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# Land Use Land Cover Changes and Its Impact on Land Surface Temperature in Rajpur-Sonarpur Municipal Area, West Bengal

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**Abstract**

Rapid urban growth within short period of time creates havoc changes in land use land cover (LULC) all over the world especially in developing countries. Numerous Indian cities are facing such type of problems mainly due to the unplanned and haphazard urban growth. The present study emphasizes on the land use land cover changes using satellite imageries from 1991 to 2021 at ten years interval and its impacts on land surface temperature (LST) in Rajpur-Sonarpur Municipal area located in the district of South 24 Parganas, West Bengal. It was found that over the last 30 years, positive changes occurred in case of built-up area (9.26% to 45.96%) and open space (1.24% to 23.05%) while negative changes found in vegetation coverage (40.99% to 19.32%), water bodies (4.34% to 2.03%) and agricultural land (44.16% to 9.63%) in terms of total geographical area. On the time being there is an increasing tendency of construction sites and built-up areas at the cost of vegetation coverage as well as the water bodies and agricultural lands which in turn increase the land surface temperature as a continuous process. An average 3 degree Celsius (°C) temperature increased during the study period. So, to arrest the rising temperature and minimize the ill effects of such changes immediate thinking of new urbanism should be adopted and implemented.

**Keywords**: Urban Growth; Land Use Land Cover Changes; Land Surface Temperature; NDVI; RS and GIS

## Introduction

Human activities changing the land use land cover rapidly in the last few decades is causing depletion of natural resources which leads to the different significant environmental problems (Hurni, Tato & Zeleke, 2005). Among them increasing land surface temperature is the most important problem in the earth's surface specially in the urban areas because of the transformation of vegetation coverage into impervious surfaces (Mallick et al., 2008) and conversion of vegetation coverage into bare waste land (Pal & Akoma, 2009). These conversions largely influence the rate of solar radiation absorption, evaporation, transmission of heat to soil, albedo etc. which in turn changes the near-surface atmospheric condition drastically over the urban areas (Mallick et al., 2008). Not only that it also changes the water and energy balances (Oke, 1987) and other significant environmental processes (Weng et al. 2004). About 69% of the world's total population will experience these vulnerabilities by 2050 (United Nations, 2010). The reason behind all of these is the process of urbanization with overwhelming population pressure triggered by the rural to urban migration, development in infrastructure etc. is very high both in terms of intensity and areal coverage in developing countries such as India. This urban expansion influences the LULC change very significantly (Chen et al. 2013; Yirsaw et al. 2017) which in turn affect the climatic condition, environmental fluctuation and biodiversity degradation (Rimal, 2012; Nath et al. 2020). Human demands are changing very fast with the advancement of technologies. To fulfill these demands different new constructions or infrastructures such as apartments, complexes, flats, roads and so on are being constructed that increases the land use proportion. These gradual changes are often notified and reported by the researchers in present day (Jia et al. 2014; Lu et al. 2012).

Satellite imageries based study always provide clear, consistent and repetitive coverage of the earth surface (Owen et al., 1998). Remote sensing data shows the synoptic views of spatial and temporal changes of land use land cover (Friedl et. al. 2010; Solaimani et al. 2010; Jia et al. 2011; Aredehey, Mezgebu & Girma, 2018). It is also helpful for environmental and regional planning. On the other hand LST is broadly utilized by the researcher to know the trend of fluctuation in precipitation and temperature along with vegetation coverage, water bodies and urban area aggregation (Yu et. al. 2021; Zhou & Wang, 2010; Owojori & Hongjie, 2015; Mahato & Pal, 2019). Remote sensing indices like NDBI, NDVI and NDWI help for extracting the built-up area, vegetation coverage and water bodies respectively (Dissanayake, 2020; Forkel et al. 2013). In last few decades NDVI has frequently been used to measure the vegetation percentage of any region ranges from -1 to +1 indicate less or non-vegetation coverage to rich and healthier vegetation coverage respectively (Guo et. al. 2021). In India only the metropolitan cities like Kolkata (Maity & Srivastava, 2020), Mumbai (Grover & Singh, 2015), Delhi (Mallick, et al. 2008; Grover & Singh, 2015; Chakraborty, Kant & Bharath, 2014), Chennai (Lilly Rose & Devadas, 2009), Jaipur (Jalan & Sharma, 2014)) are considered for such type of studies. Only few studies have been carried out on small cities or town such as English Bazar, West Bengal (Pal & Ziaul, 2017) which are started nucleating for heating. So studies on such types of cities or town can help to find out the main causes and give support to adopt proper policies at early stage to overcome or minimize the problems. Keeping this sense in mind present study is based on the rapidly growing Rajpur-Sonarpur Municipal Area, West Bengal, India. It is one of the significant and fastest rising municipalities in India

LST has very strong connection with the NDBI and NDVI and it significantly varies according to the LULC classes with time (Julien et. al. 2011; Tania, Gazi, & Mia, 2021; Chi et al. 2015; Akter, Gazi & Mia, 2021). Ogashawara & Bastos (2012) considered the relationship between built-up land and land surface temperature; water bodies and land surface temperature and vegetation coverage and land surface temperature of the urban centers located in Brazil and mentioned that built up area increases the urban LST on the other hand LST becomes moderate over vegetation coverage and water bodies. Rajpur-Sonarpur Municipal Area as a peripheral part of the Kolkata City and southern continuum of the Kolkata Metropolitan Area (KMA) was a small town with rural ambience just before three decades ago covering only 20.98 Sq. Km. But overwhelming population pressure has transformed it into a big city with polluted urban environment that drastically changes the land use land cover and natural ecological balance of the study.

Main objectives of this study are to find out LULC change during 1991 to 2021 at ten years interval b) NDVI extraction for expansion and intensity of vegetation coverage identification c) LST generation and change detection d) correlation between LST with NDBI and NDVI d) suggest few strategies to improve the environmental degradation and urban planning.

**Study Area**

Rajpur-Sonarpur is one of the oldest municipalities of the district South 24 Parganas in the state of West Bengal extends from $22^015^/$N to $22^019^/$N latitude and $88^032^/$E to $88^034^/$E longitude (Fig.1). It is a part of Gangetic Delta with an average elevation of 8.5m. It was formed in 1876 in the style of South Suburban Town committee and the first census report was published in 1981. It ranked seventh in West Bengal in terms of total population among the Municipal Corporation and Municipalities after Kolkata, Asansol, Howrah, Siliguri, Durgapur and Maheshtala with an area of 49.25 sq. km. It is an important and one of the fastest increasing municipalities in India (Paul, 2017) in terms of population growth rate. In between 1991 and 2001 population growth rate was 459.55% due to reclassification of its jurisdictional area in 1993. This municipality is bounded to the north by Kolkata Municipal Corporation, to the south by Baruipur Community Development block and to the east as well as to the west by the Sonarpur Community Development block. The municipality is served by five Eastern Railway Stations namely New Garia, Garia, Narendrapur, Sonarpur and Subhasgram. Due to its location within the KMA and closeness to the city of Kolkata Rajpur-Sonarpur Municipality performs as a gateway of the district South 24 Parganas (Paul, 2016) which makes it significant in terms of gathering peoples both from city core and remote areas of the district. This continuous process contributes to the rapid pace of urban growth with havoc changes in LULC within a short period of time in the study area. People from adjoining and remote areas of the district choose this area as their area of residents to avail the city services, on the other hand they can keep contacts with their parental houses through eastern railway.

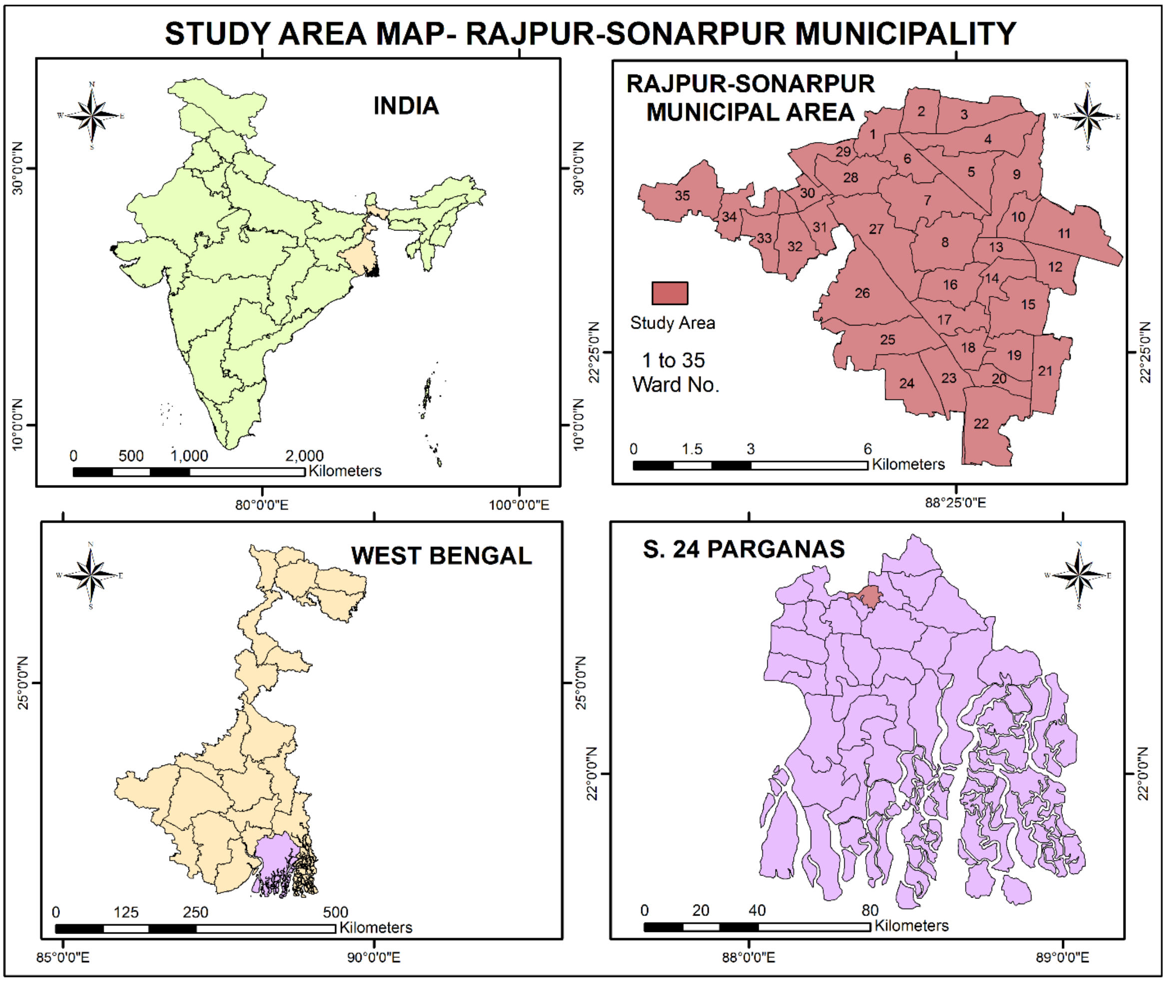



Fig. 1. Location Map of the Study Area

**Database and Methodology**

**Data Used**

From 1991 to 2021 is the time frame of the present study. That's why, Landsat 5 TM (for 1991, 2001 and 2011) and Landsat 8 OLI (for 2021) satellite imageries at 10 years interval have been downloaded from United States Geological Survey (USGS) for detecting the Land Use Land Cover changes, changing scenario of urban green space and Land Surface Temperature with 30m resolution (Table. 1). Not only that, topographical maps of the study area (1959-1960 and 2009-2010) are also collected from Survey of India Office, Kolkata and municipal boundary map gathered from Rajpur-Sonarpur Municipal Head Office, Harinavi. Google Earth Images have also been utilized in this study. Demographic data acquired from secondary sources as the official website of Census of India.

Table 1. Specification of Satellite Imageries

| Data used | Year | Path/Row | Resolution | No. of Bands | Source |
|---|---|---|---|---|---|
| Landsat TM (5) | 1991 | 138/44 | 30 m | 7 | https://earthexplorer.usgs.gov/ |
| Landsat TM (5) | 2001 | 138/44 | 30 m | 7 | https://earthexplorer.usgs.gov/ |
| Landsat TM (5) | 2011 | 138/44 | 30 m | 7 | https://earthexplorer.usgs.gov/ |
| Landsat OLI (8) | 2021 | 138/45 | 30 m | 11 | https://earthexplorer.usgs.gov/ |

### Data Pre-processing

ArcGIS 10.3 software has been used throughout the study. At first municipal boundary map collected and scanned and transformed into digital raster image. After that it has been geometrically rectified through nearest neighbor resampling algorithm and also geo-referenced to UTM Zone 45 North and WGS 84 datum. Atmospheric correction and radiometric correction of imageries have also been performed. Municipal boundary raster data has been converted to vector layer through on screen digitization and it has been used to subtract the Landsat Imageries corresponding to the area of Rajpur-Sonarpur Municipality.

### Image Classification and Accuracy Assessment

For preparing the Land Use Land Cover maps supervised classification with maximum likelihood classifier have been adopted in the present study. Using the spatial resolution of the satellite imageries and surveying the study area five main Land Use Land Cover classes have been identified to represent the physical as well as cultural fabric of the study area. Proposed Land Use Land Cover classes have been selected based on the land cover classification scheme determined by Food and Agricultural Organization (Latham et al. 2002; Di Gregorio & Jansen, 2000). Change detection analysis has also performed for detecting the land alteration in the study area through 'pixel by pixel basis' (Hassan, 2016).

Accuracy assessment is an important tool used to find out the correspondence between the aspect of the surface of the earth and classified images (Owojori & Xie, 2016). To resolve the misclassification issues an accuracy assessment has performed with 135 random ground points for each considered year (1991, 2001, 2011, 2021.) through a recoding method with the help of Google Earth Images, other reference images along with ground truth verification. The results have been analyzed using Overall Accuracy (OA) and Kappa Coefficient (k). It has been found that overall accuracy 84.83% (k = 0.74) for the year 1991, 86.55% (k = 0.81) for the year 2001, 86.93% (k = 0.82) for the year 2011 and 87.53% (k = 0.83) for the year 2021 have achieved. It is found that the accuracy of LULC maps is increasing with time because of the availability of referenced maps with more detailed and higher resolution over time. An Overall Accuracy of 85% for remotely sensed data is quite satisfactory (Anderson et. al. 1976).

**Normalized Difference Vegetation Index (NDVI)**

For the extraction of NDVI value method of Townshend & Justice (1986) has followed by applying equation 1.

$$\text{NDVI} = (\text{NIR} - \text{Red}) / (\text{NIR} + \text{Red}) \quad (1)$$

Where, NIR is the Near-Infrared and R is the Red Band in the satellite imageries.

For Landsat 5 data, NDVI = (Band 4 - Band 3) / (Band 4 + Band 3)

For Landsat 8 data, NDVI = (Band 5 - Band 4) / (Band 5 + Band 4)

Value of NDVI ranges from +1 to -1. Higher the NDVI value indicates dense greenery.

**Normalized Difference Built-up Index (NDBI)**

For extracting Normalized differential built-up index (NDBI) method of Zha et al. (2003) is used. Equation 2.

$$\text{NDBI} = (\text{MIR} - \text{NIR}) / (\text{MIR} + \text{NIR}) \quad (2)$$

Where, MIR is the Middle Infrared and NIR is the Near-Infrared Band in the satellite imageries.

For Landsat 5 data, NDBI = (Band 5 - Band 4) / (Band 5 + Band 4)

For Landsat 8 data, NDBI = (Band 6 - Band 5) / (Band 6 + Band 5)

Value of NDVI ranges from +1 to -1.

**Land Surface Temperature (LST) for Landsat TM (5)**

To calculate Land Surface Temperature for Landsat Data 5 Thermal Band 6 has been used. At first Digital Number has converted into Spectral Radiance (L) following equation 3. ((Mansor & Cracknell, 1994).

$$L = \left(\frac{LMax - LMin}{DNMax}\right)(Band) + LMin \quad (3)$$

Where, L is that the Spectral radiance, Lmax is that the 15.600 (The spectral radiance of DN value 255), Lmin is the 1.238 (The spectral radiance of the DN value 1) and DN is the digital number.

Then Radiance converted into Temperature (Kelvin) following equation 4.

$$T = \frac{K2}{\left[In\left(\frac{K1}{L\lambda}+1\right)\right]} \quad (4)$$

Where, T= Surface Temperature in Kelvin, K1= Calibration Constant 1 (607.76 mWcm-2sr-1µm-1), K2 = Calibration Constant 2 (1260.56 Kelvin), LΛ = Spectral radiance [Watts / ($m^2$ *srad *µm)]

After that Degree Kelvin has converted to Degree Celsius following equation 5.

$$C = T - 273.15 \quad (5)$$

**Land Surface Temperature (LST) for Landsat OLI (8)**

To calculate Land Surface Temperature for Landsat Data 8 Thermal Band10 is used. First Digital Number has converted into Spectral Radiance (L) following equation 6 (Halder et al. 2021).

$$L = \left(\frac{LMax - LMin}{DNMax}\right)(Band) + LMin \quad (6)$$

Where, L is the Atmospheric Spectral Radiance (SR) in watts/ (m2*srad* µm), Lmax is the Maximum spectral radiance of DN value, BandLmin is the Minimum spectral radiance of Band, DNmax is the maximum and minimum difference of sensor calibration.

Then, Spectral Radiance has converted to Brightness Temperature following equation 7 (Gutman et al.2013).

$$BT = \frac{K2}{\left[In\left(\frac{K1}{L\lambda}+1\right)\right]} - 273.15 \quad (7)$$

Where, BT is the Brightness temperature in Celsius. K2 and K1 represents the band-specific thermal conversion constants and Lλ is the Spectral radiance.
Calculation of NDVI by applying equation 8 (Halder et al. 2021).

$$NDVI = (Band\ 5 - Band\ 4) / (Band\ 5 + Band\ 4) \quad (8)$$

Based on the NDVI value Proportion of Vegetation value has been calculated by applying equation 9 (Yu el al. 2014).

$$PV = (NDVI - NDVI\ M_{in} / NDVI\ m_{ax} - NDVI\ Min)^{2} \quad (9)$$

Based on the Proportion of Vegetation value Land Surface Emissivity (LSE) value has been calculated by applying equation 10. (Avdan & Jovanovska, 2016)

$$LSE = 0.004 \times PV + 0.986 \quad (10)$$

After that Land Surface Temperature has been calculated by applying equation 11 (Avdan & Jovanovska, 2016).

$$LST = BT/1 + \{\lambda BT/PV\}\ In\ (LSE) \quad (11)$$

Where, λ is the Wavelength of the emitted radiance

### Correlation between LST with NDBI and NDVI

To show the correlation between LST with NDBI and NDVI 1076 point features have been created and extracted the three values for each point of the year 2021 by using the create fishnet and extract multi values to point tools in Arc GIS software. After getting the values of three variables Pearson's correlation analysis has been adopted to find out the relation between them.

## Result and Discussion

### Origin and Growth of Rajpur-Sonarpur Municipality

The Rajpur-Sonarpur Municipality came into being as the South Suburban Town Committee in 1869. At time passed, awareness of people around Harinavi aroused and they started fighting to claim a separate municipality under the leadership of Zamindar Nabinchand Ghosh ((Bhattacharjee, 2013, Sarkar, 2015). As a result on 1st April, 1876 Rajpur Municipality was set up as a separate municipality with an area about 2 Sq. miles and 5 wards including the villages Rajpur, Jagaddal, Kodalia, Harinavi and Malancha (O'Malley, 1914). According to Rajpur-Sonarpur Municipal Head Office total area of this urban body increased from 5.18 Sq. Km to 20.98 Sq. Km in between the year of 1901 and 1911. At that time most of the land was under agriculture specially paddy cultivation (Chakraborty, 2015). Huge area was covered with natural vegetation and innumerable water bodies. Fishing was another important occupation at that time. (Mukhopadhyay, 1999). The town was growing slowly. After partition of the country in 1947 huge influx of refugees from East Pakistan (Bangladesh) had occurred in many phages which had great influence on the population growth rate in the study area. Growth rate of population was about 52.13% in 1961. As per field survey (2018-2023), 38.81% of the total migrated households came from East Pakistan and distributed all over the municipal area. In 1980 Rajpur municipality was free from administrative rules (Samanta, 2013) and it was implemented various multipurpose plans and projects which helped the residents a lot. Different health projects such as CUDP III (Calcutta Urban Development Project III), IPP-VIII (India Population Project-VIII) etc. were applied, PWD (Public Works Department) started working as a separate wing for public works and Ward Wise Problem Identification Workshop was also conducted (Official Website of Rajpur-Sonarpur Municipality). It was acted as a magnet to pull people from faraway places by providing the urban services at satisfactory level. On the other hand, due to the rapid rate of urbanization in the adjacent areas of the municipality the Panchayat Administration and Development Programme was failure to fulfill their needs. Therefore, the requirement of civic amenities enhanced in manifolds. At that time, the Government of West Bengal took decision to merge the surrounding semi urbanized Panchayat and Non-municipal town areas of Sonarpur C. D block under 26 Mouzas (28.27 Sq.km) with the existing area of Rajpur Municipality (20.98 Sq.km). That's why on 16th December in the year of 1993 Rajpur municipality took the present form with the total area of 49.25 Sq.km and renamed as Rajpur-Sonarpur municipality with a population of about 2, 28,000 and 30 wards (RSM Head Office, Harinavi).

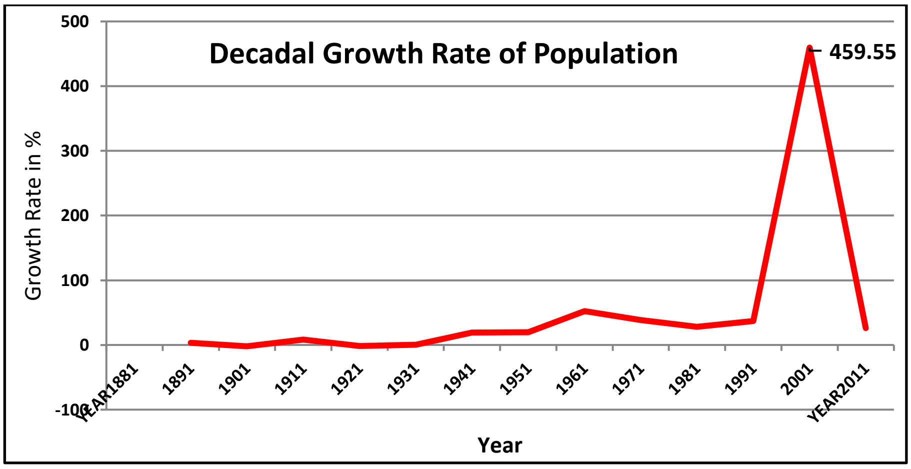



Fig. 2.

Source: District Census Handbook, South 24 Parganas, 2011

| Table 2. Decadal Growth Rate of Built-Up Area | | |
|---|---|---|
| Year | Built-up Area (Sq. Km) | Growth Rate (%) |
| 1991 | 4.5621 | |
| 2001 | 8.8253 | 93.45 |
| 2011 | 14.8734 | 68.53 |
| 2021 | 22.6345 | 52.18 |

Source: Landsat TM (1991-2011) and Landsat OLI (2021)

**Population Growth Rate**

Figure 2 shows the trend of urban growth rate of the study area from 1881 to 2011. Up to 1991 it was not noticeable but fluctuating in nature due to the immigration of refugees from East Pakistan in different phases. But in 2001 it was not only increased but also attained to 459.55% due to the reclassification of its jurisdictional area in 1993. Though in between 1993 and 2001 population growth rate was 5.88% per annum (Rajpur-Sonarpur Municipal Head Office, Harinavi) following the average trend of developing countries mainly due to rural rush that becomes is an important feature of urbanization in India. According to 2011 census report 31.1% of the total population is urban population in India and it will reach about 53% in 2050 (UN World Urbanization Prospect, 2018). As per field survey (from 2018 to 2023) 62.59% of the total households are immigrated among which 38.69% is international mainly from Bangladesh and 26.13% is intra-district. Not only that, this municipality ranked first among the seven municipalities (Maheshtala, Baruipur, Pujali, Jaynagar-Mazilpur, Budge-Budge, Diamond-Harbour and Rajpur-Sonarpur) in the district of South 24

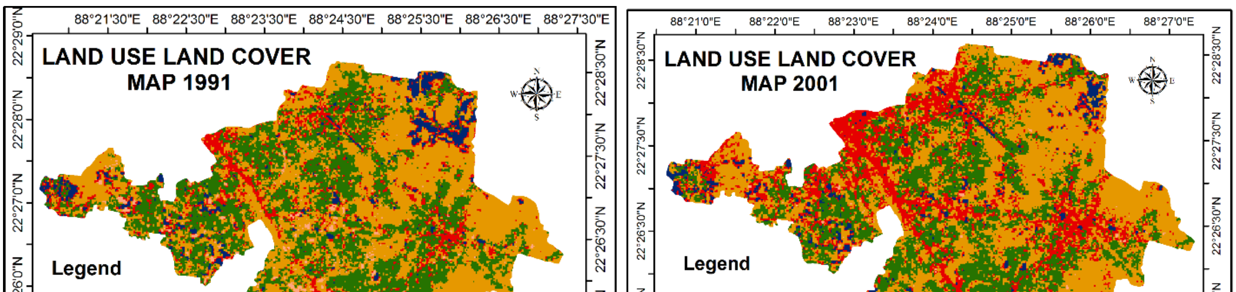
Parganas in terms of population growth rate (26.03%) in 2011 (Census of India, 2011) with the primacy index value 5.52. On the other hand, table. 2 reflects the trend of growth rate of the built-up area. Highest growth rate has observed between 1991 and 2001 following the same trend of population growth rate.

### Land Use Land Cover Analysis

Based on the interest of the study, spatial resolution of the satellite imageries and field survey in the study area five main Land Use Land Cover classes have been identified that shows an impression of the major Land Use Land Cover types of Rajpur-Sonarpur Municipal Area from 1991 to 2021 (Figure no. 3 a-d). These major LULC classes are built-up area, water body, vegetation, open space and agricultural land. Temporal changes in area under each LULC class and rate of change have shown by figure no. 4a and 4b considering the overall landscape of Rajpur-Sonarpur Municipality. Now, the municipal total area is 49.25 Sq. Km.

### Changes in Land Use Land Cover

Land Use Land Cover change analysis is an important measure for monitoring the urban growth and as well as the thermal variation on the earth surface. Pattern of LULC changes for the year 1991, 2001, 2011 and 2021 has shown by the figure no. 4a and 4b. It is revealed that agriculture was the predominant land use class (21.75 Sq. Km) in 1991 and covered about 44.16% of the total geographical area of the study area. Vegetation coverage is another important land cover type of Rajpur-Sonarpur Municipal Area occupied about 20.19 Sq. Km in 1991 which shared about 40.99% of the total land. Agricultural land and vegetation coverage decreased at an annual rate of 2.61% and 1.76% and reached to 9.63% and 19.32% in 2021 respectively. Less or marginal profit in agricultural practices demotivated the farmers to continue their agricultural activities and forced to sell their productive agricultural land to the property dealers, real estate managers, developers etc. that transforms to built-up area in short future. Negative changes occurred in another significant land cover type i. e. water body at an annual rate of 1.78% with around 4.34% to 2.03% since 1991-2021. Filled up the water bodies has now become an almost daily occurrence in the study area. Not only that according to the reputed News Paper there have been reports of the collusion of local leaders in such incidents. Most of land under these three types of LULC converted into built-up land to support huge population pressure during the study period. Process of urbanization enhanced the urban growth mainly through the migration as well as the natural increase of population in the study area. This class of LULC has experienced positive and the highest rate of change. In between 1991 and 2021 recorded areal expansion has taken place from 9.26% to 45.96% with an annual rate of 13.21% at the cost of vegetation coverage, water body and agricultural land. Its location within KMDA, closeness to the city of Kolkata, well connectivity with the state capital through road ways (E.M Bypass Road, N.S.C. Bose Road, Garia Sation Road et.) and Suburban Railway Sealdah South Section and easy accessibility of the city core, availability of land are the main reason behind the rapid urban growth rate. People from adjacent and remote rural areas migrates to the Rajpur-Sonarpur Municipal area mainly to avail employment opportunities, to get educational and health facilities and to enjoy other urban services from the municipality as well as the city of Kolkata on the one hand, on the other hand they can keep contact with their parental houses through both the road ways and railways.



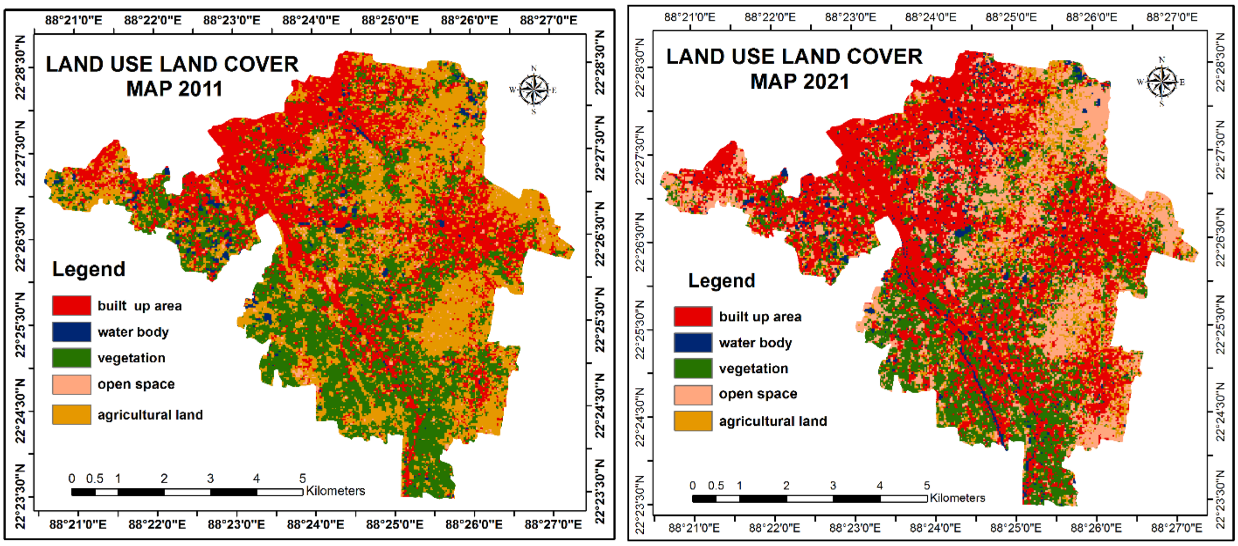



Fig. 3. Land Use Land Cover Maps of 1991(a), 2001(b), 2011(c) and 2021(d)

Another important conversion has been observed in area under open space that is from 1.24% to 23.05% during the study period mostly capturing the agricultural land. Most of the open space keeps for selling purpose. Huge population pressure creates high demand of land which in turn increase the land value.

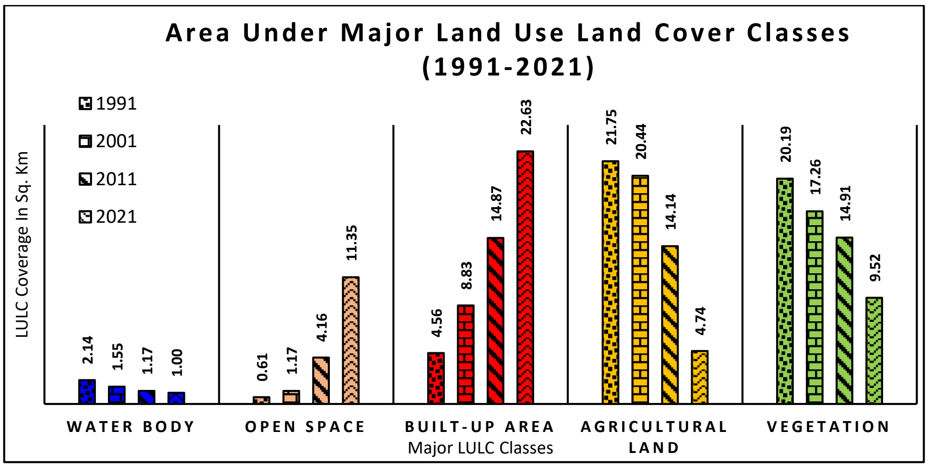



Fig. 4 a. Area under Different LULC Classes (1991, 2001, 2011 and 2021)

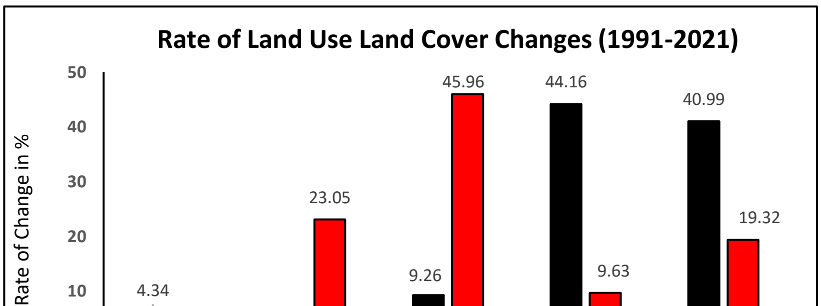
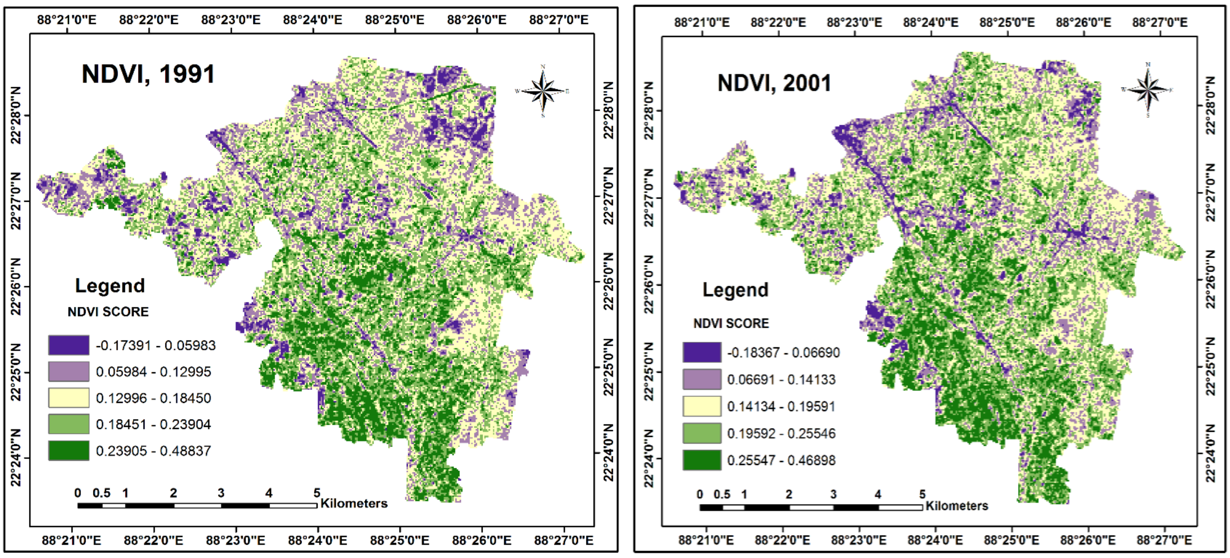


Fig. 4 b. Percentage of Area under Different LULC Classes (1991 and 2021)

**Normalized Differences Vegetation Index (NDVI) and its Changes**

Vegetation coverage is an important part of the earth's surface. Its distributional pattern, intensity, continuity play an important role for influencing the land surface temperature in any area. Figure 5.a-d reveals the spatial pattern and intensity of the vegetation coverage in the study area extracted from the satellite imageries from 1991 to 2021 at ten years interval as mentioned in the data used section in this study. NDVI value varies from +1 to -1. Negative value indicates lack of vegetation coverage and the other types of land use like built-up areas (Singh & Javeed, 2020). Higher values reveal rich and healthier vegetation coverage (Jothimani & Gunalan, 2021). Rapid and huge growth of built-up area and open space and squeezing of agricultural land are the main controlling factors behind the dynamics of NDVI in the study area. NDVI ranged from -0.17391 to 0.48837 in 1991 and from -0.14831 to 0.38138 in 2021.
NDVI score varies due to the intensity and canopy coverage of the vegetation land. Maximum changes observed in the south western part of the study area which had covered with dense vegetation in 1991 but continuous urban growth along the N.S.C. Bose Road (State High Way 1) and newly constructed Eastern Metropolitan Bypass Road have decreased the intensity of the green space. Not



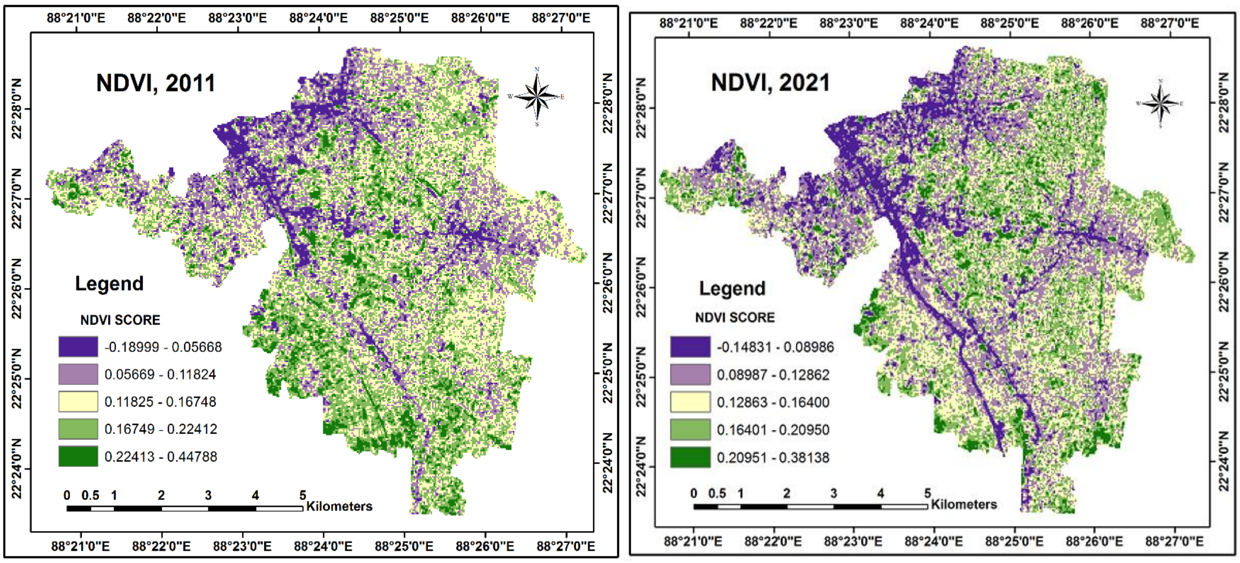


Fig. 5. Normalized Difference Vegetation Index, 1991(a), 2001(b), 2011(c) and 2021(d)

only that, quality of the vegetation coverage also declined during the study period (Table no. 3 to 7). It has been observed that in 1991 area under rich and healthier vegetation coverage was 44.14 Sq. Km and reduced to 30.73 Sq. Km in 2021 due to the continuous human intervention on nature.

Table 3. Statistics of Normalized Differences Vegetation Index (NDVI)

| | 1991 | 2001 | 2011 | 2021 |
|---|---|---|---|---|
| Minimum | -0.17391 | -0.18367 | -0.18999 | -0.14831 |
| Maximum | 0.48837 | 0.46898 | 0.44788 | 0.38138 |
| Mean | 0.15723 | 0.14266 | 0.12895 | 0.11654 |
| Standard Deviation | 0.46830 | 0.46149 | 0.45104 | 0.37454 |

Table 4. NDVI Score, 1991 and Area Under Each Class

| Class | Count | Area | Percentage |
|---|---|---|---|
| -0.17391-0.05983 | 2771 | 2.49390 | 5.04993 |
| 0.05984 - 0.12995 | 9203 | 8.28270 | 16.77176 |
| 0.12996 - 0.18450 | 18680 | 16.81200 | 34.04286 |
| 0.18451 - 0.23904 | 16103 | 14.49270 | 29.34648 |
| 0.23905 - 0.48837 | 8115 | 7.30350 | 14.78896 |

Table 5. NDVI Score, 2001 and Area Under Each Class

| Class | Count | Area | Percentage |
|---|---|---|---|
| -0.18367-0.06690 | 2541 | 2.28690 | 4.63078 |
| 0.06691 - 0.14133 | 8955 | 8.05950 | 16.31980 |
| 0.14134 - 0.19591 | 18104 | 16.29360 | 32.99315 |
| 0.19592 - 0.25546 | 16744 | 15.06960 | 30.51465 |
| 0.25547 - 0.46898 | 8528 | 7.67520 | 15.54162 |

| Table 6. NDVI Score, 2011 and Area Under Each Class | | | |
|---|---|---|---|
| Class | Count | Area | Percentage |
| -0.18999-0.05668 | 4633 | 4.16970 | 8.44329 |
| 0.05669 - 0.11824 | 12664 | 11.39760 | 23.07917 |
| 0.11825 - 0.16748 | 18443 | 16.59870 | 33.61095 |
| 0.16749 - 0.22412 | 14683 | 13.21470 | 26.75864 |
| 0.22413 - 0.44788 | 4449 | 4.00410 | 8.10796 |

| Table 7. NDVI Score, 2021 and Area Under Each Class | | | |
|---|---|---|---|
| Class | Count | Area | Percentage |
| -0.14831 - 0.08986 | 6483 | 5.83470 | 11.81477 |
| 0.08987 - 0.12862 | 15024 | 13.52160 | 27.38009 |
| 0.12863 - 0.16400 | 16502 | 14.85180 | 30.07363 |
| 0.16401 - 0.20950 | 12841 | 11.55690 | 23.40174 |
| 0.20951 - 0.38138 | 4022 | 3.61980 | 7.32979 |

Source: Normalized Difference Vegetation Index obtained from Landsat TM (1991-2011) and Landsat OLI (2021)

**Land Surface Temperature and Its Changes**

Figure 6.a-d shows the temporal trend and spatial pattern of the land surface temperature in the study area from 1991 to 2021 at ten years interval. In all the LST maps bright reddish tone indicates the comparatively higher temperature and greenish tone indicates comparatively lower land surface temperature in degree Celsius (° C). The trend and pattern of LST highlights the rapid changes in land use land cover in the study area. LST was confined within the range of 19.6 ° C and 24.6 ° C in month of March, 1991 and mean temperature was 22.1 ° C during this time. Comparatively high temperature has observed mainly along the transportation network (N.S.C. Bose Road and Eastern Railway line) but most of the areas experienced comparatively moderate to low temperature with the range of 20.9 ° C to 22.4 ° C. In the next three phases both the maximum and minimum land surface temperature have heaved up. Maximum temperature raised up by 1.5 ° C, 1.2 ° C and 1.4 ° C during 1991-2001, 2001-2011, and 2011-2021 respectively. Similarly minimum temperature has also increased by 1.0 ° C, 0.8 ° C and 1.2 ° C. Average land surface temperature has increased by about 3.6 ° C between 1991 and 2021 with an increasing rate of 0.12 ° C per year which is quite alarming for the environment.

South eastern part of the study area exhibit comparatively low range of temperature because of the presence of more vegetation than the other areas. Not only that, there were many swampy ground at the earlier stage. On the other hand it is observed that northern and north eastern part of the study area have experienced highest land surface temperature throughout the study period. Maximum urban growth has taken place in this portion as a peripheral part of the Kolkata city. People mostly likes to stay in touch of the megacity. Moreover, comparatively low price of land, more availability of land, low cost of living reinforce the urban growth rate in this area. Value of LST also high along the Eastern Railway Line due to the concentration of population in this area.

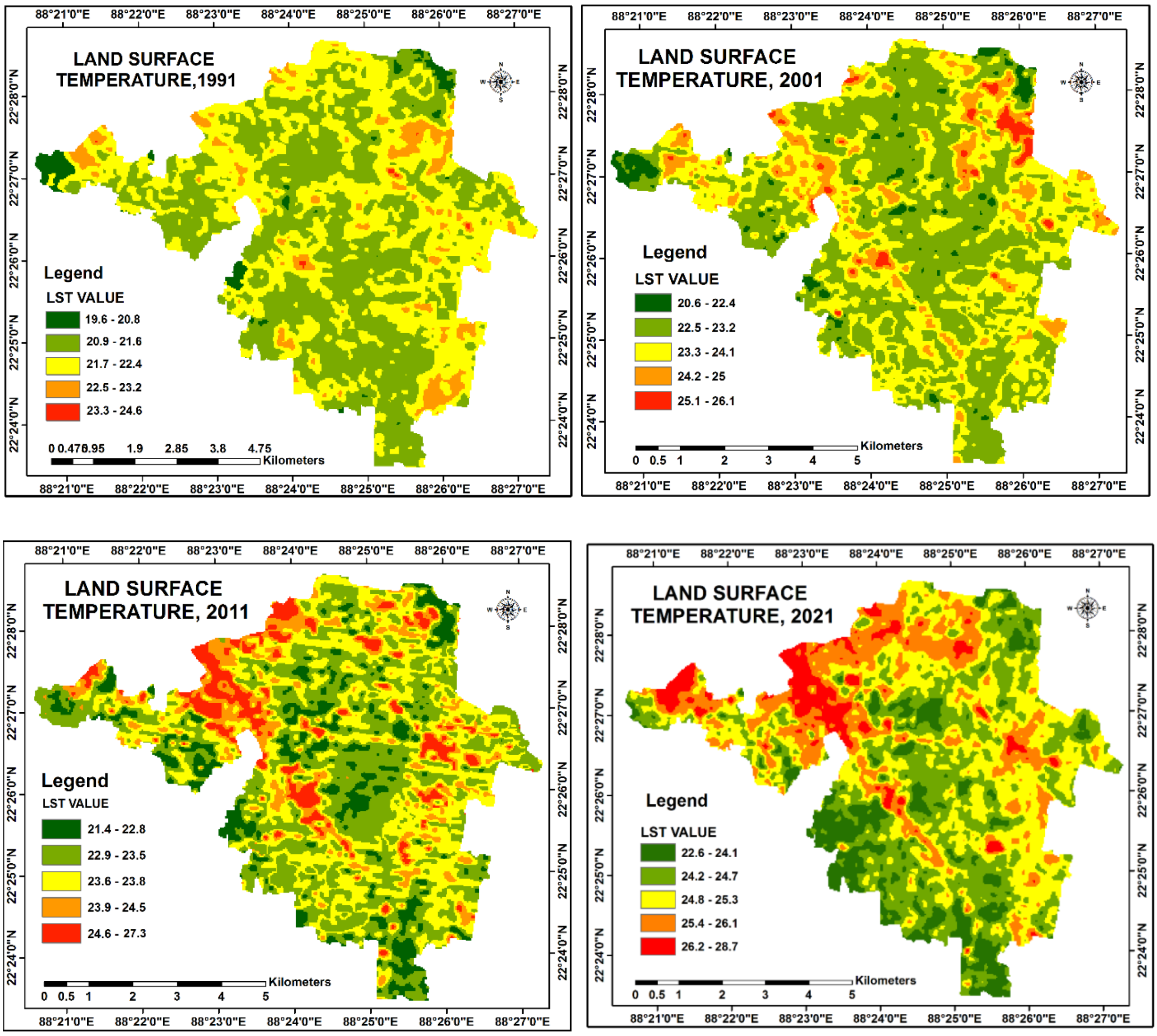



Fig. 6. Land Surface Temperature Map, 1991 (a. February), 2001 (b. February), 2011 (c. February) and 2021 (d. March)

**Temperature Variations on Different Land Cover Types**

Remotely sensed land surface temperature means recorded radiative energy emitted from different types of ground surfaces such as built-up areas including roofs of the buildings, paved surfaces etc., vegetation coverage, bare ground and water bodies (Arnfield, 2003; Voogt & Oke, 2003). To understand the influence of land use land cover on surface radiant temperature, studies on LST over different LULC class specially the main types must be needed. To show the LST variation according to land use land cover three cross sections line A-B, C-D, E-F (Fig. 7) have been drawn across the study area. It is observed that north, north western and eastern part of the study area experienced high land surface temperature (26.73° C in profile AB) due to the dominance of built-up areas causes huge land use changes. Well connectivity with the city of Kolkata through both the railway and roadway, attachment with the city are the main reasons behind the population concentration and urban growth in these areas. Not only that, highest temperature always recorded over built-up areas during the study period (24.6 ° C in 1991, 26.1 ° C in 2001, 27.3 ° C in 2011 and 28.7 ° C in 2021). It indicates that urban growth carries up LST with non-evaporation based surfaces such as metal, concrete, stone etc. by replacing the less evaporation based natural and semi-natural surfaces.

**LST Profiles (AB, CD and EF) Drawn Over LST Map (March, 2021)**

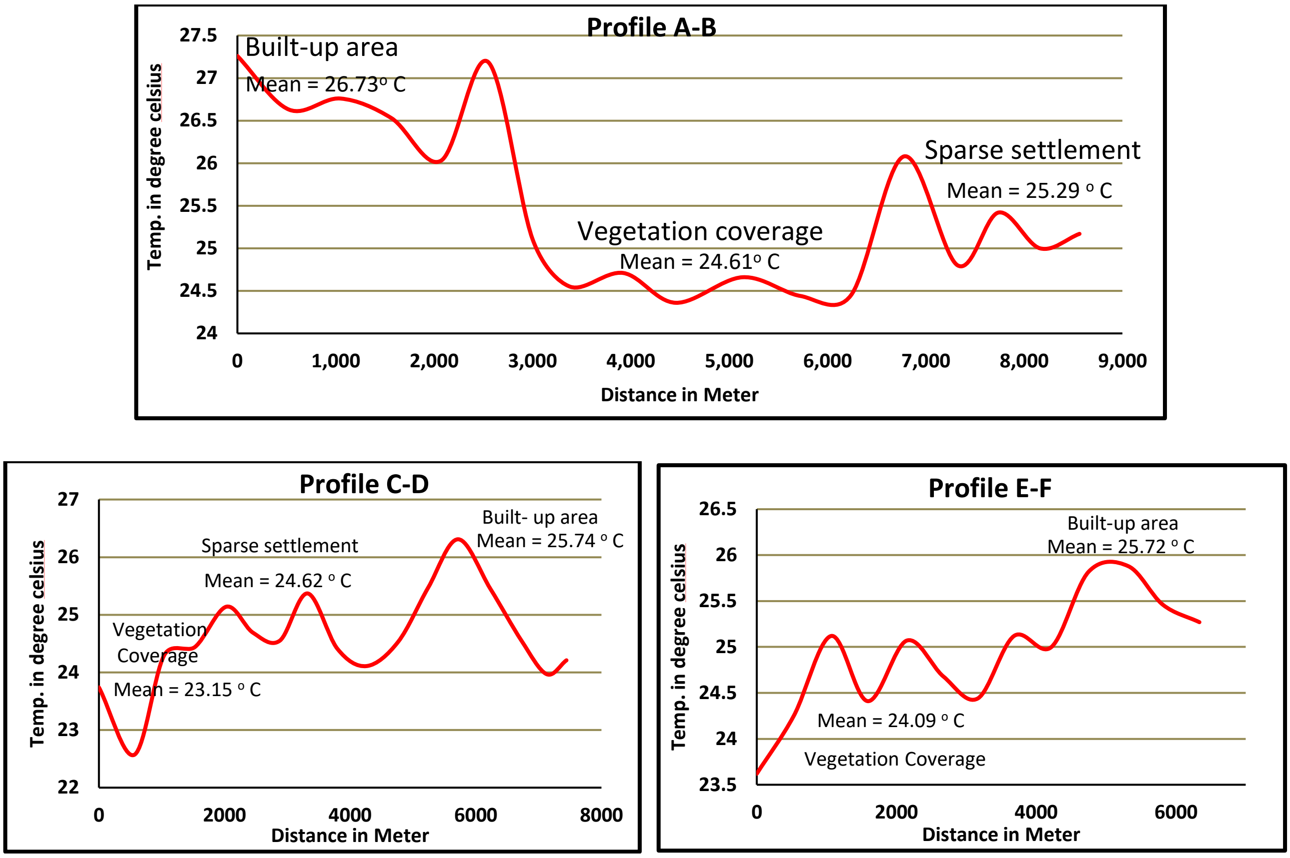



Fig. 7. Land Surface Temperature Profiles (A–B; C–D; E–F) drawn over LST Map 2021

On the other hand city core, southern and south western part exhibit comparatively lower land surface temperature (average LST is 24.61° C in profile AB, 23.15° C in profile CD and 24.51° C in profile EF) than the other parts of the study areas because of the presence of maximum vegetation coverage. Sparse settlement experienced moderate LST ranged between built-up areas and

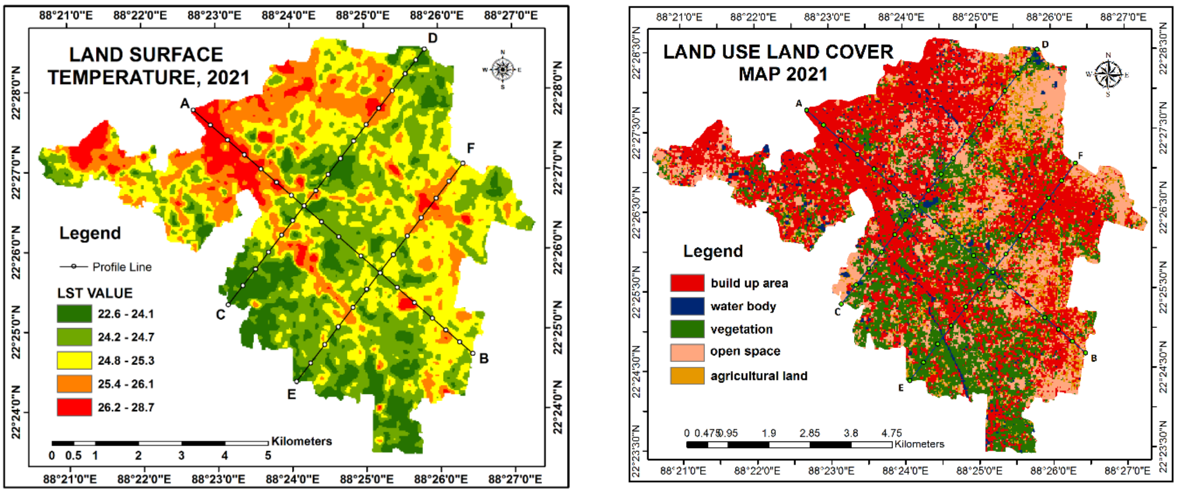



Fig. 8. Three Profiles Drawn over LST Map and LULC Map, 2021

vegetation coverage. Vegetation coverage express comparatively low radiant temperature (24.61 °C in profile AB, 23.15 °C in profile CD and 24.09 °C in profile EF) during this period as the proportion of heat stored within it is reduced through the transpiration (Fig. 8).

### Association of NDBI with LST

A study on correlation between land surface temperature with the normalized difference vegetation index and normalized difference built-up index of the year 2021 has been done. In terms of association of LST and NDBI it is found that built-up area strongly influences the land surface temperature in the study area. High temperature is associated with built-up areas, densely populated zones (Xiong et al. 2012). Such type of relationship is also documented by Lilly Rose & Devadas (2009), Mallick et al. (2008), Zhang & Huang (2015), Ogashawara & Bastos (2012). But due to the variation in intensity of built-up areas and density of population land surface temperature also varies within built-up land in urban areas from place to place area (Mallick et al. 2008). Xiao et al. 2007 mentioned that high land surface is positively correlated with the impervious surface in Beijing, China.

Fig.9 a. shows the extracted normalized difference built-up index classes representing the intensity and spatial pattern of impervious built-up land for 2021. Resultant highest and lowest NDBI values ranged from 0.142857 to -0.362668. On the other hand fig.9 b. reflects the variation in Land Surface Temperature over various land use land cover classes in the study area for 2021. The relationship between these two factors (LST and NDBI) is reflected by the fig. 9 c. Present study just follows the same trend as documented in previous literatures. LST is strongly related with the NDBI in the study area. Value of r (0.586533) intensely indicates that built-up area positively control the land surface temperature means high intensity prone built-up area retains maximum land surface temperature and vice versa.

### Association of NDVI with LST

Many studies have already done to find out the relationship between LST and NDVI (Muralitharan & Wuletaw, 2019; Inamdar, French & Hook, 2008; Li, Saphores & Gillespie, 2015). Fig.10 a. shows the extracted normalized difference vegetation index classes representing the intensity and spatial distributional pattern of vegetation coverage in the study area for 2021. Correlation between extracted NDVI score and LST value for 1076 points located in the study area shows that the two variables are inversely related to each other which means lower level of LST is observed over high vegetative areas and vice versa (Figure 10 b.). Value of r is -0.47987. Visual reflection of the LST map (9.b) and NDVI map (10.a) of 2021 also indicates the inverse relationship between them.

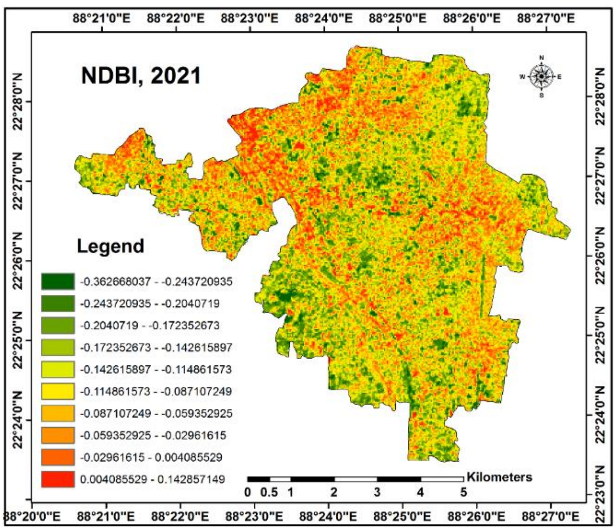



Fig. 9 a. NDBI Map, 2021

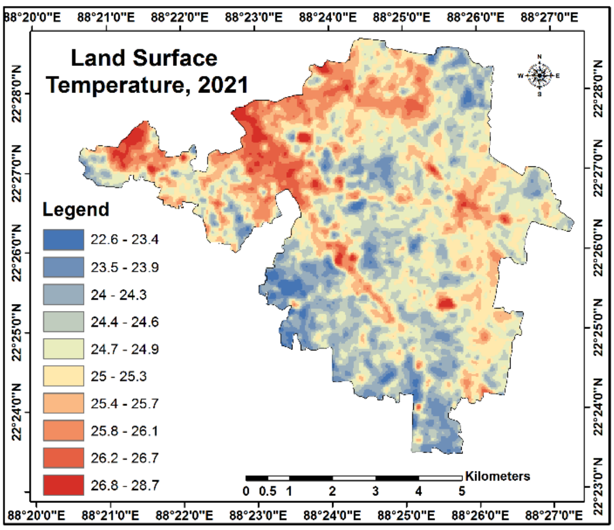



Fig. 9 b. LST Map, 2021

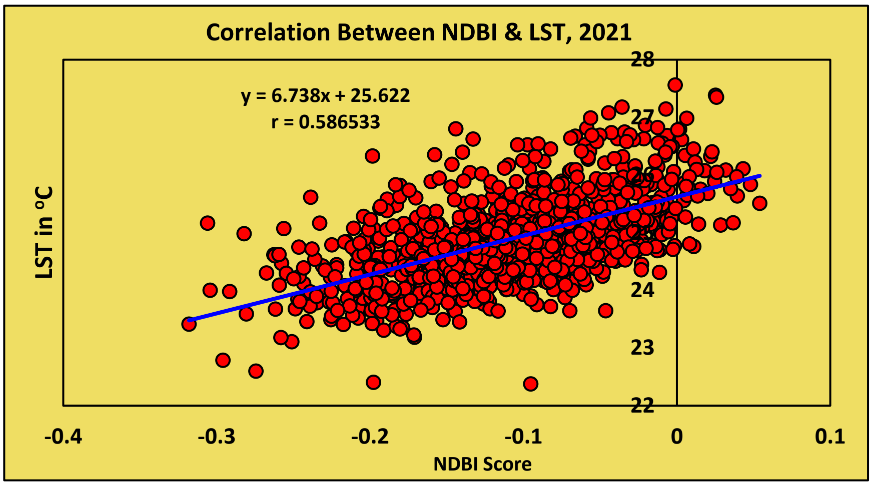
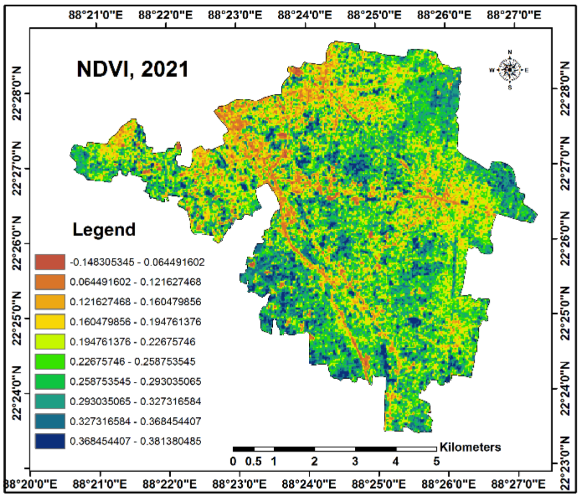



Fig. 9 c. Correlation between NDBI and LST, 2021



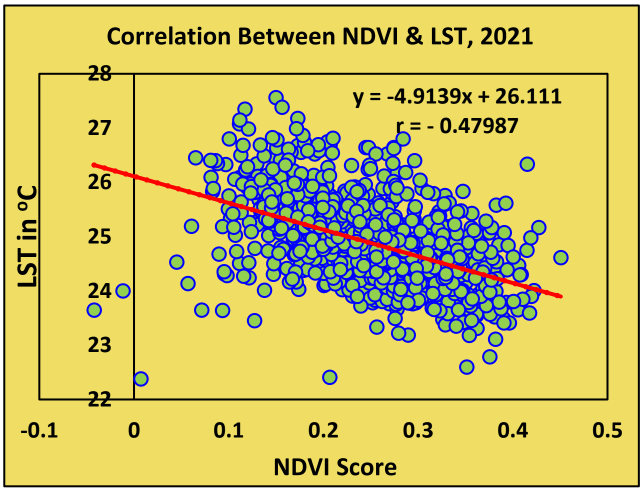




Fig. 10 a. NDVI Map, 2021 Fig.10 b. Correlation between NDVI and LST, 2021

## Conclusion

Rajpur-Sonarpur Municipal Area is the exterior part of the city of Kolkata. Its location within KMDA (Kolkata Metropolitan District Area), closeness to the state capital, strong connectivity with the megacity through both the rail way (Eastern Railway, Sealdah South Section) and road ways (N. S. C. Bose Road, Garia Main Road, Eastern Metropolitan Bypass Road), easy accessibility of the city core, location of metro railway stations at the marginal part etc. play important role behind the rapid rate of urban expansion in the study area. Three to four decades ago a big proportion of the land was under paddy cultivation. Minimum or less profits motivated the farmers to sell their agricultural land to the property dealers, developers, small industrialists, governments which has been converted into built-up areas in short of time.

In this study spatio-temporal trend of LULC, NDVI, LST and the correlation between NDVI and NDBI with the LST have analyzed methodologically using Landsat 5 and 8 remote sensing data of the study area. Dynamics of LULC sharply indicates the increase of built-up areas and other urban amenities at the cost of vegetation coverage, water bodies and agricultural land which in turn develops the heat stress over the study area. Degradation of the vegetative area, filling up of the water bodies, setting up of small scale industries accelerate the increase of land surface temperature. Interrelationship between NDVI and LST shows a negative association between comparatively low LST over green vegetation coverage with high NDVI value and vice in the study area. So, the urban planners of the Rajpur-Sonarpur Municipality can use this knowledge to manage the city's land surface temperature by applying different green building concepts and afforestation programmes such as rooftop gardening, hanging gardening, roadside greeneries etc. Protection of the rest of the green lawns can be done by applying green belt policy suggested by Park, 1986 as in Dhaka Municipality, Bangladesh. Not only that, implementation of new urbanism concept such as green building policy should be done in the planning permission stage will be helpful for reducing the LST in the study area (Kibert, 2012). In contrast, high LST value reflects positive connection with the densely built-up areas. Keeping free the earthen places can also help to reduce the city's land surface temperature.

The findings of this study will be helpful to the planners, policy makers, different administrative and stakeholders to make the city sustainable following the guidelines of sustainable development goals 2030. Not only that this study also provides a justification for constant monitoring of land management and making development policies for this.

### Statements and Declarations

There is no conflict of interest regarding paper publication.

### Funding Statement

There is no financial support for this research study.

### Statement Regarding Data

All the sources of relevant data are given. Therefore, declaration regarding data availability is not applicable in the paper publication.

### Authors' Contribution

Pompa Mondal and Dr. Tapas Mistri both the authors have written the main manuscript text and also reviewed the manuscript. Pompa Mondal has prepared all the figures, tables and maps.

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