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Urban Heat Island and its effect on Dweller of Kolkata Metropolitan area using Geospatial Techniques

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Abstract- The significance of Urban heat island (UHI) is to space heater than the urban adjacent area. This heat energy creates by urban people, house, shops, cars, buses, trains, industrial zone, etc. The UHI be an vital occurrence of urban environment in addition to gives direct and circumlocutory effect lying on urban population. In UHI calculating using landsat thermal band, Landsat TM, ETM+ and OLI satellite image (2000, 2008, 2017 Year) data processed to obtain a atmoshphire window method use to retrieve the land surface temperature (LST) using specifically band-6 (TM, ETM+) and band 10 (OLI) for data procurement and investigation. UHI consequence related with rising impermeable surface both spatially and temporally. This study aims to analyze the changes in LST with advent of the Kolkata Metropolitan Area (KMA). The result found that the (LST) is increasing sharply. The mean temperature of the area was 22.33°C in 2000 which became 23.68°C in 2008 and 23.79°C in 2017. The relation of built-up (NDBI) and LST is found positively correlated with a r value of 0.96 in 2000 and 0.78in 2017 and the relation with vegetation (NDVI) is negatively related and the r value is -0.98 in the years of 2000 and the r value is -0.97 in 2017, several heat zones are highlight and have been identified on the map of the KMA area. The addition of Geospatial technology be set up in the direction of valuable in monitor and analyze urban expansion pattern and in evaluation urbanization collision on surface temperature. Finally, the study suggests considering the possible micro-climatic changes in Kolkata metropolitan area and planning for the sustainable improvement.

***Keyword*:** Urban Heat Island (UHI), land surface temperature (LST), Normalized differential build up index (NDBI), Normalized differential vegetation index (NDVI).

I. INTRODUCTION

The Kolkata metropolitan area is a planning area, formed 1970 by metropolis development organization by the administration of west Bengal. It mechanism at the present in condition of the west Bengal municipality and country (development and improvement) act, 1979 its planning directorate was set up 1974[1-2]. The Land Surface Temperature (LST) images consequent from space borne satellite sensors have been used for Urban Heat Island (UHI) studies. The present study utilizes thermal data for mapping of UHI [3-8]. Landsat TM, ETM+ and OLI data have also been used to analyses the effect of different degrees of urbanization on LST and UHI [9-17]. Other thermal sensors such as Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), [18-19] National Oceanic and Atmospheric Administration-Advanced Very High Resolution Radiometer (NOAA-AVHRR) and Envisat Advanced Along-Track Scanning Radiometer were also used for urban LST and interrelated application [20-21].

The present study of spatial spreading out of urban built-up areas of Kolkata Metropolitan areas always needs precise information on the size, shape and spatial construction of built-up features [22-24]. Therefore, a scientific and vigorous method is necessary to rapidly retrieve such information, temporal resolutions, consistent and repetitive measurements and synoptic views of Land Use and Land Cover (LULC) [22, 25-28].These techniques can be broadly grouped into three categories: (a) pixel-based classification; (b) object-based classification [29-30] and (c) application of spectral indices such as Normalized Difference Built-up Index (NDBI)[31-35]. For the calculating NDVI and Normalized Difference Built-up Index (NDBI) were modified by changeover of TM bands with corresponding ETM+ bands. Finally, the satellite image was obtained by simple arithmetic process on enhanced NDBI, modified NDVI and modified NDBI images of incessant type [34, 36-37].

The UHI of Kolkata city region which is significance that heat heater than the urban nearby area [38, 15]. The perception of UHI consider the air temperature distinction among a city center and the surrounding area, UHI depends on environmental phenomena that are Land Surface Temperature (LST). The LST is depends on isolation as well as nature of the surface or object materials that is vegetation area, water bodies, soil, sand, and built up area. So, the present study area we are found that there is positive relation between LST and urbanization. Accordingly, acquire LST is the most important and explanation pace to the urban heat island analysis [39]. Finally, the study area reveals to estimate that Land surface temperature (LST) for the year of 2000, 2008 and 2017 to correlate Normalized Differential Vegetation index (NDVI) and Normalized Differential Built up Index with Land Surface Temperature to suggest considering the potential of micro-climatic changes in KMA and planning for the sustainable development. Every day planners use geospatial technology to research, build up, implement, and observe the procedure of their plans. Urban planners and decision-makers have to be more susceptible in the decision-making process and by analyzing qualified data, to make the best decisions. Finally we attempted that to specific objectives are to assess metropolitan expansion patterns in the KMA and to analyze the collision of the urban expansion on surface temperature.

II. MATERIALS AND METHOD

A. Study Area

The present study of urbanized area abstraction was led on KMA; geographical location is 22.36N to 23.08N latitude to 88.39E to 88.42E longitude (Figure. 1) and total 1010 sq km area and capital of West Bengal. To settled mainly along the banks of the river Hooghly about 150 km to the north of the Bay of Bengal right over the Gangetic delta plains [24]. This is one of the important built-up areas in India, as well as of the urban world characterized by swift urbanization and related spatio-temporal difference in biophysical practices. KMA, the largest metropolitan accumulation in eastern India, extending over 1851.41 km^2 comprises 4 municipal corporations, 39 municipalities, and 1 cantonment, and parts of 24 panchayat samiti (rural local governments at the in-between equal in governmental construction of India) [24]. Kolkata is the most essential commercial and industrialized center of east and north-east Indian vicinity, and it holds essential manufacturing and transportation infrastructure [40]. The population of core Kolkata was 1.5 million in 1901, 11 million in 1991 and an exceptional 14.2 million in 2011[24].

B. Land surface temperature (LST) Formation

The present study area collected Landsat 5 TM, Landsat 7 ETM+ and 8 OLI satellite image year of 2000, 2009 and 2017 in month of February, downloaded from “Earth Explorer” website of United States Geological Survey (USGS), path 138, and row 44. This image universal transverse projection (UTM) (with zone 45 north) and World geodetic system (WGS) – 1984 datum applied this image and pixel size 30 × 30 meters (Table1). We are using the LST data from Landsat TM, ETM+ Band 6 (TIR) and OLI band 10 (TIR) are geometrically corrected, and conducted from Arc GIS and Erdas Imagine software and LST data thermal infrared (TIR) were radio metrically and geometrically corrected images to elaborate satellite temperature calculate and emissivity for the image year of 2000, 2008 and 2017. At first, the DN value of Landsat TM band was transformed in to spectral radiance [41-42].

$L\lambda = ((LMAX\lambda - LMIN\lambda)/(QCALMAX-QCALMIN)) * (QCAL-QCALMIN) + LMIN\lambda$[43]

Where:

Lλ = Spectral Radiance at the sensor's aperture in watts/ (meter squared * ster * µm)

LMAXλ = the spectral radiance that is scaled to QCALMAX in watts/(sq. m)

QCALMIN = the minimum quantized calibrated pixel value (corresponding to LMINλ) in DN

QCALMAX = the maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN.

Step - II

Next spectral radiance has been converted to Temperature in Kelvin by formula is

$$T = \frac{K2}{In\left(\frac{K1}{L\lambda} + 1\right)}$$

Where:

T = Effective at-satellite temperature in Kelvin

K2 = Calibration constant 2 from metadata

K1 = Calibration constant 1 from metadata

Lλ = Spectral radiance in watts/ (sq. m)

Next Kelvin converted in Temperature (C = K – 273.15) and get the Temperatures. This Land surface temperature are closely related vegetation and built up area so their calculation this model NDVI and NDBI.

Where,

The NDVI is calculated from the equation

NDVI = (NIR – Red) / (NIR + Red)

Where

NDVI = (NIR – RED) / (NIR +RED)

In this Landsat 5 and 7 Image = (band 4 – band 3) / (band 4 + band 3)

NDVI = Normalized Differential vegetation index

NIR = Near Infra-Red band and RED = Red band

NDBI = (SWIR – NIR) / (SWIR + NIR).

In this Landsat 5 and 7 Image = (band 5 – band 4) / (band 5 + band 4).

NDBI = Normalized Differential built up index

SWIR = Short wave Infra-Red, NIR = Near Infra-Red

Calculation different year result Correlation between LST and NDVI and NDBI [43].

III. RESULT AND DISCUSSION

A. Spatial Temperature Change

In this LST map represent that Spatial Temperature on the surface; the author founded that in year of 2000 maximum temperature 30°C at central Kolkata Municipal Corporation area and Kalyani and that is the build and industrial area, and minimum temperature 10°C at Maheshtala and Budge Budge municipal area that is the fellow land. Temperature variation is 20°C and means LST was 22.33°C and standard deviation 1.21°C (Figure. 2 and Table 2). In year of 2008 found that maximum temperature 33.12°C founded at central Kolkata Municipal Corporation area and Howrah Municipal Corporation and Kalyani and Dum Dum Municipal area that is the build and industrial area, and minimum temperature 20.26°C at Uluberia, Budge Budge, Sonarpur, Chanddanagar Municipal area and average temperature 23.68°C and standard deviation 1.28°C (Figure. 3 and Table 2). Year of 2017 found that maximum temperature 35.00°C founded at central Kolkata Municipal Corporation area and Howrah Municipal Corporation and Kalyani and Dum Dum Municipal, Barrackpur and Garuliya municipal area that is the build and industrial area, and minimum temperature 14.37°C at Uluberia, Budge Budge, Sonarpur, Baidyabati, Chapdani and Barasat Municipal corporation area that are the agricultural land and fellow land average temperature 23.35°C and standard deviation 1.47°C (Figure. 4 and Table 2).

B. Correlation Matrix between LST, NDVI and NDBI

The correlation among LST, NDVI and NDBI was explored for every built up area during relationship analysis (pixel to pixel). Figure 6 and Table 3-5 shows the correlation coefficients among the two fundamentals in 2000, 2008 and 2017. The significance of each correlation coefficient was determined using a regression matrix. It is apparent from table 3-5 that LST values be inclined to depressingly associate NDVI values for all land surface types in both years.

The correlation matrix results the year of 2000 where NDVI maximum 0.56 their temperature 9.95°C and whereas NDVI value -0.49 there LST 30°C and (r = -0.98). In the year of 2008 whereas NDVI maximum 0.57 their temperature 20.26°C and where NDVI value -0.37 there LST 33°C and (r = -0.97). The year of 2017 whereas NDVI maximum 0.67 their temperature 14.37°C and where NDVI value -0.99 there LST 35°C (r = -0.97). The relation between LST and NDVI negative and correlation between NDVI and LST have shown (Figure. 5 and Table 3-5).

The correlation matrix results the year of 2000 where NDBI maximum 0.04 their temperature 30.00°C and NDVI value -0.95 the value of LST 9.95°C and (r = 0.96). The year of 2008 where NDBI maximum 0.50 their temperature 33.00°C and NDBI value -0.61 there LST 20.26°C and (r = 0.94). The year of 2017 whereas NDVI maximum 1their temperature 35.00°C and where NDVI value -1 there LST 14.37°C and (r = 7.8). Finally, the relation between LST and NDBI positive and LST change increase in the maximum build up area have been shown (Figure. 6 and Table 3-5).

The results show that the strong, negative correlation between LST, NDVI and NDBI implies that the higher biomass a land cover has, the lower the surface temperature. Because of this relationship between LST, NDVI and NDBI have an indirect impact on surface temperatures through NDVI. The values of NDVI in every year were scaled according to the subsequent matrix, as the complete values of NDVI tend to very temporally in a non-systematic manner [44] .

C. Different yearly Land Surface Temperature Change

The impact of land features of surface temperature preserve as well to observe spatially. The surface temperature change image obtained by image different is recorded into KMA area zones on the digital techniques method of equal interval. The interrelation correlation matrix change results to analysis, the different years; the LST maps of 2000 to 2008 was -12.09°C and 5.09°C (Figure. 7) and year of 2008 to 2017 was -7.91°C and 9.64°C (Figure. 8) and year of 2000 to 2017 was -12.90°C and 7.15°C (Figure. 9). The Land Surface Temperature Change of Kolkata Metropolitan area from 2008 to 2017 it is increase more than 2000 to 2008 and 2000 to 2017 map cumulative effect. At this time build up area road, buildings and industrial area increase maximum. Such as this change LST is creating Urban Heat Island like other area. The change of LST was Maximum 7.15°C to 9.64°C in area of Kolkata municipal Dum Dum, Barrackpur, Kalyani and Kancharapara Municipal area are respectively. The GIS method and correlation analysis between the temperature zones of urban expansion of hit island to gives multiple *r* value 0.98 in the years of 2000 and the r value is -0.97 in 2017, thus the most important to the conclusion that spreading out is contributing to the amplify in surface temperature.

IV. CONCLUSIONS

Beyond the study and analytical work, it is able to be accomplished that UHI phenomenon is connected with the urbanization progression. The method of assessable remote sensing and GIS vis-s-vis digital image processing matrix, correlation and regression analysis, remote sensing and GIS technique validate that urbanized area increase to built-up stretch has through influence over the ecological possessions.

The amalgamation of geospatial technology provides a resourceful method to sense urban growth of hit island and also appraise its collision on surface temperature. The DIP techniques attached with GIS has established its aptitude to present inclusive information on the environment, velocity and position of urban land expansion. The UHI effect has been more prominent core area of Dum Dum, Barrackpur, Kalyani and Kancharapara Municipal area are respectively. It's in addition to experiential that the urban expansion introduces UHI concentration during the progression of degradation of vegetation covers. The study reveals that the remote sensing image is ideal for analyzing the Urban Heat Island effect of last 17 years 'span. The satellite data analyzing and interpretation results shows the different years we found that development of Calcutta Metropolitan Area growth building and road and industries causes for Land Surface Temperature Increase in Kolkata and surrounding area a micro climate heat zone. So needed a prior attention is needed to address the micro-climate changes of the area for a sustainable city development. Finally, to observe the ecological crash of urban growth, the map pattern of ecological change can be associated to urban growth pattern by correlation analysis.

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Table 1 details of Landsat data used (Sources: USGS Earth Explorer)

Sl.No	Satellite	Sensor	Date of acquisition
1	Landsat 5	TM	01/12/2000
2	Landsat 7	ETM+	17/11/2008
3	Landsat 8	OLI	02/12/2017

Table 2 Changing LST in KDMA area

Year	Land Surface Temperature (LST) in °C				
	Maximum	Minimum	Range	Mean	Standard Deviation
2000	30	10	20	22.33	1.21
2008	33.12	20.26	12.86	23.68	1.28
2017	35	14.37	20.63	23.35	1.47

Table 3 Correlation (r) among NDVI, NDBI, and LST, 2000

Correlation	NDVI	NDBI	LST
NDVI	1		
NDBI	-0.98	1	
LST	-0.98	0.96	1

Table 4 Correlation (r) among NDVI, NDBI, and LST, 2008

Correlation	NDVI	NDBI	LST
NDVI	1		
NDBI	-0.98	1	
LST	-0.97	0.94	1

Table 5 Correlation (r) among NDVI, NDBI, and LST, 2017

Correlation	NDVI	NDBI	LST
NDVI	1		
NDBI	-0.93	1	
LST	-0.97	0.76	1

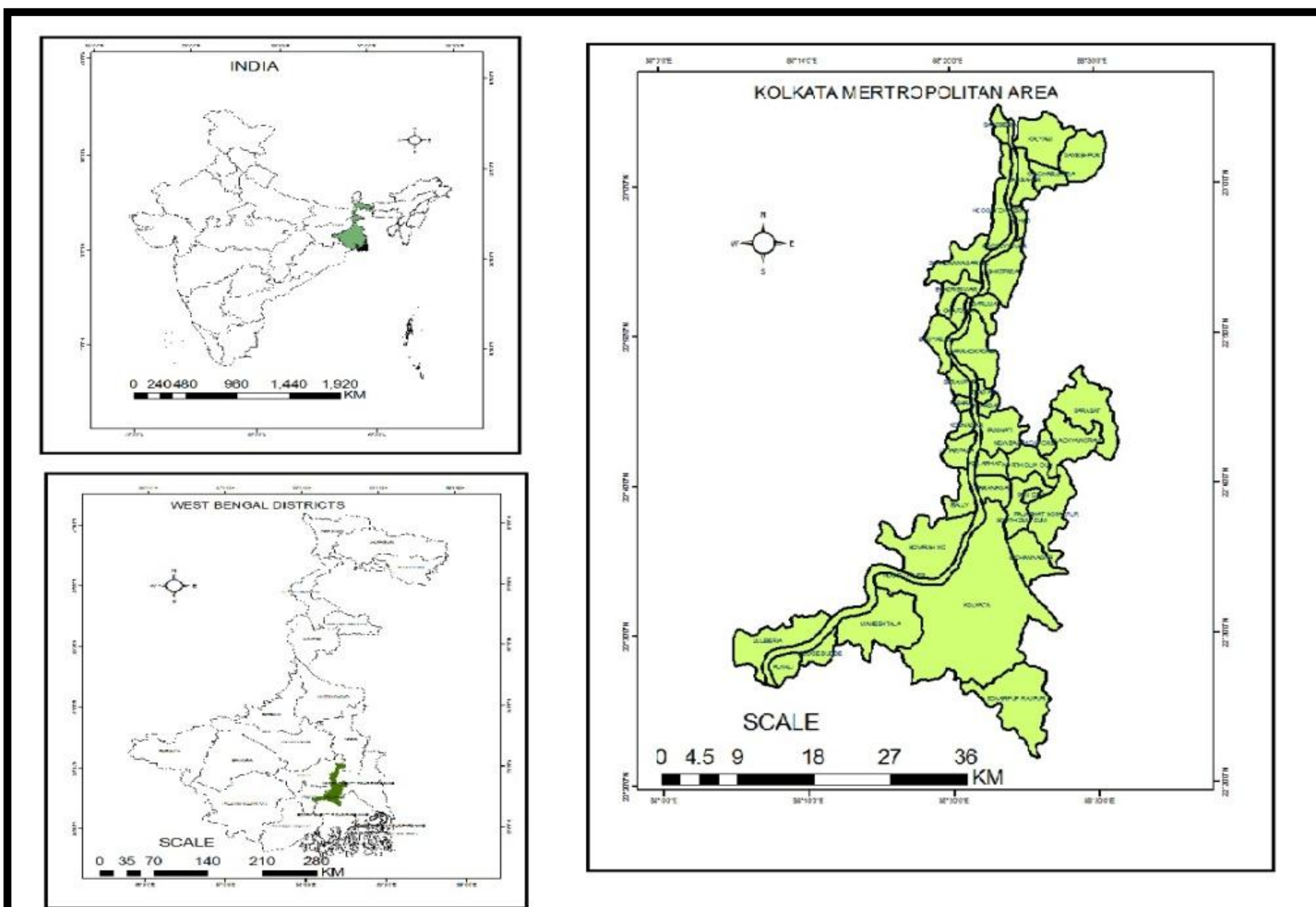

Fig. 1. Location Map (Source: KDMA)

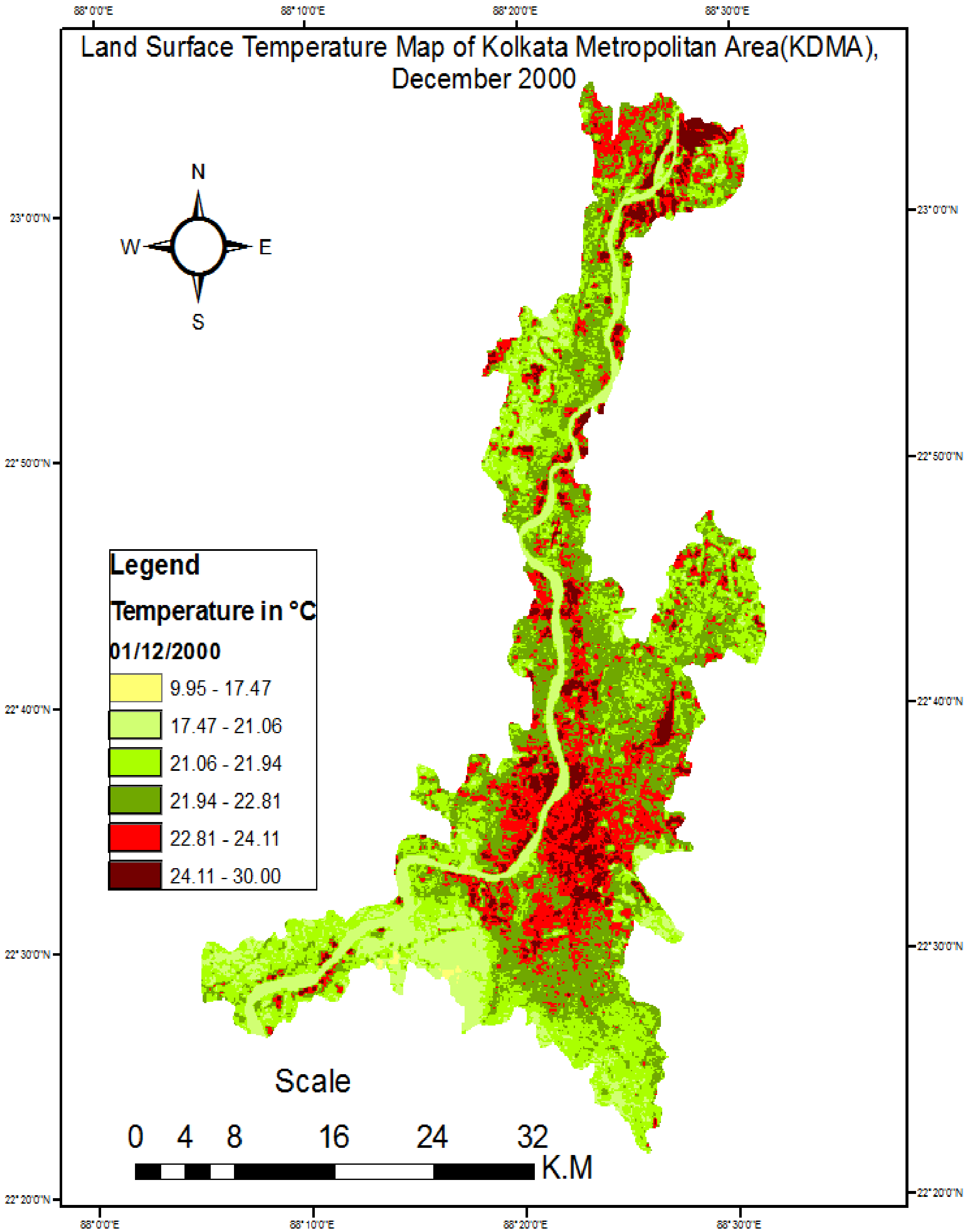

Fig.2. Land Surface Temperature Map 2000

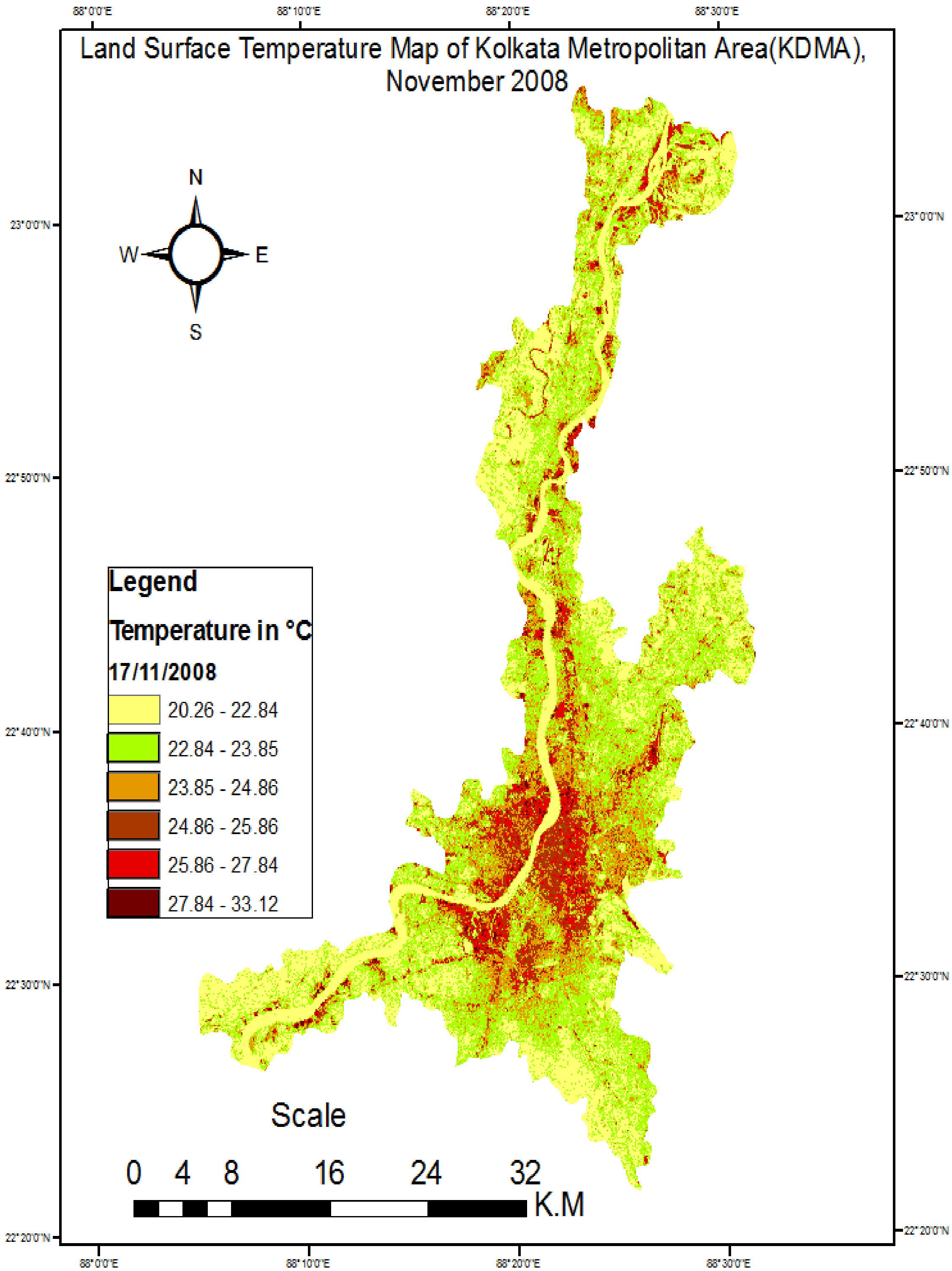

Fig.3. Land Surface Temperature Map 2008

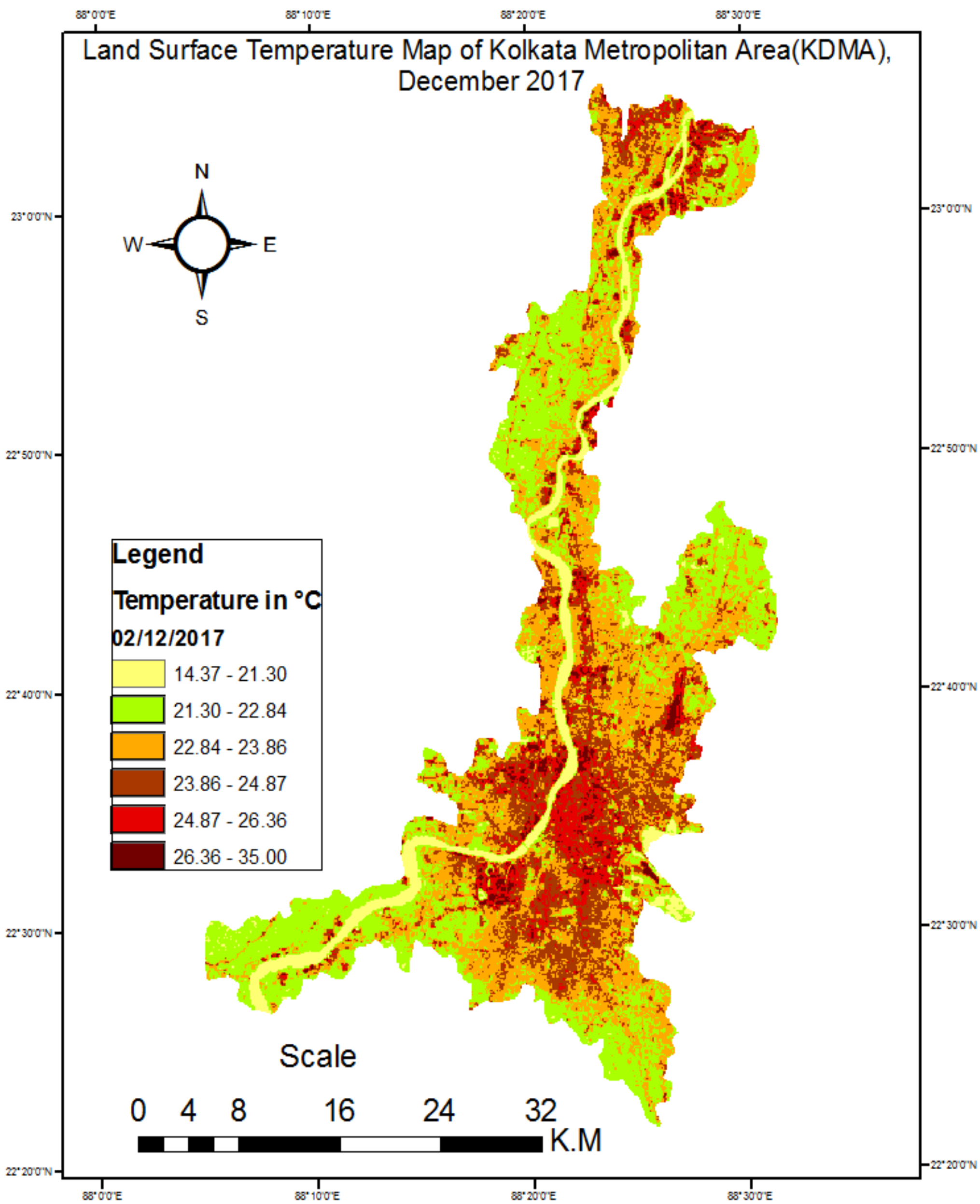

Fig.4. Land Surface Temperature Map 2017

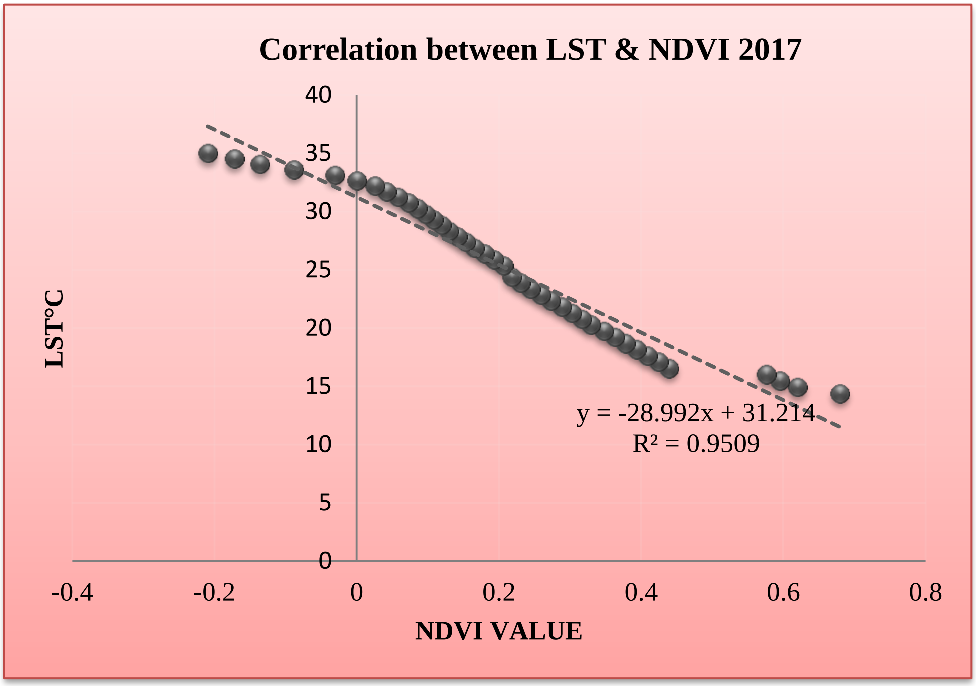

Fig. 5. Correlation between LST and NDVI

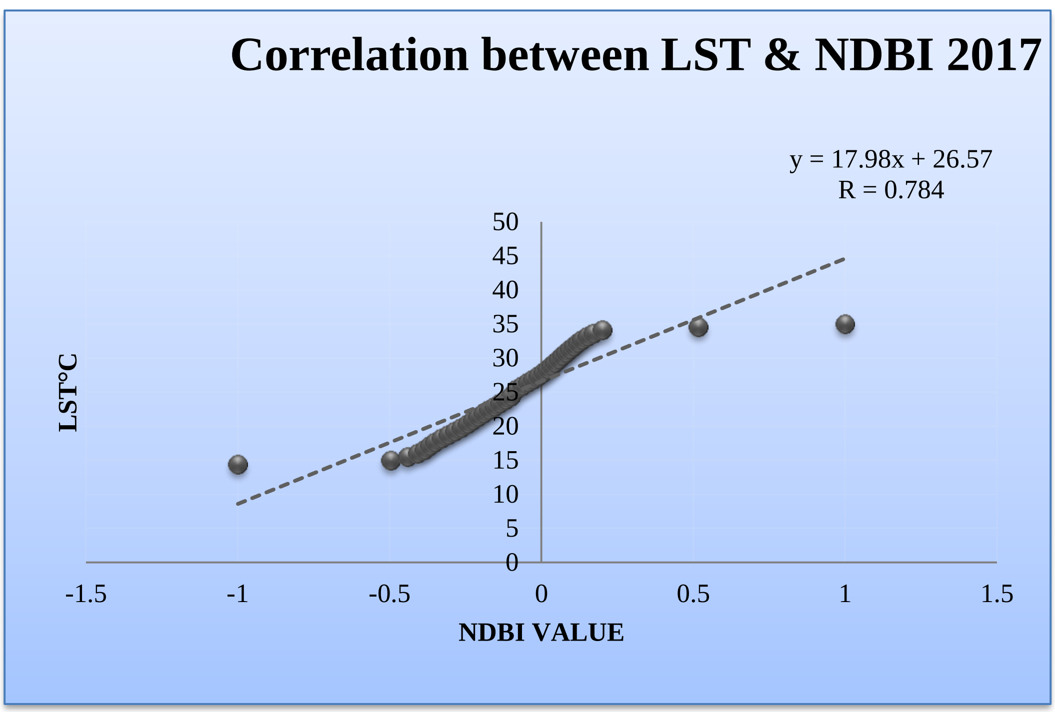

Fig. 6. Correlation between LST and NDBI

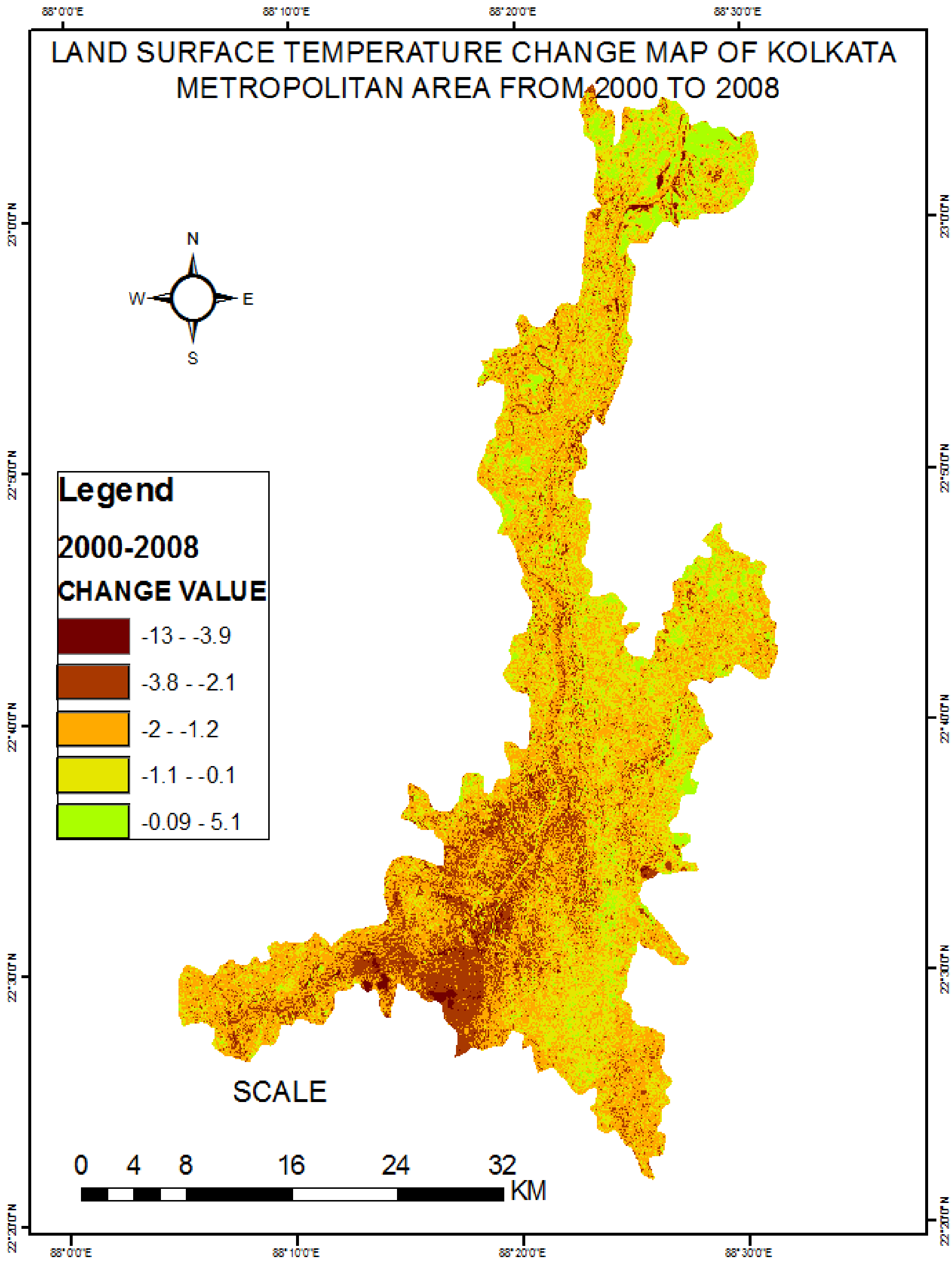

Fig. 7. Land Surface Temperature Change Map of 2000 to 2008

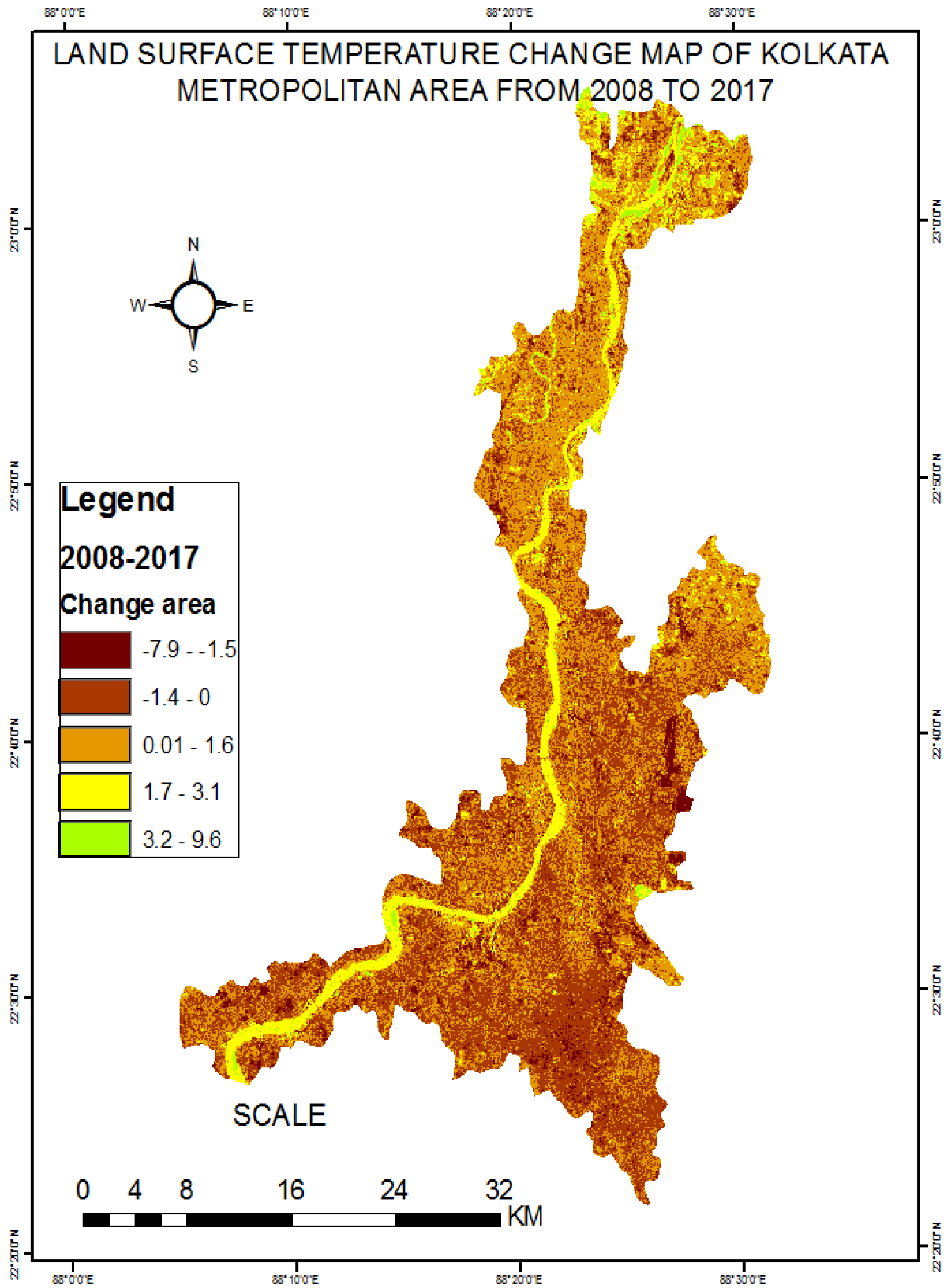

Fig. 8. Land Surface Temperature Change Map of 2008 to 2017

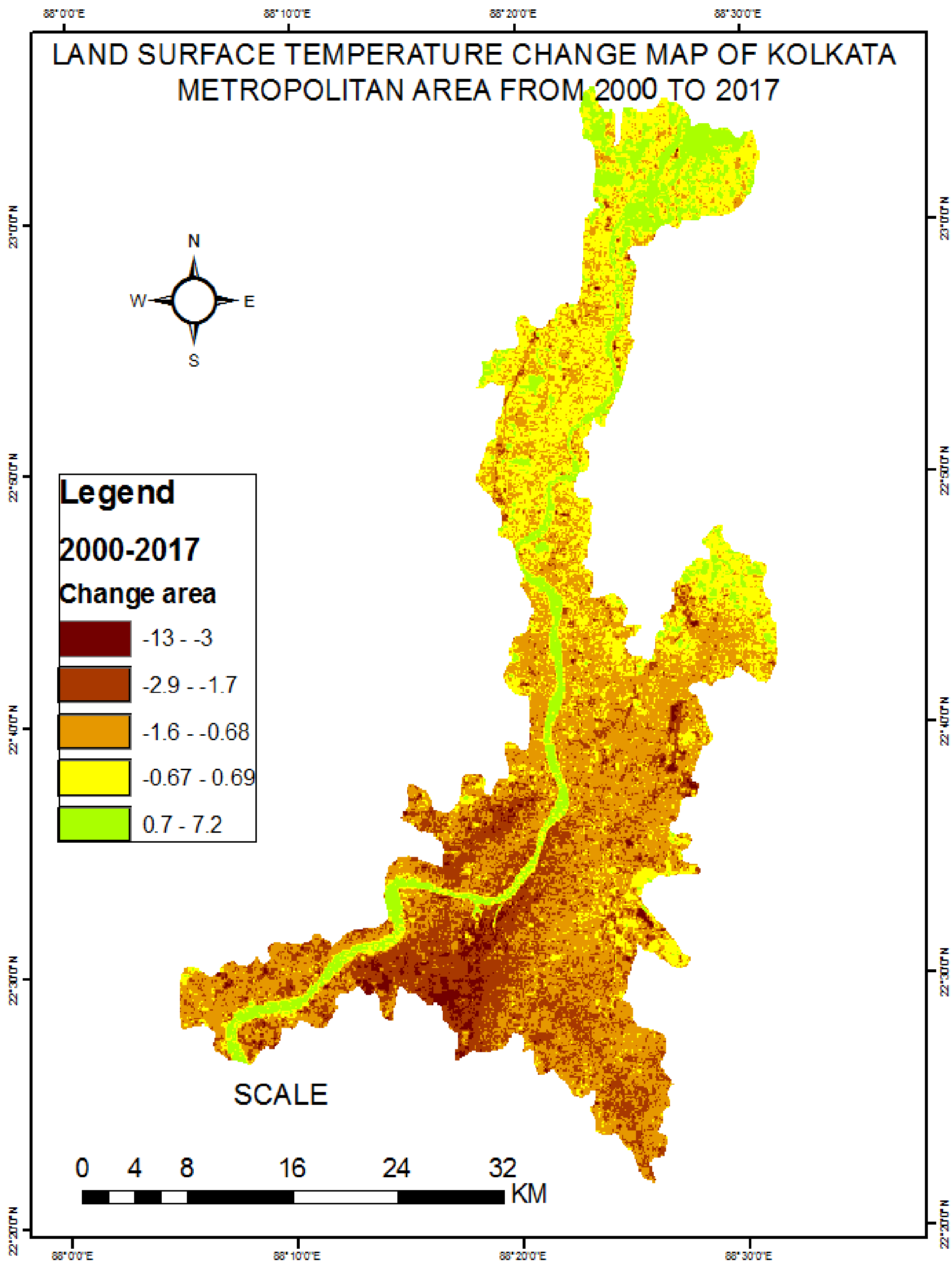

Fig. 9. Land Surface Temperature Change Map of 2000to 2017

