperature kept on increasing for these areas. Thus making them UHI for the built-up regions.

There are 9 such buffers plotted in the Built-up areas. These consist of areas of Bairagarh, Lalghati, near airport, old subhash nagar, near Niyamatpura, BHEL, areas of settlement nearby BHEL, Raisen road area near oriental college and Mandideep. The areas are mostly either from old city of Bhopal, or from industrial and dense settled areas.

From Chart-1, it can be inferred that the area near Shahpura lake might not had the minimum temperature in 2014, but it had minimum variation in temperature or not so much increase of temperature in the years 2016 and 2018. Regarding years 2016 and 2018, the temperature of this area almost remained same. The area is thus safe from turning into heat island in near future.

It can be observed that areas like Misrod had not so high temperature as compared to other urban areas have had more rise in temperature in years 2016 and 2018 as compared to other built-up areas.

The average temperature for 1000 points collected is found out for having more accuracy in the temperature, as to gain the more accuracy it is needed to collect more samples. Thus, there are very high chances of having accurate average temperature of Built-up of the year by finding average of these many samples. The average temperature of Built-up thus found for years 2014, 2016 and 2018 respectively are 33.30^{o}C, 40.43^{o}C and 43.99^{o}C respectively and shown in the Fig -5, Fig-6 and Fig-7.

Table -2:

Temporal LST for some of the selected study points

Northing (m)	Easting (m)	Area	LST of May 2014 (^{o}C)	LST of May 2016 (^{o}C)	LST of May 2018 (^{o}C)
2557610	729313	biksiganj	36.37	43.63	46.08
2564030	738090	ratibad	34.71	43.63	46.08
2569350	744992	kotra	33.91	41.52	45.57
2572120	744417	Doordarshan colony	30.89	39.25	42.91
2564390	747295	kolar road	31.13	38.86	42.61
2565440	749435	Gulmohar Colony	34.48	40.13	44.37
2567790	748388	Near Shahpura Lake	33.32	39.35	43.42
2569190	746368	MACT ce dept	31.12	34.54	35.12
2569680	748415	board colony	33.00	41.45	46.31
2569810	746243	MACT sq slums	33.14	40.50	43.89
2571080	749123	MP nagar	27.30	39.96	43.76
2569720	751533	Saketnagar park	32.00	39.67	43.35
2571630	749532	Housing board colony	33.31	40.32	43.96
2572080	748336	Arera hills	31.60	39.15	42.95
2570740	747754	Jawahar baludhyan	32.19	39.85	43.10

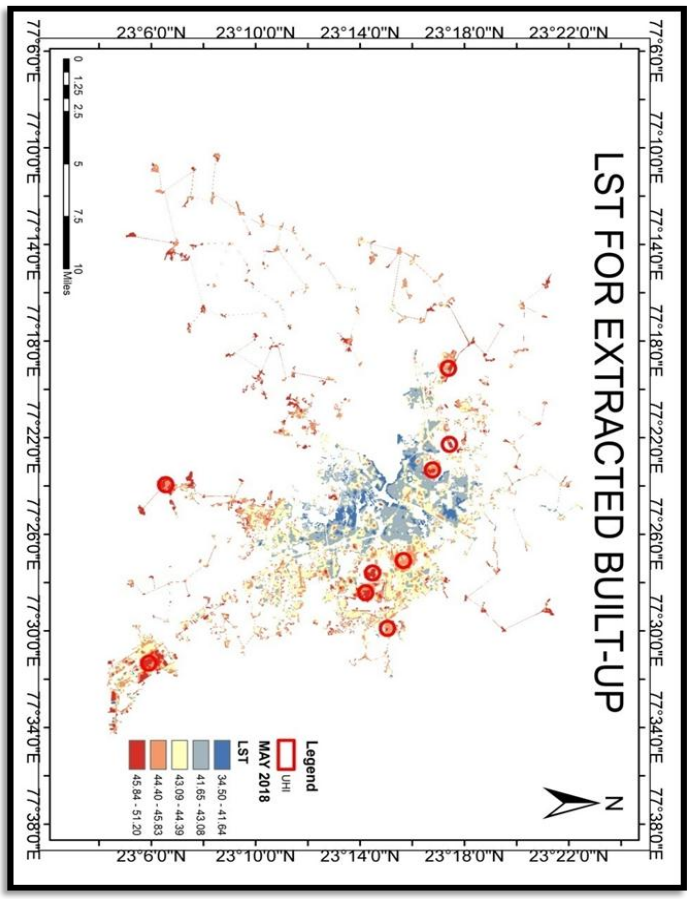

Fig -8: Urban Heat Islands spotted in Built-up using LST from Landsat 8 Imagery

3. CONCLUSIONS

The study is completed successfully using Remote sensing and GIS for the city of Bhopal and mainly focused on the Built-up areas. The temporal LST is prepared and GIS successfully analyzed the data to reach certain conclusions . The study conducted shows that the approximate increase in temperature of Built-up of Bhopal city is varying with certain locations. And also with the year increasing, temperature is increasing although, but the incremental change has decreased from 2014 to 2018. The study helped to spot areas which are most probable to turn in or might have turned into UHI among the Built-up areas, as these places had too much higher temperature as compared to nearby places every year. There were 9 such areas spotted and buffer zone of 500 m is prepared as this much area was seen darker than the nearby areas in LST imagery.

Required steps should be taken to prevent other places turning into UHI. The places which have already termed as trending UHI should be given concern as far as possible, like increasing plantation over those areas, buildings should have roof-top plantation, green buildings should be constructed, if possible, artificial lakes should be constructed, vertical plantation along the walls of the buildings should be adopted in order to keep them cooler. Thus, environment need to be protected from being depleted by avoiding certain steps:

Green roofs is one big solution to the problem.

Carbon Dioxide is a leading pollutant which is absorbed by plants. Thus, plantation should be adopted.

Colors used for buildings can be preferred to be the lighter one as they reflect more sunlight and traps lesser heat. While the darker surfaces trap more heat.

The buildings which are tall have multiple surfaces which absorbs and reflect sunlight multiple times, which increases the intensity of urban heat islands. Thus, vertical plantations on walls can be done.

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