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A comparative temperature study of south indian metropolitan cities in india using remote sensing and gis technique

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ABSTRACT

The present study has been conducted among three south Indian cities to analyze the surface temperature namely Hyderabad, Chennai and Bangalore. This study was conducted at three levels, first to find out the temporal changes of temperature, second to compare the spatial extension of temperature, and finally to compare the temperature between different land uses. The necessary satellite data for the study was downloaded through the internet and it was pre-processed for analysis. The software ERDAS was used for the image analysis and ArcGIS was used for the vector based analysis. The result of the study shows that, the temperature of Bangalore city has increased much more than the other two cities, that the city Chennai has increased moderately and Hyderabad's temperature has witnessed least change. The surface temperature variation between different land uses shows that, built-up land and barren areas have the highest temperature when compared to other land uses while water bodies and vegetation have the minimum temperature.

Keywords: Land Surface Temperature, Temporal Variation, Transect Profile

INTRODUCTION:

The study of temperature is very important in our present scenario, since global temperatures are increasing the one hand and the sea level is rising on the other hand. The earth releases its temperature all over its surface but the urban centers are releasing much more heat than other places which is caused by the large number of industries, the use of automobiles, dense settlement, uses of air conditioners and the lack of trees and other vegetation. Urban centers have the unique characteristics that they pull in populations from the rural areas due to the availability of employment, education and medical care which therefore increases the population. This increasing population converts open spaces and vegetation into built areas. The increasing surface temperature in an urban centers threatens human life by producing an environment that causes health problems, particularly sunburnt (skin diseases), mental stress, and dehydration. Therefore the study of urban surface temperature can find out the level of increase, where it is and why it has increased to suggest how to maintain the resources and surface temperature. The present study has been conducted in Hyderabad, Chennai and Bangalore. The development of information technology and its services in the selected cities have increased the population and consequently, the surface temperature. The current study analyzed the variation of temperature spatially and temporally.

2. STUDY AREA

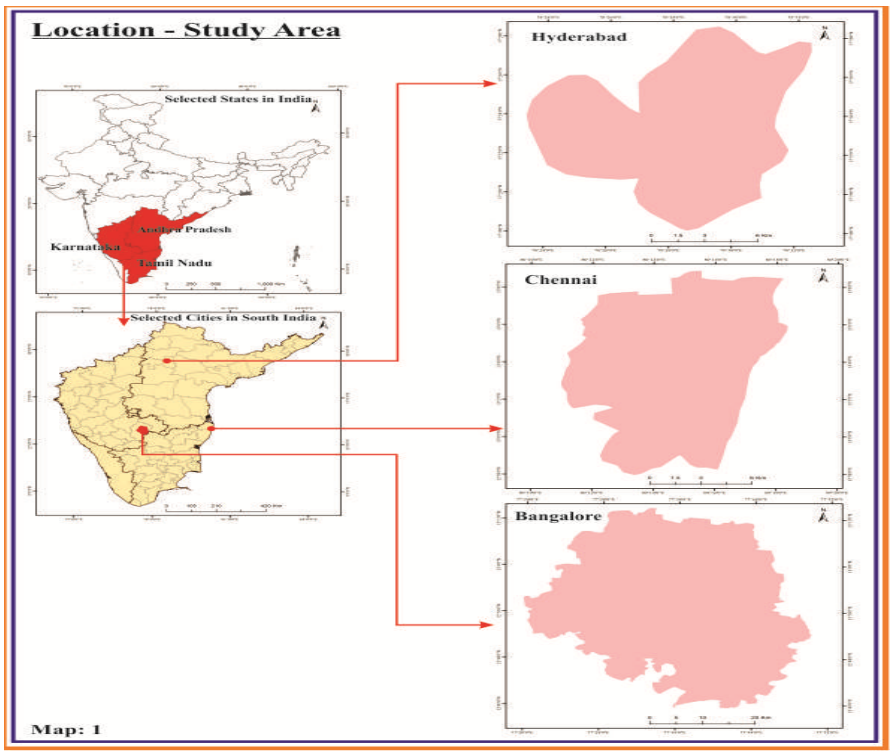
The selected cities for the present study are located in the southern part of India which is shown in Map: 1. These international business hubs have developed largely after globalization because skilled labour moved from well-developed educational via the good accessibility of international airports to other cities in the world, as well as the natural environment and helpful policies made by the local government.

The city of Hyderabad is the capital of the Telangana and the Andhra Pradesh states in India which is located on the Deccan Plateau in the southern part of India. The geographic location of the city is $17^0$20´ N Latitude and $78^0$30´ E longitude, at an altitude of 542 meters above sea level.

Chennai is the capital of the state of Tamil Nadu, which lies between 13º04´ of the northern latitude and 80º17´E of the southern longitude. As the city is located on the coast of the Bay of Bengal it has an almost flat land surface over the entire city. The even topography of the land throughout the city renders sub-divisions into natural regions rather difficult. It rises slightly as the

distance from the sea-shore increases but the average elevation of the city is not more than 22m above mean seal-level. Chennai is one of the leading cities in India today from the point of view of trade and commerce, with the fourth largest port in the country and the first to have developed a full-fledged container terminal to international standards. The port provides trade links with Japan, Singapore, Malaysia, Burma, Bangladesh, Ceylon and other far eastern countries. Chennai is also one of the most important industrial cities of the sub-continent.

Bangalore is the capital of the state of Karnataka, which is located at $12^0$59' North latitude and $77^0$57' East longitude, and is situated at an altitude of 920m above mean sea level. This is one of the fastest growing cities in Asia, which has recently attained the fame of a 'Silicon City', due to its progressive trend in Information technology. The city is also known as the Garden City because of having many parks. The city is well connected by ground and air with the other cities in India as well with other countries, which makes accessibility possible and easy. It has witnessed rapid vertical and horizontal growth after the boom in information technology, which is the reason for the high density of population, increased air pollution, water overconsumption and increase in temperature.



3. Methodology

The study has been conducted based on secondary data, which has been collected from the concerned departments and downloaded from authorized websites. The satellite data of the study has been downloaded from the earthexplorer.com for which the details are given in Table 1.

Table: 1 Details of Satellite Imageries

S.N	Type of Landsat Sensors	Name of Cities	Name of State	Path/ Row	Date of acquisition	Temporal Variation
1	TM – OLI/TIRS	Bangalore	Karnataka	144/051	16/03/2000 and 15/03/2014	14 Years
2	TM – OLI/TIRS	Hyderabad	Andhra Pradesh	144/048	29/02/2000 and 15/03/2014	14 Years
3	ETM + – OLI/TIRS	Chennai	Tamil Nadu	142/051	27/02/2006 and 17/03/2014	8 Years

For the cities of Bangalore and Hyderabad, fourteen years of interval data has been obtained but for the city Chennai the same interval data was not available so the study has adopted the eight year interval data which was available from above mentioned source. Figure 1 shows the step by step data process.

Each satellite has several sensors and each sensor captures the data on the specific wavelength of the electromagnetic spectrum which is called the band. Among these several bands, some have been captured in the thermal spectrum, which can be used to find out the land surface temperature. For example, the bands 6 in TM sensor, 6.1 in ETM+, and 10 in TIRS are thermal bands which were used for the present study.

Once the preprocessing of the satellite data was over, a spatial model was prepared in ERDAS Imagine to convert the digital number of satellite imagery into spectral radiance, then the temperature in degree Kelvin was found from the spatial radiance, and finally the Kelvin spatial values were converted to Celsius values to find out the spatial temperature of the study area.

The pre designed formula to convert Landsat 5, 7, and 8 thermal bands into temperature bands was obtained from the Landsat User guide.

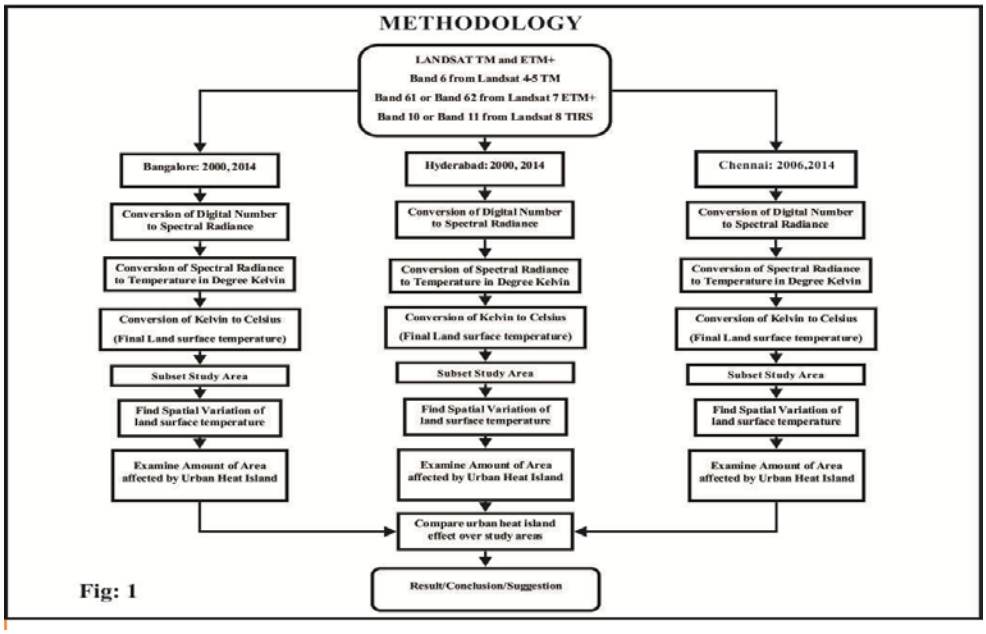


Fig: 1

3.1 Landsat 5 and 7 the formula are as follows:

- The formula to convert Digital Number (DN) to Spectral Radiance (L), (USGS, 2001).

$$L = \left(\frac{LMAX + LMIN}{QCALMAX}\right)QCAL$$

Where,

QCALMAX = the maximum quantized calibrated pixel value (DN=255).

QCAL = Digital Number (or) Raw Thermal Band.

The LMIN and LMAX are the Minimum and Maximum Spectral Radiances of the thermal band respectively and can be obtained from Metadata file (.met) along with the downloaded files.

- Conversion of the Spectral Radiance to Temperature in Kelvin, The TM and ETM+ thermal band data can be converted from spectral radiance temperature, which assumes surface emissivity = 1 (USGS, 2001).

$$T_{Kelvin} = \frac{K_2}{Ln\left(\frac{K_1}{L} + 1\right)}$$

Where,

T_{Kelvin} = Effective at-satellite temperature in Kelvin (Surface Temperature)

K_1 =Pre-Launch Calibration constant 1

K_2 =Pre-Launch Calibration constant 2

L= Spectral radiance (watts/meter squared*ster*µm)

Table 2: Pre-calibrated constants value of Landsat 5 and Landsat 7

Sensors	Bands	K_1	K_2	LMIN	LMAX
Landsat 5 TM	Band 6	607.76	1260.6	1.238	15.6
Landsat 7 ETM+	Band 6-1	666.09	1282.7	0	17.04

- Conversion of Kelvin to Celsius: the formula to convert Kelvin to Celsius is

3.2 Landsat 8 OLI/TIRS iimagery

The conversion formula of Landsat 8 differs from other imagery since its data has been saved in 16 bit radiometric resolution. Landsat 8 carries two individual sensors to capture the thermal waves, and these bands are ordered as band 10 and 11 in the Landsat sensors band order. The formulas given below are used to find out the surface temperature from the Landsat 8 images, which were obtained from the Landsat User's Guide.

- Digital Numbers to Top-of-atmospheric TOA radiance (R_{toa})

$$R_{toa} = G(DN)+B$$

Where,

G=Rescaled gain; Radiance Multiplier.

DN=Raw Thermal Band.

B= Rescaled bias; Radiance Add.

- Convert radiance into degrees Kelvin

$$T_{Kelvin} = \frac{K_2}{Ln\left(\frac{K_1}{R_{toa}} + 1\right)}$$

Where,

R_{toa} = Top-of-atmospheric radiance

K_1 =Pre-Launch Calibration constant 1

K_2 =Pre-Launch Calibration constant 2

- Conversion of degrees Kelvin into Degree Celsius

$T_{Celcius} = T_{Kelvin} - 273$

Table 3: Pre-calibrated constants for Landsat 8

Landsat 8 TIRS	**Band 10**
Radiance Multiplier	0.000334
Radiance Add	0.10
K_1	774.89
K_2	1321.08
Source: Landsat 8 User Guide	

4. Spatial Model Designing:

The spatial models were designed in ERDAS Imagine using a pre-designed formula by USGS. Fig: 2 indicates the three models which were built for Landsat 5, Landsat 7 and Landsat 8 respectively.

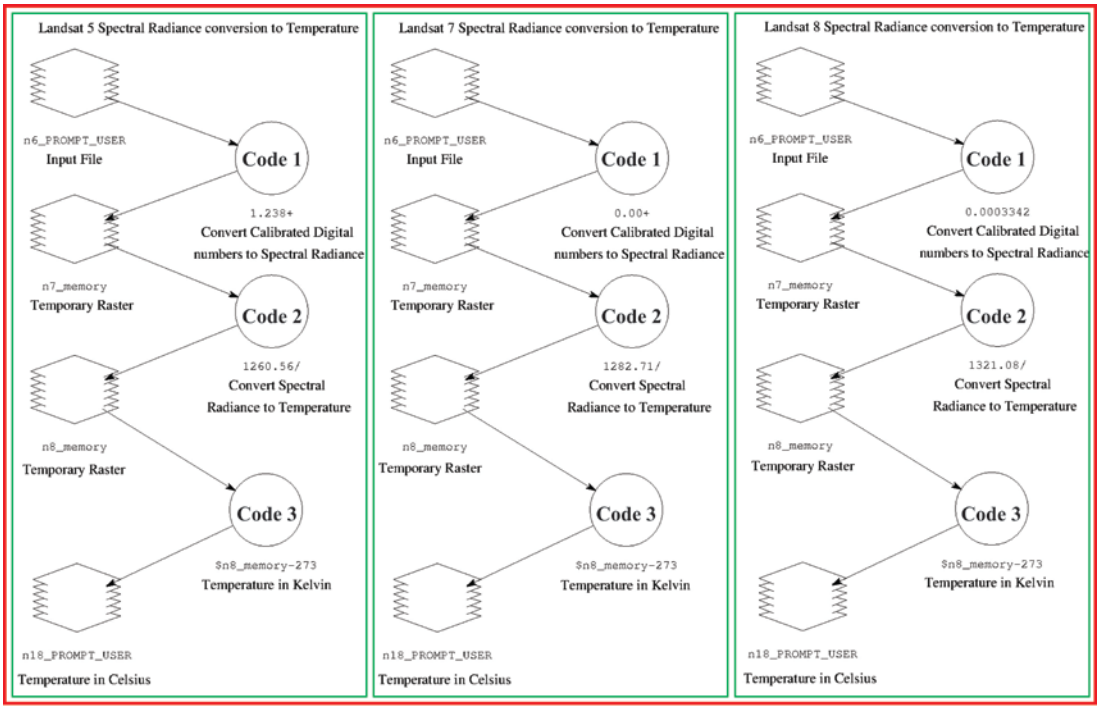


Fig: 2

Code 1:

For Landsat 5 = 1.238+(15.600-1.238)*$n6_PROMPT_USER(1)/255

For Landsat 7 = 0.000+(17.040-0.000)*$n6_PROMPT_USER(1)/255

For Landsat 8 = 0.0003342 * $n6_PROMPT_USER(1)+0.1

Code 2:

For Landsat 5 = 1260.56/(LOG (607.76/$n7_memory+1))

For Landsat 7 = 1282.71/(LOG (666.09/$n7_memory+1))

For Landsat 8 = 1321.08/(LOG (774.89/$n7_memory+1))

Code 3:

For Landsat 5 = $n8_memory-273

For Landsat 7 = $n8_memory-273

For Landsat 8 = $n8_memory-273

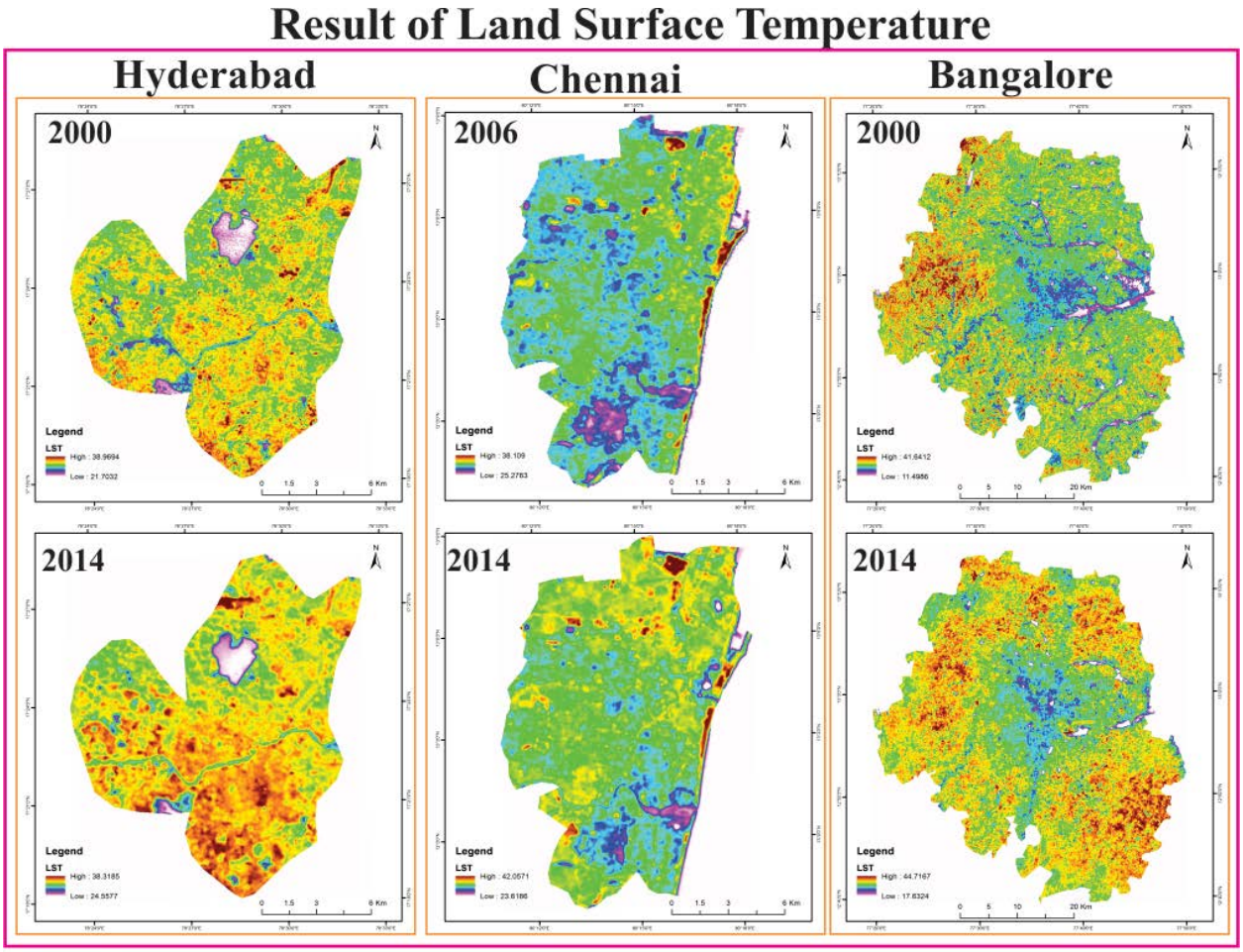
Once the results were obtained using the models, each year's results were compared with other years for that city to find out the temporal variation of temperature, and each city's temperature results were compared with other cities to find out how the temperature varies from one another. Finally a transect profile in ArcGIS was used to find out the variation of temperature between different uses of land.

5. Result and Discussion

The study has been conducted to assess, a) how the cities temperatures have changed over the selected years, b) to compare the spatial extension of temperature and c) how the temperature between the different land uses varies. The each goal of the study has been discussed below in detail.

5.1 Temporal Changes of Temperature

The temperature variation between selected years has been calculated for each selected city and mapped (Map: 2)



Map: 2

The result of the temporal study has showed that the minimum temperature of Hyderabad was 21.70^{0}C while the maximum was 38.96^{0}C in the year 2000, and these values changed in the year 2014 with a minimum of 24.50^{0}C and maximum of 38.31^{0}C, which demonstrate that the minimum temperature of the city has increased by 2.8^{0}C while the maximum has decreased by 0.5^{0}C.

Chennai's minimum temperature was 25.27^{0}C while the maximum was 38.10^{0}C in the year 2006, and it has changed to a minimum 23.61^{0}C and a maximum 42.06^{0}C in 2014, which is evidence that the minimum

temperature has decreased by 1.66^{0}C and the maximum has increased by 3.96^{0}C.

Bangalore's minimum temperature was 11.49^{0}C while the maximum was 41.64^{0}C in the year 2000, which has changed to a minimum of 17.63^{0}C and a maximum of 44.71^{0}C in 2014, which shows that the minimum temperature has increased by 6.14^{0}C while the maximum has increased by 3.07^{0}C.

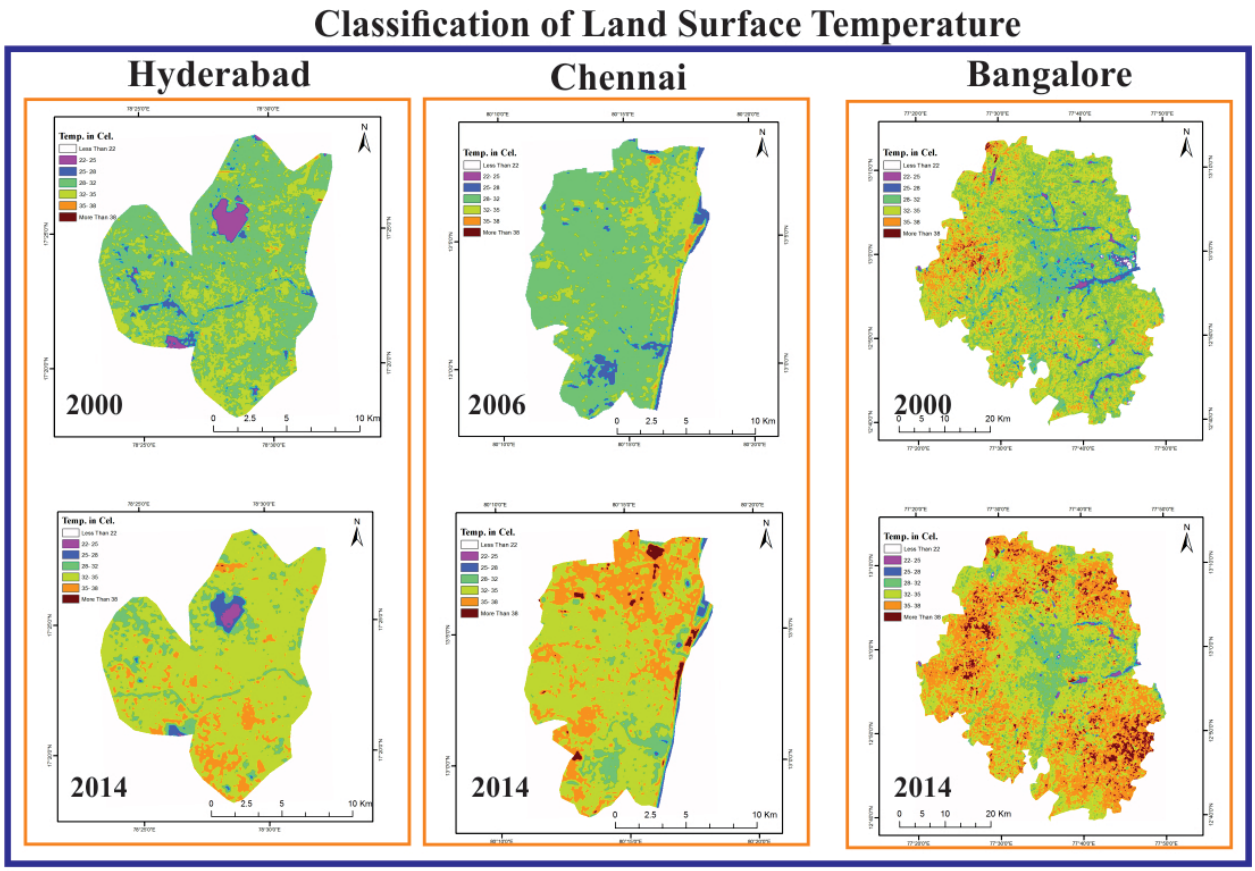
Table 4: Temporal Changes of Temperature

Name of Cities	Temperature in Degree Celsius					
	T1		T2		Variation	
	Min	Max	Min	Max	Min	Max
Hyderabad	21.70	38.96	24.50	38.31	2.80	- 0.50
Chennai	25.27	38.10	23.61	42.06	- 1.66	3.96
Bangalore	11.49	41.64	17.63	44.71	6.14	3.07
T1 indicates the year 2000 for Hyderabad and Bangalore while 2006 for Chennai, T2 indicates the year 2014						
Source: Analytical Result						

Table 4 and Map 2 clearly show the minimum and maximum temperature changes of the selected cities. From this it is clear that Bangalore's temperature has increased more than the other two cities, followed by Chennai and Hyderabad respectively.

5.2 Spatial Extension of Land Surface Temperature

The results of the land surface temperature study have been classified into 7 groups to compare the spatial extension of temperature, such as, very low (< 22^{0}C), low (22^{0}C -25^{0}C), moderate (25^{0}C -28^{0}C), high (28^{0}C-32^{0}C), very high (32^{0}C-35^{0}C), extreme (25^{0}C-38^{0}C) and torrid (>38^{0}C) (map: 3). ArcGIS was used to classify the raster layer into 7 classes and each class spatial extension has been calculated (table 5).



Map: 3

Table:5 Spatial Variation of Land Surface Temperature (Area in Km^2)										
S.N.	Temperature Classification (in Deg. Cel.)	Hyderabad			Chennai			Bangalore		
		2000	2014	Changes	2006	2014	Changes	2000	2014	Changes
1	< 22 (Very Low)	0.00	0.00	0.00	0.00	0.00	0.00	4.50	0.30	-4.21
2	22-25 (Low)	4.91	1.33	-3.58	8.90	0.05	-8.85	19.27	10.02	-9.25
3	25-28 (Moderate)	5.33	3.74	-1.59	128.32	2.24	-126.08	87.72	16.09	-71.63
4	28-32 (High)	114.49	18.87	-95.62	37.48	13.58	-23.90	676.17	232.93	-443.24
5	32-35 (Very High)	52.79	127.82	75.03	2.29	103.71	101.41	1082.04	840.49	-241.54
6	35-38 (Extreme)	0.61	26.40	25.79	0.02	54.33	54.31	301.36	969.84	668.48
7	>38 (Torrid)	0.03	0.03	0.00	0.00	3.06	3.06	13.91	114.57	100.66
Source: Analytical Result										

Table 5 depicts the spatial extension of temperature in each class. The classification of the result for Hyderabad shows that, there was no area covered by very low (< 22^0C) temperature, low, moderate and high temperature class areas have decreased, very high, and extreme areas have increased while torrid had no changes. This clearly demonstrates the increasing land surface temperature in Hyderabad.

The spatial extension of Chennai's temperature shows that there was no area of low temperature (like Hyderabad) in both years, and also that there was a decrease in low, moderate and high temperature areas. Very high, extreme and torrid areas showed an increase which evidence of the increasing land surface temperature in Chennai.

The spatial extension of Bangalore's temperature shows decrease in all the classes except extreme and torrid which have increased highly. The results for Bangalore represent the spatial increase of temperature in the city.

The overall view of spatial extension of temperature is evidence that the areal unit of higher temperature is increasing while lower temperatures are decreasing in all the cities. Bangalore has witnessed the highest change in the areal extension of temperature over the period when compared to the other cities. About 668.48 km^2 area has increased to the extreme class which was previously lower than this class and the torrid class has also increased 100.66 km^2. This higher amount of increasing areal temperature extension shows that the city's temperature has increased greatly followed by Chennai where 101.41 Km^2 is very high, 54.31 Km^2 is extreme and 3.06 is torrid. The areal unit of the city of Hyderabad has also increased in very high (75.03 Km^2) and extreme (25.79 Km^2). The areal extension of increased temperature areal unit in the city Hyderabad is lower when compared with the other two cities.

5.3 Variation of temperature between different land uses

The temperature of land surface varies from one usage area to another as each feature on the earth's surface has its unique capable of reflecting and holding temperature. To find out temperature variation between different land uses the transect profile has been created on the on the temperature raster in ArcGIS. To create the transect profile one should consider the origin point (where it should start) so the study has considered the Central Business District (CBD) as the origin place of each city. The Charminar's area has been considered as the central business district for Hyderabad while Adyar is for Chennai and Majestic for Bangalore.

The transect profiles have been created towards the North, East, South and West from the CBD on each city's temperature raster. The result of the transect profile is then compared with the land use and land cover data of each city to find out how the temperature is changing from one place's use to another. Figure 3 shows the created transect profiles and the numbers on the profile line indicate the temperature of different land's use and land cover. The exact location and the associated land use are given in Table 6. The x – axis of profile graph shows the distance from the CBD to the end point of a specific direction in meters whereas the y-axis shows the temperature values in Celsius. The fluctuating values of temperature shows the lows and highs in the graph, and the numerical value of the result has been tabulated in order to measure the temperature of different places.

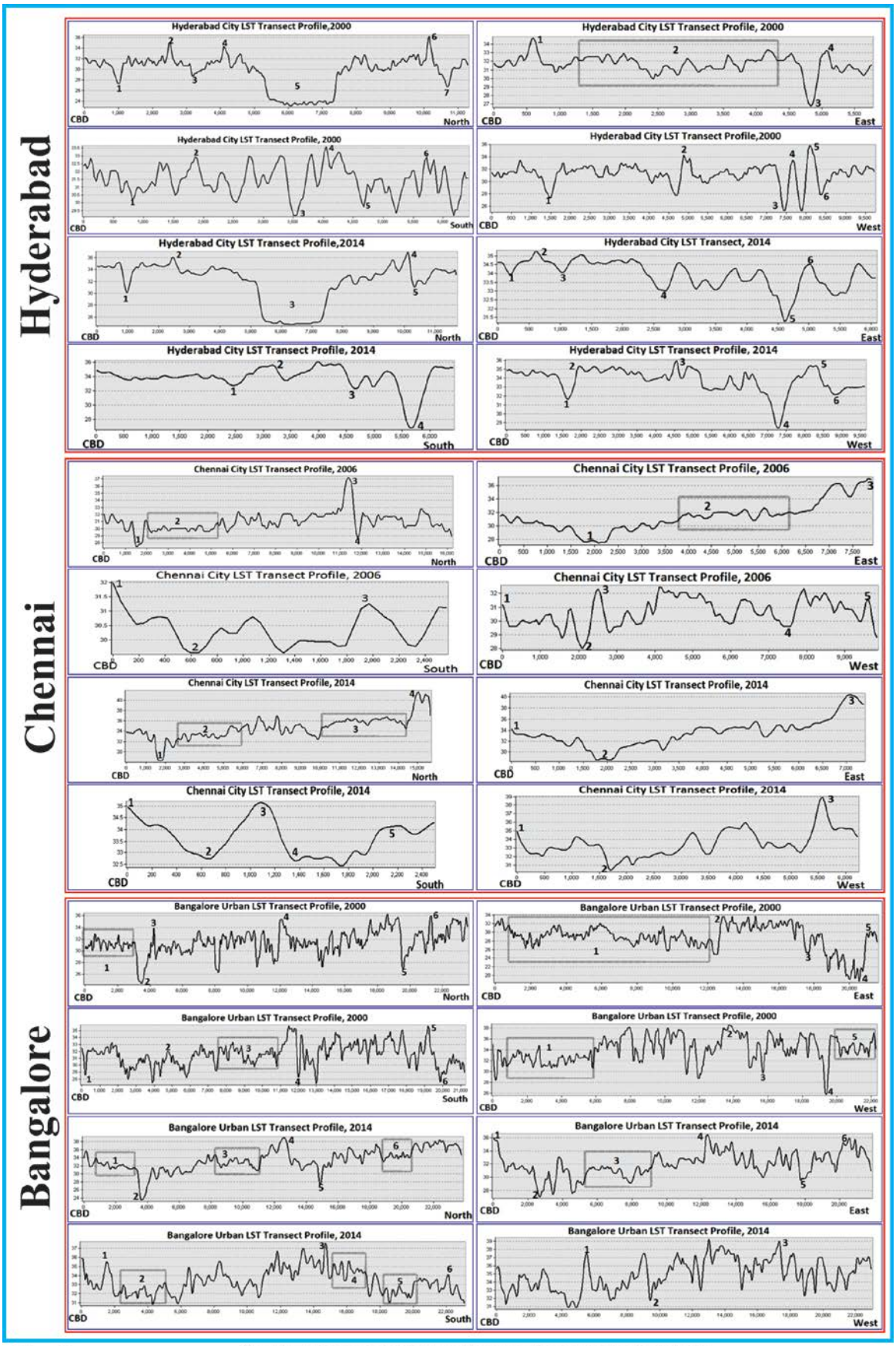


Fig: 3 X axis = Distance in Meters; Y axis = Temperature in Celsius

Table: 6

Identified Land Use/Land Cover

Hyderabad

Table 7.1 Hyderabad - CBD to North (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Mussi river	27.5	Waterbody
2	Nizam Shahi road	35.0	Builtup
3	Chirag Ali Lane	28.8	Builtup
4	Punjab National Bank ATM	34.1	Builtup
5	Hussian Sagar Lake	23.0	Waterbody
6	Old Airport Rd, Sancharpuri Colony	36.2	Builtup
7	Hyderabad Metropolitan Development Authority Urban Forest	26.8	Vegetation

Table 7.2 Hyderabad - CBD to South (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Vegetation near Hari Bowli road	30.3	Vegetation
2	Building	33.0	Built up
3	Dense Vegetation	29.0	Vegetation
4	Inner Ring road	33.5	Builtup
5	Water Tank	29.7	Waterbody
6	Inner ring road	33.2	Builtup

Table 7.3 Hyderabad - CBD to East (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Mir Alam Mandi road	35.0	Builtup
2	Zehra nagar colony to Afzal nagar	32-33.5	Builtup
3	Musi river	26.5	Waterbody
4	Zinda Tilismath Rd, Quadri Bagh, Amberpet	33.2	Builtup

Table 7.4 Hyderabad - CBD to West (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Musi River	27.5	Waterbody
2	KMG road	34.1	Builtup
3	Water body near Master Mind	25.0	Waterbody
4	Hyderabad Golf Course	33.2	Builtup
5	Golf Course Road	35.9	Builtup
6	Golf Course Road near to vegetation	28.0	Vegetation

Table 7.5 Hyderabad - CBD to North (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Mussi River	30.0	Waterbody
2	Mozamjahi Market	36.1	Builtup
3	Hussain Sagar Lake	24.2	Waterbody
4	Begumpet Airport, Runway	37.0	Builtup
5	Hyderabad Metropolitan Development Authority Urban Forest	31.1	Vegetation

Table 7.6 Hyderabad - CBD to South (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Rajanna Bhai Layout	31.2	Builtup
2	Falaknuma Road	35.5	Builtup
3	Inner Ring road	32.2	Builtup
4	Salkam Cheruvu Lake	26.0	Waterbody

Table 7.7 Hyderabad - CBD to East (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Vegetation	34.0	Vegetation
2	Mir Alam Mandi Road	35.5	Builtup
3	Vegetation	34.0	Vegetation
4	Channal of Mussi river	33.0	Waterbody
5	Mussi river	31.1	Waterbody

Table 7.8 Hyderabad - CBD to West (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Musi river bypass	31.7	Waterbody
2	Jiyaguda Road	35.3	Builtup
3	Golconda road	36	Builtup
4	Qutub Shahi Masjid Park	28	Park
5	Builtup	35.2	Builtup
6	Neknampur Road	32.1	Builtup

Chennai

Table 8.1 Chennai - CBD to North (2006)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Adyar River	27.0	Waterbody
2	Green Way Road to Dr. Radhakrishnan Salai	29.5-31	Builtup
3	Demellows Road	37.2	Builtup
4	Rajiv Gandhi Park	28.8	Park

Table 8.2 Chennai - CBD to South (2006)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Adyar Depot	32.0	Builtup
2	Vegetation Cover near Dr. Muthulakshmi Road	29.5	Vegetation
3	Builtup near Pulliyar Kovil Street	31.3	Builtup

Table 8.3 Chennai - CBD to East (2006)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Adyar River	27.7	Waterbody
2	Sundareshwarar street to Lloyds Street	31-32.9	Builtup
3	Marina Beach Offshore	37.5	Sand

Table 8.4 Chennai - CBD to West (2006)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Building near Second Avenue Road	31.1	Builtup
2	Tamilnadu Science and Technology Center	28.0	Vegetation
3	CEG Sports Ground	29.6	Barren Land
4	Sivan Park	29.6	Vegetation
5	Kaamarajar Saalai Road	31.5	Builtup

Table 8.5 Chennai - CBD to North (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Adyar River	28.0	Waterbody
2	Kaamarajar Saalai to Lloyds road	32.2-35	Builtup
3	Choolai to golden colony	34.5-36.2	Builtup
4	Kodungaiyur Landfill Site	42.0	Dump yard

Table 8.6 Chennai - CBD to South (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Mahathma Gandhi Road	35.0	Builtup
2	Dense Vegetation Near Dr. Muthulakshmi Road	32.7	Vegetation
3	Barren Land near Lattice Bridge Road	35.5	Barren Land
4	Vegetation along pedestrian	32.6	Vegetation
5	Pandian Street	34.1	Builtup

Table 8.7 Chennai - CBD to East (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Mahathma Gandhi road	34.1	Builtup
2	Adyar River	28.2	Waterbody
3	Offshore Marina Beach	41.0	Sand

Table 8.8 Chennai - CBD to West (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Adyar Bus stop	35.0	Builtup
2	IIT Madras	29.1	Vegetation
3	Parthasarathy road	39.0	Builtup

Bangalore

Table 9.1 Bangalore - CBD to North (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Settlements	32-33.2	Builtup
2	Sankey Tank	24.1	Waterbody
3	Building	33.9	Builtup
4	Barren Land	35.2	Barren Land
5	Nagadasana Halli Lake	26.9	Waterbody
6	Aadiganahalli Builtup	36.0	Builtup

Table 9.2 Bangalore - CBD to South (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Plantation	28.6	Vegetation
2	Buildings	32.1	Builtup
3	Buildings	29.5-33.6	Builtup
4	Plantation	28.3	Vegetation
5	Rock Region, Bannerghatta road	36.0	Hill

Table 9.3 Bangalore - CBD to East (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Chikpete to Vignana Nagara	28.1-32.2	Builtup
2	Akme Ballet, Building	33.9	Builtup
3	Reserved Forest Mixed Plantation	25.2	Vegetation
4	Dense Vegetation	19.2	Vegetation
5	Building	30.0	Builtup

Table 9.4 Bangalore - CBD to West (2000)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Malagala to Binnipete	32-35	Builtup
2	Seegehalli Road	38.9	Builtup
3	Pipeline Road	29.8	Builtup
4	Bychakuppe Vegetation	25.9	Vegetation
5	Dense Vegetation	36.2-37	Vegetation

Table 9.5 Bangalore - CBD to North (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Shastri nagar to Kodandaraamapura	31.5-34	Builtup
2	Sankey tank	25.8	Waterbody
3	Badrappa Layout to Medical and Aromatic Shrub area	31-34.9	Mixed
4	Gofo Technologies, Yelahanka	39.0	Builtup
5	Puttanna halli lake	27.5	Waterbody
6	Barren land	33.1-36.0	Barren Land

Table 9.6 Bangalore - CBD to South (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Mysore Road	35.5	Builtup
2	Chikkanna garden to Yediyur	33.1-33.2	Mixed
3	Rockey hill	38.0	Hill
4	Vegetation	33.5-35.4	Vegetation
5	Bannerghatta Zoo	31.0-33.0	Vegetation
6	Bannerghatta National Park	33.9	Vegetation

Table 9.7 Bangalore - CBD to East (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Majestic, Kempegowda Bus Stop	36.0	Builtup
2	Cubbon park	29.2-31.4	Vegetation
3	Building	36.3	Builtup
4	Offshore Doddanekundi lake	37.0	Sand
5	Nallura halli lake	29.8	Waterbody
6	Spring Dale, Building	36.0	Builtup

Table 9.8 Bangalore - CBD to West (2014)

Identifier	Place Identified	Temp. (^{0}C)	Associated LU/ LC
1	Building	37.5	Builtup
2	Spoorthi Dhama	31.8	Vegetation
3	pipeline road	39.0	Builtup

Source: Computed by the Researchers

5.4 Univariate statistical table of spatial variation in Land Surface temperature associated with various environment types

Once the variation of temperature between different land uses was found, the results were consolidated as maximum, mean and minimum temperatures for each year of the selected cities in respect to its land use and land cover (Table: 7).

Table 7: Consolidated Spatial Variation of Land Surface Temperature

Study Area / Year	Associated land use / land cover	Min Temp. (^{0} C)	Max Temp. (^{0} C)	Mean Temp (^{0} C)
Bangalore / 2000	Builtup	29.5	38.9	34.20
	Water Body	13.0	18.9	15.95
	Vegetation	14.2	18.2	16.20
	Barren Land	25.0	30.0	27.50
Bangalore / 2014	Builtup	28.1	38.9	33.50
	Water Body	24.1	26.9	25.50
	Vegetation	19.2	37.0	28.10
	Barren Land	35.2	36.0	35.60
Hyderabad / 2000	Builtup	28.8	36.2	32.50
	Water Body	23.0	29.7	26.35
	Vegetation	26.8	30.3	28.55
	Barren Land	-	-	-
Hyderabad / 2014	Builtup	39.0	31.2	35.10
	Water Body	24.2	33.0	28.60
	Vegetation	28.0	34.0	31.00
	Barren Land	-	-	-
Chennai / 2006	Builtup	29.5	37.2	33.35
	Water Body	27.0	27.0	27.00
	Vegetation	28.0	29.6	28.80
	Barren Land	29.6	37.5	33.55
Chennai / 2014	Builtup	32.2	39.0	35.60
	Water Body	28.0	28.2	28.10
	Vegetation	29.1	32.7	30.90
	Barren Land	35.5	42.0	38.75

Source: Computed by Researchers

The consolidated table shows that built up land use has higher temperatures than other land uses, followed by barren and vegetation while water bodies have the lowest temperature in all the selected cities. Therefore it is clear that built up areas covered by concrete or asphalt with scarcity of vegetation on the earth surface leads to an increase in the temperature of the land surface. Vegetation produces a lower temperature as it consumes most of the radiation energy during the evapotranspiration process while water bodies have least temperature.

6. CONCLUSION

The present study has concentrated on three aspects to find out the temporal changes of temperature, compare the spatial extension of temperature, and compare the temperature between different land uses. The result of the first aspect of temporal changes shows that the minimum and maximum temperatures of Bangalore city has increased, Chennai has decreased by 1.66^{0}C minimum and increased by 3.96^{0}C maximum and Hyderabad has risen 2.8^{0}C minimum and fallen by 0.5^{0}C maximum temperature. The overall study of temporal changes shows that, Bangalore's temperature has increased higher than other two cities while Chennai and Hyderabad come in second and third places respectively.

The second aspect of the spatial extension of temperature shows that, the areal unit of higher temperature has increased while the lower temperatures have decreased in all the cities. Especially has Bangalore

witnessed highly in the areal extension of temperature over period than the other cities, where about 769.14 km^2 area has increased to extreme and torrid classes which were previously lower than these classes. In the city Chennai, the area has increased about 101.41 Km^2 in very high, 54.31 Km^2 in extreme and 3.06 in torried from the lower classes. The result for Hyderabad shows an increased area in very high 75.03 Km^2 and in extreme 25.79 Km^2. The comparison of these three cities increased areal unit in higher temperatures demonstrates that Bangalore has changed more than the other two cities while Chennai and Hyderabad come second and third respectively.

The third aspect which was conducted to find out the temperature variation between different land uses shows that built-up and barren lands have higher temperatures than other land uses while vegetation and water bodies have the lowest temperatures, which clearly shows that increasing cultivation of vegetation and protection of water bodies in city area can reduce the surface temperature.

REFERENCES:

1. *A. D. Prasad, Kamal Jain, Ajay Gairola (2013);* Surface Temperature Estimation using Landsat Data for part of the Godavari and Tapi Basins, India: A Case Study; International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249-8958, Volume-2, Issue-3
2. *Aderoju Olaide .M, Samakinwa E Kayode, Ibrahim dris(2013);* An Assessment of Urban Heat Island in Akure Using Geospatial Techniques; IOSR Journal of Environmental Science, Toxicology And Food Technology (IOSR-JESTFT); e-ISSN: 2319-2402,p- ISSN: 2319-2399. Volume 6, Issue 3,PP 24-34
3. *Adinna E.N , Enete Ifeanyi Christain and Arch Tony Okolie (2009);* Assesment of Urnban Heat Island and possible adaptation in Enugu Urban using Landsat-ETM, Journal of Geography and regional planning vol 2(2) pp 030-036
4. *Alex Anas, Richard Arnott and Kenneth A. Small (1988);* Urban Spatial Structure; Journal of Economic Literature, Vol-36, No-3 pp1426-1464.
5. *Ana J. Picón (2007);* Use of ATLAS Visual and Thermal Imagery to Study the Urban Heat Island Effect in San Juan, Puerto Rico,
6. *Ayad Ali Faris and Y. Sudhakar Reddy (2010);* Estimation of Urban Heat Island Using Landsat ETM+ Imagery at Chennai City - A Case Study; International Journal of Earth Sciences and Engineering; ISSN 0974-5904, Vol-03, No-03, pp332-340
7. *Bakhtiar Feizizadeh and Thomas Blaschke (2013);* Examining Urban Heat Island Relations to Land Use and Air Pollution: Multiple Endmember Spectral Mixture Analysis for Thermal Remote Sensing; Ieee Journal Of Selected Topics In Applied Earth Observations And Remote Sensing, Vol. 6, No.3
8. *Becker F and Li (1995);* Surface Temperature and emissivity at various scales: Definition, Measurement and related problems, Remote sensing review-12; pp 225-253.
9. *CP. Lo, DA. Quattrochi and J. C. Luvall (1997);* Application of high- resolution thermal infrared remote sensing and GIS to assess the urban heat island effect, International Journal of Remote Sensing, Vol-18 No-2, pp287-304.
10. *CP. Lo and Dale A. Quattrochi (2003);* Land-Use and Land-Cover Change, Urban Heat Island Phenomenon, and Health Implications: A Remote Sensing Approach; Photogrammetric Engineering & Remote Sensing; Vol-69, No-9, pp1053–1063.
11. *Cathy Aniello, Ken Morgan, Arthur Busbey , and Leo Newland (1995);* Mapping Micro-Urban Heat Islands Using Landsat TM and a GIS, Computers & Geoscience; Vol-21, No-8, pp965-969.
12. *Fei Yuan and Marvin E. Bauer (2006);* Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery, p-12.
13. *J. P. Majra and A. Gur (2009);* "Climate change and health: Why should India be concerned?" Indian Journal Occupational and Environmental Medicine; 13(1): pp11–16
14. *J.A. Voogt and T.R. Oke (2003);* Thermal remote sensing of urban climates, Remote Sensing of Environment No-86 pp370–384.
15. *Janet Nichol (2005);* Remote Sensing of Urban Heat Islands by Day and Night, Photogrammetric Engineering & Remote Sensing Vol-71, No-5, pp613–621.
16. *Javed Mallick, India, Atiqur Rahman, India, Pham Viet Hoa, Vietnam and P.K.Joshi, India(2009);* Assessment of Night-Time Urban Surface Temperature -- Land Use/Cover Relationship for Thermal Urban Environment Studies Using Optical and Thermal Satellite Data; pp 19-22
17. *Javed Mallick, Yogesh Kant and B.D.Bharath(2008);* Estimation of land surface temperature over Delhi using Landsat-7 ETM+; J. Ind. Geophys. Union Vol-12, No-3, pp 131-140
18. *Jianguo Tan , Youfei Zheng , Xu Tang , Changyi Guo , Liping Li ,Guixiang Song , Xinrong Zhen , Dong Yuan ,*

Adam J. Kalkstein , Furong Li & Heng Chen (2010); The urban heat island and its impact on heat waves and human health in Shanghai; International Journal of Biometeorology,54:pp75-84

19. *Juan P. Montavez, Antonio Rodriguez and Juan I. Jimenez (2000);* A Study of the Urban Heat Island of Granada; Int. J. Climatology No-20: pp899-911.
20. *K. Babu Govindha Raj and Kevin Fleming (2008);* Surface Temperature Estimation from Landsat ETM+ Data for a part of the Baspa Basin, NW Himalaya, India;Bulletin of Glaciological Research 25 19-26.
21. *Kim Y.H, Baik J.J (2005);* Spatial and Temporal structure of Urban Heat Island in Seoul, American Meterological Society 44(5), pp 591-605
22. *Kun Li and Zhuang Yu(2008);* Comparative and Combinative Study of Urban Heat island in Wuhan City with Remote Sensing and CFD Simulation ; Sensors 2008, 8, 6692-6703; ISSN 1424-8220
23. *Laosuwan T and Sangpradit S. (2012);* "Urban heat island monitoring and analysis by using integration of satellite data and knowledge based method", International Journal of Development and Sustainability, Vol. 1 No. 2, pp. 99–110.
24. *László Mucsi László Henits, and János Unger (2010);* Analysis of the Relationship Between Urban Land Use and Urban Heat Island Using Remote Sensing Methods,2010
25. *Lin Liu and Yuanzhi Zhang (2011);* Urban Heat Island Analysis Using the Landsat TM Data and ASTER Data: A Case Study in Hong Kong; Remote Sensing ISSN 2072-4292, Vol-3, pp1535-1552
26. *Luke Howard (1833);* The Climate of London Deduced from Meteorological Observations, Made in the Metropolis of London, And at Various Places around It, vol-1, p-8.
27. *M Anul Haq, Dr. Kamal Jain, Dr K.P.R. Menon (2012);* Surface Temperature Estimation Of Gangotri Glacier Using Thermal Remote Sensing, International Archive of the photogrammetry, Remote Sensing and Spatial information science,2012
28. *Manat Srivanit and Kazunori Hokao(2012);* Thermal Infrared Remote Sensing for Urban Climate and Environmental Studies: An Application for the City of Bangkok, Thailand,pp83-100.
29. *Manju Mohan, Anurag Kandya, Arunachalam Battiprolu(2011);* Urban Heat Island Effect over National Capital Region of India: A Study using the Temperature Trends; Journal of Environmental Protection, pp465-472
30. *Monjit Borthakur , Bhrigu Kr. Nath(2012);* A Study of Changing Urban Landscape and Heat Island Phenomenon in Guwahati Metropolitan Area; International Journal of Scientific and Research Publications, Volume 2, Issue 11, ISSN 2250-3153
31. *N.L. Ukwattage and N.D.K. Dayawansa(2012);* Urban Heat Islands and the Energy Demand: An Analysis for Colombo City of Sri Lanka Using Thermal Remote Sensing Data; International Journal of Remote Sensing and GIS, Volume 1, Issue 2, pp124-131
32. *Noorazuan Bin Md. Hashim, Asmala Bin Ahmad and Mardina Binti Abdullah(2007);* Mapping urban heat island phenomenon: Remote sensing approach; Journal - The Institution of Engineers, Malaysia Vol-68, No-3
33. *Norman, J.M & Becker F (1995);* Terminology in Thermal infrared remote sensing of natural surfaces Agriculture and Forest Meteorology, No-77; pp 153-166.
34. *Oke T.R (1981);* Canyon Geometry and the nocturnal urban heat island: Comparison of scale model and field observation; Journal of Climatology; p 237-54
35. *Pradnya Nesarikar-Patki , Pratima Raykar-Alange(2012) ;* Study of Influence of Land Cover on Urban Heat Islands in Pune Using Remote Sensing; IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684 PP: 39-43
36. *Qihao Weng (2001);* A Remote Sensing–GIS evaluation of urban expansion and its impact on surface temperature in the Zhejiang Delta, China. int. j. remote sensing, vol-22, no-10, pp1999–2014.
37. *Qihao Weng (2009);* Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends; ISPRS Journal of Photogrammetry and Remote Sensing 64,pp 335-344
38. *Qihao Weng (2014)* ; Generating daily land surface temperature at Landsat resolution by fusing Landsat and MODIS data; Remote Sensing of Environment 145 pp55–67
39. *Ramachandra T. V. and Uttam Kumar (2010);* Greater Bangalore: Emerging Urban Heat Island,Center for Ecological Studies, Indian Institute of Science, Bangalore
40. *SH. A. Sherafati M. R. Saradjian , S. Niazmardi(2013);* Urban Heat Island Growth Modeling Using Artificial Neural Networks and Support Vector Regression: A case study of Tehran, Iran;International Archieves of the Photogrammetry,Remote Sensing and Spatial information science,vol XL-1/W3,2013
41. *Sinasi Kaya , Umut Gul Basar , Mehmet Karaca , Dursun Zafer Seker(2012);* Assessment of Urban Heat Islands Using Remotely Sensed Data; Ekoloji Vol-21, No-84,pp 107-113

42. *Siti Nor Afzan Buyadi , Wan Mohd Naim Wan Mohd , Alamah Misni (2013);* Impact of Land Use Changes on the Surface Temperature Distribution of Area Surrounding the National Botanic Garden, Shah Alam; Procedia - Social and Behavioral Sciences 101 pp 516 – 525

43. *Siti Nor Afzan Buyadi, Wan Mohd Naim Wan Mohd, Alamah Misni (2013);* Green Spaces Growth Impact on the Urban Microclimate; Procedia - Social and Behavioral Sciences pp 547 – 557

44. *Steve Kardinal Jusuf , N.H. Wong, Emlyn Hagen, Roni Anggoro, Yan Hong(2007);* The influence of land use on the urban heat island in Singapore; Habitat International 31 pp 232–242

45. *Sundara kumar , Dr. P. Udaya bhaskar , Dr. K. Padmakumari(2012);* Estimation Of Land Surface Temperature To Study Urban Heat Island Effect Using Landsat ETM+ Image, International Journal of Engineering Science and Technology (IJEST); ISSN : 0975-5462 Vol. 4 No.02

46. *Taha H. (1997);* Modeling the impacts of large-scale albedo changes on ozone air quality in the south coast air basin. Atmospheric Environment, No-31; pp1667–1676.

47. *Umamaheshwaran Rajasekar, Qihao Weng (2009);* Urban heat island monitoring and analysis using a non-parametric model: A case study of Indianapolis; ISPRS Journal of Photogrammetry and Remote Sensing; 64, pp86-96.

48. *Voogt JA (2005);* Urban Heat Islands: Hotter Cities; Journal of Action Biosciences; pp1-5

49. *Wei-Chyung Wang, Zhaomei Zeng Thomas R. Karl (1990);* Urban Heat islands in China, Geophysical research letters, Vol-17, No-12, P 2377-2380.

50. *Xiao-Ling Chen, Hong-Mei Zhao, Ping-Xiang Li, Zhi-Yong Yin (2006);* Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes; Remote Sensing of Environment No-104 pp133–146