



# An assessment on the changing status of urban green space in Asansol city, West Bengal

Giyasuddin Siddique · Arindam Roy · Mehedi Hasan Mandal ·  
Subhendu Ghosh · Aritra Basak · Mukesh Singh · Nabanita Mukherjee

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**Abstract** Urban green spaces play a crucial role in maintaining the sustainability of a city with the promotion of essential ecological functions to supplement the natural and social environment of the urban area. Preservation of a substantial proportion of the city's space under green cover has now become a qualification for city planning and design. But the urban green spaces are vanishing out at an alarming rate caused by rapid and unplanned urbanization—especially in India. It has posed serious threats to the ecological equilibrium of the metros. The present

study strives to explicate the spatiotemporal dynamics of green areas in industrially reliant Asansol city as a corollary of its lopsided expansion during the past years. Though more than half of the study area (55.66%) is covers with vegetation, with notable per capita green space of 44.76 m<sup>2</sup>/city dwellers, but only 0.12% area in the core region of Asansol city is occupied by green cover with a negligible amount of per capita green space of 0.27 m<sup>2</sup>/city dweller, which is much lower than the international standard. Hence sharp discrimination in the distribution of green space has been observed between the city core and the peripheral region. Land use/land cover (LULC) map (2000 and 2018) and normalized difference vegetation index (NDVI) of the same years have been prepared to attest the land transformations in spatiotemporal context. The alterations consequent upon the surface temperature has also been appraised through land surface temperature (LST) maps of 2000 and 2018. A drastic change in LULC mosaic with vast destruction of green spaces (from 66.25 km<sup>2</sup> in 2000 to 20.41 km<sup>2</sup> in 2018) and increasing built-up and commercial spaces has been experienced over the last 18 years (2000–2018). Hence, nearly 14% of vegetated land has vanished during the observation period. Besides, a sharp increment in LST (both the maximum and minimum) has also been found during the stipulated period. The negative relationship between NDVI and LST reveals that the disappearing green spaces act as one of the active factors of increasing temperature during the study period, which has intimidated the

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G. Siddique (✉) · A. Roy · S. Ghosh ·  
A. Basak · M. Singh · N. Mukherjee  
Department of Geography, The University of Burdwan,  
Golapbag, Burdwan, West Bengal 713104, India  
e-mail: gsbu2008@gmail.com

A. Roy  
e-mail: a.roy.sc@gmail.com

S. Ghosh  
e-mail: subhhendughoshgeo@gmail.com

A. Basak  
e-mail: basakaritra5@gmail.com

M. Singh  
e-mail: mukesh01041993@gmail.com

N. Mukherjee  
e-mail: nabanita.mkj@gmail.com

M. H. Mandal  
Department of Geography, Krishnagar Government  
College, Krishnanagar, India  
e-mail: hasanmhm86@gmail.com

sustainability of the natural as well as the social sphere of the city.

**Keywords** Urban green space · Normalized difference vegetation index · City sustainability · Land surface temperature · Land use/cover change · Urban heat island

## Introduction

Urban green spaces are the public and private open spaces interspersed primarily by green plants in urban areas used for multi-functional benefits directly or indirectly received by the city dwellers and commuters (Manlun 2003). These are the most important environmental premises and sometimes eco-heritage of any city (Leeuwen et al. 2009). They are diverse in nature, variable in size, scale, function, and location (Gill et al. 2008). Public green space comprises parks, forests, play grounds, riparian areas like river banks, green promenades and trails, traffic islands and roundabouts, strip and divider plantation, community gardens, street trees, and nature conservation areas as well as less conventional spaces like green walls, green alleyways and cemeteries (Roy et al. 2012). On the other, private green space incorporates green roofs, private backyards, orchards, communal grounds of apartment buildings and corporate campuses (Wolch et al. 2014).

Value of green space in urban ecosystems is enormous. Extensive academic work in such context has been emerged with due emphasis on the needs for conservation of urban green spaces consequent upon the improvement of the quality of urban environment and health of the urban dwellers. Inclusion of sufficient green space in scientific urban planning and management has thus been suggested as essential (Haaland and van den Bosch 2015; Anguluri and Narayanan 2017). But, worldwide random urban expansion has hastily reduced urban green spaces notwithstanding their important services (Zhou and Wang 2011). Over half of the world's population now lives in urban areas, and this proportion is expected to increase to nearly 70% by 2050 (Kondo et al. 2018). Urban growth is occurring right now at an unprecedented rate globally as a shared outcome of natural growth of population and large scale rural to urban

migration (Sun et al. 2013). This process leads to extension of impervious areas and alters the urban landscape with vast loss of green space effective upon bio-psychosocial status of urban habitats, biodiversity and the structure of the urban ecosystem (Kim and Pauleit 2007).

Transformation of urban space with an unprecedented dynamics in functional land use questions the balance between 'red' (built-up spaces) and 'green'. It then becomes obligatory to conserve urban green spaces in the city's territory for its sustainability. But large or small urban centers of the developing world fail to maintain the required level of urban greenery. Asansol Municipal Corporation, the second most populous urban agglomeration of West Bengal after Kolkata, is not an exception as only 9.39% of the geographical area of the city remains under green cover. But unfortunately, the academicians have shown little interest in exploring the status of the green space and its importance in sustaining the city of Asansol. The planners and the policy makers are either less concerned in protecting the urban green or are almost indifferent to this issue. Asansol ranks 11th among Indian cities and 42nd in the world's fastest-growing cities with an average annual growth rate of 3.11% during 2006 to 2020 (IIED Report 2010). Rapid growth of the city has radically altered the city's landscape with increasing built-up and economic spaces with alarming rate of decay of green patches which has deteriorated the environmental quality and has posed threat to its sustainability.

Hence, the prime goals of the present research are:

1. To assess the present status of green cover in comparison to other metros of the country,
2. to appraise the spatio-temporal changes in the land use/land cover composition of Asansol city during 2000–2018 with special emphasis on green cover and the consequent changes in land surface temperature during the period, and

The structure of the present study begins with an informative and detailed introduction followed by brief review of literature; study area; methods and materials; results and discussion and finally ends with conclusion.

## Brief literature review

Urban green spaces are the natural environment connecting human beings with nature (Dai 2011). It provides a gamut of ecosystem services that help support the ecological integrity, sustain the environmental quality, heal several urban uncomfotabilities and improve the quality of life, especially the physical and mental health of the city dwellers (Dahmann et al. 2010). It reduces air pollution and purifies air by subsuming certain airborne pollutants and green house gasses from the atmosphere (like ‘green lungs’), assuages noise, replenishes groundwater through accelerating infiltration rate, reduces surface run-off and risk of urban flooding, moderates temperatures by producing shade and cooling effect, restricts heat island effect and restrains the evil-effects of climate change (Yuan and Bauer 2007; Escobedo et al. 2011; Tu et al. 2016). These green spaces protect local wildlife, conserve biological diversity intrinsically beneficial to the urban sphere (Sister et al. 2010; Kong et al. 2010).

The open and green spaces provide several socio-cultural benefits with immense value (Jennings et al. 2016). Green spaces, as a common arena for physical activity, mental relaxation and recreation, have positive influences on the physiological and psychological health of the urbane (Mitchell and Popham 2007; Jansson 2014). Inter-linkages among the physical and emotional well being with the availability, accessibility and utility of green spaces in cities have been imperative to several studies (Nutsford et al. 2013; Schipperijn et al. 2013; James et al. 2015; Jennings et al. 2016; Zhang et al. 2017; Nath et al. 2018; Kondo et al. 2018). Lack of access to park has been linked to higher rates of overweight and obesity, poorer self-perceived health, and higher mortality risks (Mitchell and Popham 2008; Coutts et al. 2010). Green space improves emotional, cognitive and physiological health and reduces the risks for all that cause mortality and many chronic diseases (Thompson et al. 2012; de Vries et al. 2013).

The association between urban green space and well-being has been extensively studied particularly in the developed countries of the world such as Australia, Europe and North America, while in developing/under developed countries it’s still not evaluated properly (Nath et al. 2018). There is an expanding body of research on epidemiological studies at national level

exploring the relationship between green space and health (de Vries et al. 2003; van den Berg et al. 2010) including local case studies (Grahn et al. 2010) and experimental studies (Park et al. 2010; van den Berg and Custers 2011). A positive association among physical activity, mental recreation and park proximity has been explored in several studies (Sallis et al. 2012; Evenson et al. 2013; Dadvand et al. 2016; Ngom et al. 2016). The studies affirm that green parks promote physical activity, reduce psychological stress, anxiety and depression, enhance social interaction and cohesion and restrict exposure to environmental hazards like air pollution. Green space extends opportunities to meet nature as well as to experience solitude (Fuller et al. 2007). Park visits offer freshness, enhance contemplation and provide a sense of peace and tranquility to visitors (Song et al. 2007). The cooling effect of green space reduces the risk of heat-related illnesses of the city dwellers (Cummins and Jackson 2001). A large number of studies exhibit comprehensive ways of utilizing green spaces for recreational purposes (Sanesi and Chiarello 2006; Arnberger 2006; Neuvonen et al. 2007; Aziz et al. 2018).

Previous studies have focused more on the time consuming and expensive subjective methods of perceived, self-appraised green spaces that involve the method of survey question audited by trained raters who apply specific criteria (e.g. presence/absence of various features) to assess natural environment (Gupta et al. 2012; Bardhan et al. 2016). The emergence of remote sensing (RS) and geographical information system (GIS), the availability of multi-temporal remotely sensed data with enhanced spatial resolution and coverage has facilitated more accurate and extensive monitoring of land use/cover change (Choudhury et al. 2019). Several studies have employed various techniques to quantify the amount, rate and nature of chronological change in green space in various cities of India and abroad along with the transitions of different LULC classes (Shojanoori and Shafri 2016; Chibuike et al. 2018; Singh et al. 2018; Singh 2018).

The issues of urbanization linked to LULC change and environmental implications have achieved a global dimension drawing the attraction of the researchers, administrators, environmental activists as well as the urban planners (NRC 2001). The need to represent and comprehend the spatio-temporal

alterations in land use/cover mosaic made by urbanization, especially to the green spaces, is imperative to formulate sustainable urban development strategies. The scientific understanding of how green and open space benefit people in cities in recent decades have been expanded substantially encompassing social, environmental and economic domains. The urban planners and ecologists, therefore, focus on the strategies for regeneration and preservation of urban greeneries to protect ecological as well as social sustainability (Wolch et al. 2014).

India has witnessed rapid urbanization since 1970 with sharp rise in urban population from 109 million (19.9%) in 1971 to 377 million (31.6%) in 2011. Meanwhile, the number of million-plus cities during 1991–2011 has steadily increased from 23 to 53 (Census of India 2011). Hence, the urban population in India has grown for five times within the last 50 years (Taubenböck et al. 2009). Such unrestrained urbanization has become the prime cause of fast degradation of green space both in quantity (area) and quality (density or health) (Maiti and Agrawal 2005). Despite the phenomenon, the urban green space cover in India is not well-studied except some larger metros like Bangalore (Sudha and Ravindranath 2000; Nagendra and Gopal 2011), Delhi (FSI 2009; Sinha 2013), Kolkata (Bardhan et al. 2016), Pune (Bhakar 2012) and Chandigarh (Chaudhry 2006; Chaudhry and Tewari 2010). Jain (2011) and Rao and Puntambekar (2014) have tried to evaluate the nature and functions of urban green spaces of the Bhopal city, Madhya Pradesh. In 2013, Singh has assessed the status of tree cover in eight Municipal Corporations (such as, Ahmedabad, Surat, Vadodara, Gandhinagar, Rajkot, Bhavnagar, Junagadh, and Jamnagar) of Gujarat, which found that average tree cover (8.78% of the geographical area), tree density (24.8 trees/ha) and tree cover/persons (9.5 m<sup>2</sup>) are much lower than the average of the developed countries (Singh 2013). Singh et al. 2018 has applied geospatial techniques [like Onscreen Digitization, Support Vector Machine-based classification (SVM) and Multi Resolution Segmentation (MRS)] to extract the green spaces of Hisar city of Haryana. Similarly, Lahoti et al. (2019) has shown the utility of GIS-based mapping methods in preparation of spatial database on the public urban green areas of Nagpur city, Maharashtra. Singh (2018) has computed the availability of the urban green

spaces and mapped its spatial distribution in Bathinda city of Punjab by using satellite images and GIS.

But, majority of the small and medium urban centers of India, facing the environmental challenges posed by the shrinking green space and haphazard urban growth, are not properly addressed either by the scholars or by the administrators. Rapid urbanization in India has extensively changed the dynamic relations between ecology, economy and the society at local, regional, and national scales (DeFries and Pandey 2010; Singh et al. 2010). The study of Sudhira et al. (2004) reveals that enormous loss of open spaces and urban wetlands due to urban sprawling of Bangalore city has affected the drainage network, local hydrology and ground water levels (Sudhira et al. 2004).

The status of green space of Asansol city, the 39th largest urban agglomeration of India and an important economic centre of West Bengal characterized with development of mining and industries since the British colonial time has been analyzed in this study with an objective to assess its sustainability. The area is one of the prevalent coal-mining and industrial regions in the eastern India and has accommodated a number of fronts like iron and steel industries, chemical factories, thermal power station, locomotive industry etc., and, obviously a vast number of populations (Reddy and Ruj 2003).

### **The study area: location and geo-environmental set up**

Asansol Municipal Corporation (AMC), the head quarter of Paschim Bardhaman District of West Bengal State, is located at the extreme western part of the District. The total area is 326.48 km<sup>2</sup> accommodating nearly 1.243414 Million population (Census 2011) (Fig. 1).

Established in the year 1886, the Municipality has achieved the Corporation status in 1994 by incorporating Burnpur Notified Area, some collieries and bucolic parts of Asansol Sadar Block. The urban centre took its present extent with annexation of three adjacent municipalities, i.e. Kulti, Jamuria and Raniganj within the jurisdiction of the Asansol Municipal Corporation in 2015 (AMC 2018). The AMC now consists of 106 Wards divided into 10 Boroughs. Of them, 28 wards are under Kulti Municipality, 11 under Raniganj Municipality, 13 under Jamuria

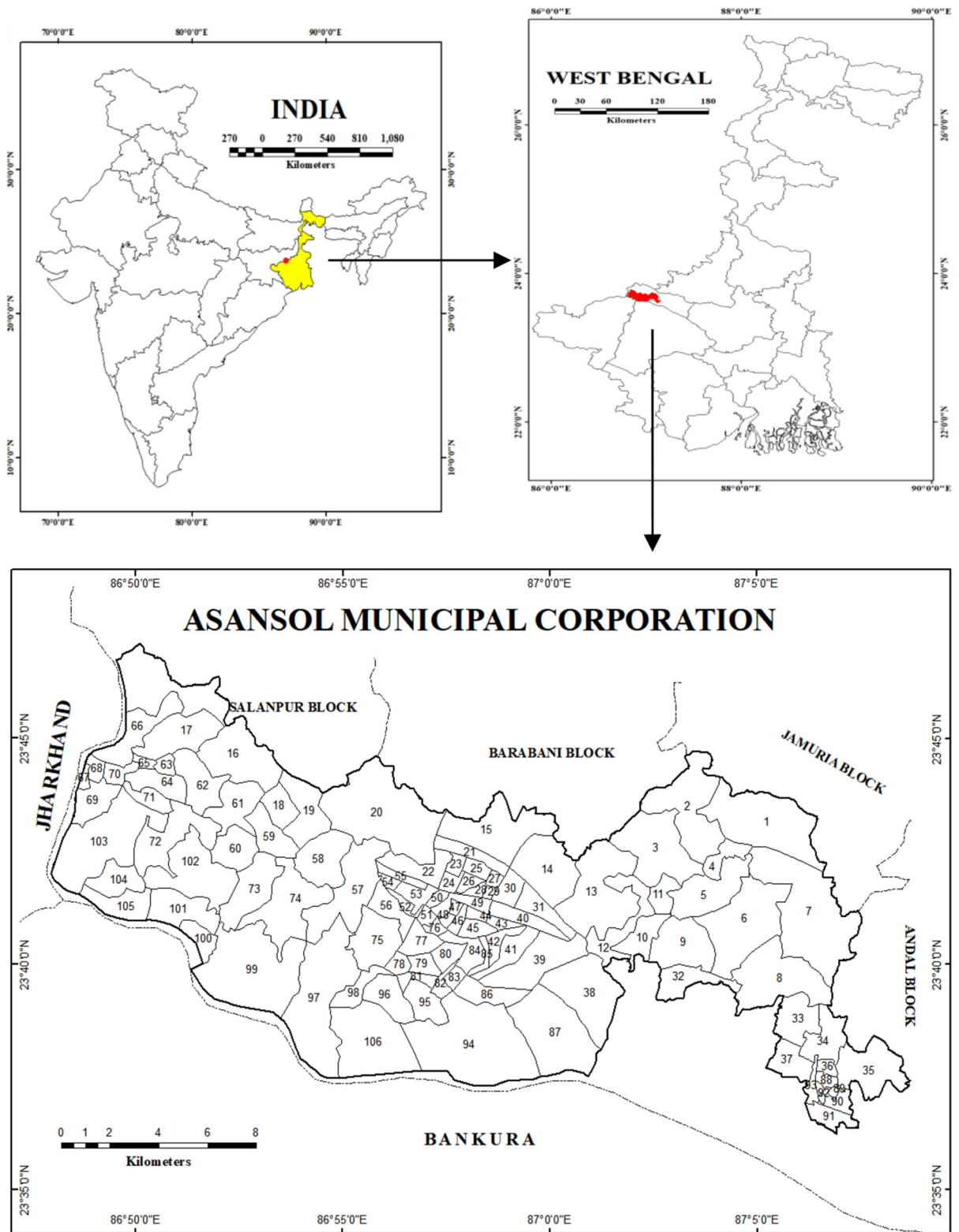


Fig. 1 The study area



Municipality while rests are directly administered by the AMC authority.

Physiographically, the urban centre is situated at the junction of the Chottanagpur plateau in the west and the Ganga plain in the east. Rocks of the region belong to five distinct geological periods i.e. Precambrian, Paleozoic, Mesozoic, Cenozoic, and the Quaternary. A major portion of the region is exposed to the Gondwana Sedimentary rocks, whereas the Archaean rocks are found on the northern and western periphery. In some places, these rocky surfaces are covered with thin alluvium (Chakravarti 1996). The western and South-western part of the area is highly dissected by the small rivulets (like Nunia, Dihika, etc.), which ultimately merges with the Ganges plain in the east. The slope of the region goes north-west to south-east. The elevation of the area varies from 59 to 183 m. Damodar and the Brakar are the two prime rivers that have encircled the urban center on the southern and the western part respectively. Besides, there are many small rivulets or nullahs like Nunia, Dihika, Damra, and Gharai, which flows through the city area (Peterson 1910).

Climate of the area is characterized by Humid Tropics with three distinct seasons i.e. dry summer, wet summer (or Monsoon), and dry winter. The average annual temperature of the area varies from 18 °C (January) to 32 °C (May) and average precipitation is nearly 1100 mm respectively. In summer months, the maximum temperature often goes above 40 °C with blowing of dry hot local wind known as 'loo' while in winter temperatures go below 10 °C. The monsoon lasts from June to September. The Köppen Climate Classification subtype for this climate is "Aw" (Tropical Savanna Climate).

The soil in the area is characterized by coarse gritty combined with disintegrated rock fragments of pegmatite, quartz, and sandstones. Intense weathering and erosion of the plateau rock are responsible for preponderance of Red and Yellow soil. Coal mining and resultant debris have highly modified the soil characteristics of the region. Laterite is the largest group of soil found in the western part of the region. New alluvium is noticed in some places due to the flooding activities of the major rivers of the area.

## Methods and materials

The entire study is based on both primary and secondary data as required. Secondary data has been collected from the Office of the Asansol Municipal Corporation, whereas the primary data has been acquired through frequent field visits to the study area. Temperature at nearly 50 points selected randomly across the city has been recorded with Thermo-anemometer. Temperatures for all the points have been recorded from the open roads and adjacent green spaces to assess the difference of temperature of these two important land use/land cover.

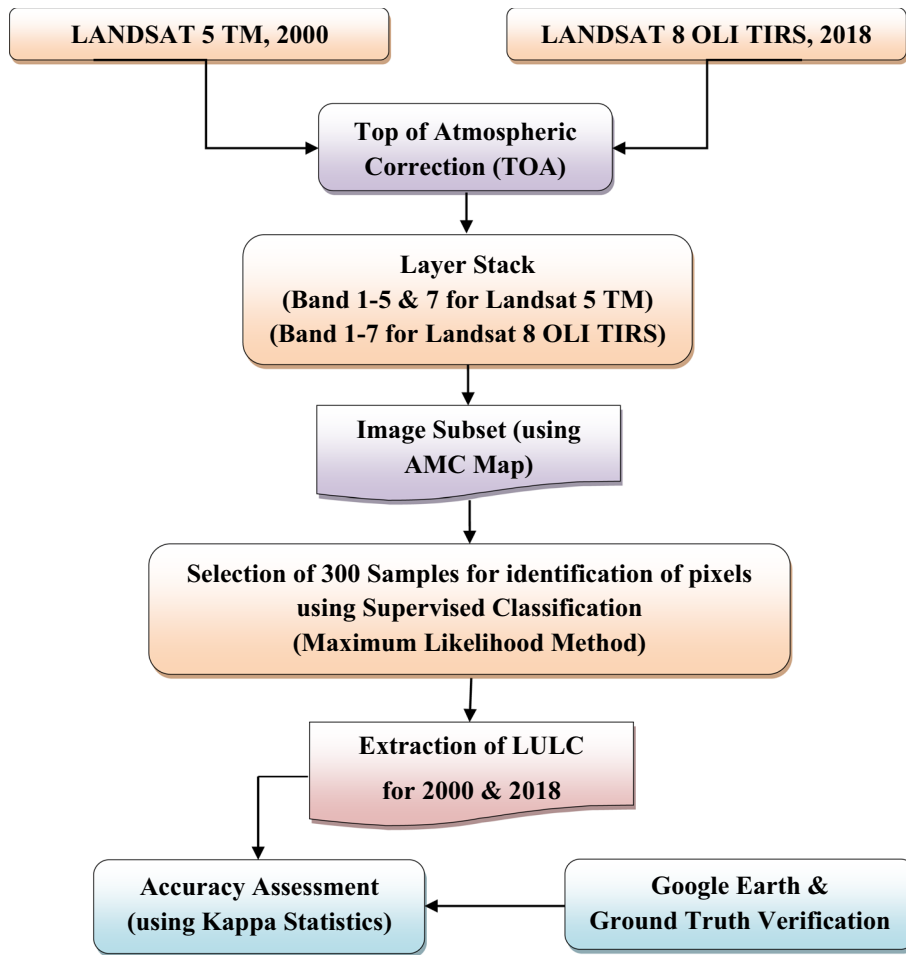
LANDSAT 5TM of May 2000 and LANDSAT 8 OLI TIRS of May 2018 (For both the images—Datum: WGS-84; Projection: UTM Zone 45 N; Path/row: 139/44; Spatial resolution: 30 m) are used to extract the relevant information on the spatio-temporal changes of vegetation cover, surface temperature and land use/cover classes. All the data thus obtained have been arrayed, tabulated and analyzed with the help of simple quantitative techniques. Finally, the obtained result has been discussed and represented using suitable cartographic techniques.

### Method for land use/land cover (LULC) classification

The LULC maps for both the years have been prepared through supervised classification using the Maximum Likelihood method with the help of Arc GIS 10.3.1. Band 1–5 and Band 7 of Landsat 5TM imagery have been considered for the classification, excluding the Band 6 for its thermal properties. On the contrary, Band 1–7 of LANDSAT 8 OLI TIRS has been stacked for the purpose by using the image analyst tool of the software. Then the signature of the pixel is marked by training sample manager tool and nearly 300 sample points are selected randomly from the entire imagery. The following schematic diagram shows the entire procedure of LULC classification (Fig. 2).

Confusion matrix or error matrix has been used to assess the accuracy of the obtained result of LULC, as it explains the actual and predicted identification of the pixel (Pal and Ziaul 2017). To calculate the overall accuracy, the following formula has been employed:

$$T = \frac{\sum D_{ii}}{N}$$



**Fig. 2** Procedures for LULC classification

where  $T$ : Overall accuracy;  $\sum D_{ii}$ : The total Number of Correctly Classified Pixels; and  $N$ : Total number of pixels in the matrix.

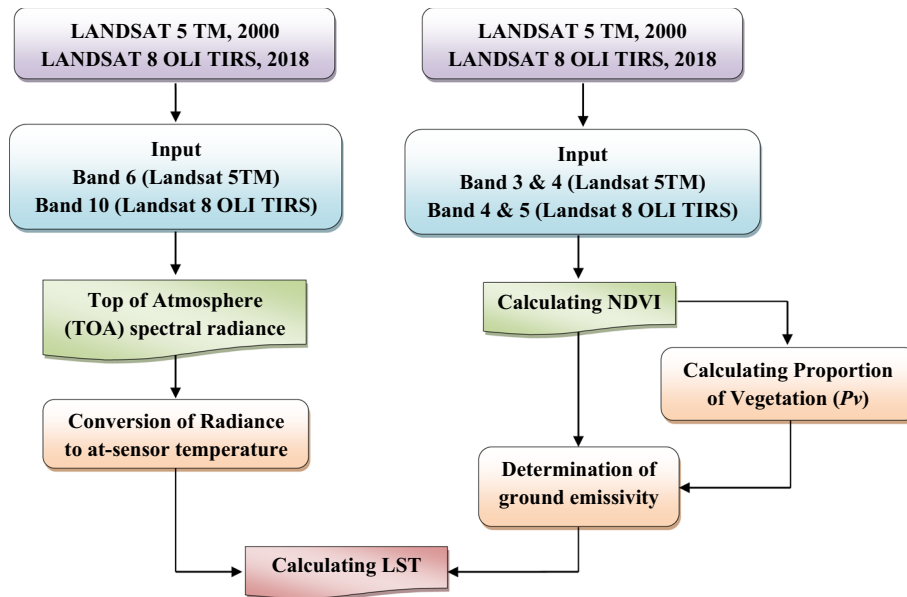
A total number of 300 sample sites (50 random points for six LULC classes) have been selected for ground truth verification from the Google Earth and the actual Ground Control Points (GCPs) with the help of the Global Positioning System (GPS) in this regard. Besides Kappa Coefficient (Kappa hat or  $\hat{K}$ ) is used for accuracy assessment, as it is consider the most efficient measure of accuracy of LULC maps (Foody 1992). The K-value ranges between 0 and 1, where 0 refers to ‘poor agreement’ and 1 represents ‘almost perfect agreement’ (Table 1). Nearly 300 sample sites (50 sites from each LULC Class) have been selected from the entire map to obtain the K-value.

**Table 1** Remarks of the agreement for kappa coefficient  
Source: Landis and Koch 1977

Value of	Nature of Agreement
$0.80 \leq \hat{K} \leq 1$	Almost Perfect Agreement
$0.61 \leq \hat{K} \leq 0.80$	Substantial Agreement
$0.41 \leq \hat{K} \leq 0.60$	Moderate Agreement
$0.21 \leq \hat{K} \leq 0.40$	Fair Agreement
$\hat{K} \geq 0.20$	Slight Agreement
$\hat{K} < 0.00$	Poor Agreement

Calculation of NDVI

Vegetation indices derived from satellite imageries are widely used to monitor global vegetation cover and



**Fig. 3** Procedures of LST extraction

health (Townshend and Justice 1995). The normalized difference vegetation index (NDVI) is one of the most suitable, proficient and widely used techniques for mapping chronological changes in the vegetation health over a wide area (Newnham et al. 2011). Live green plants absorb solar radiation in the photo-synthetically active radiation range and scatter the near-infrared spectral band to avoid over-heating. The NDVI algorithm subtracts the red (R) (0.631–0.692  $\mu\text{m}$  for TM and 0.636–0.673  $\mu\text{m}$  for OLI TIRS) reflectance from the near-infrared (NIR) (0.77–0.90  $\mu\text{m}$  for TM and 0.851–0.879  $\mu\text{m}$  for OLI TIRS) and divides it by the sum of the two (Rouse et al. 1974; Tucker 1979):

$$\text{NDVI} = \text{NIR} - \text{R} / \text{NIR} + \text{R}$$

The values of NDVI range between  $-1$  and  $+1$  with greater positive values indicating luxuriant green and values near to  $-1$  denotes barren land (Bardhan et al. 2016). For the present study, 0.2 has been taken as a threshold and values  $< 0.2$  were not considered, as it represents non-green features like water body.

#### Land surface temperature estimation

The land surface temperature for May 2000 and 2018 has been derived from thermal bands of Landsat 5TM (Band 6) and Landsat 8 OLI TIRS (Band 10) by using

Spectral Radiance Model and Split Window Method. The entire procedure to extract LST has been illustrated below and presented in the following schematic diagram (Fig. 3).

The spectral radiance was first computed by conversion of digital number (DN) contained in the images. It should be noted that, there is a slight difference in conversion of spectral radiance ( $L_\lambda$ ) between Landsat TM and OLI TIRS images. For Landsat TM image, the following equation has been employed for conversion:

$$L_\lambda = LMIN_\lambda + [(LMAX_\lambda - LMIN_\lambda) / (QCALMAX - QCALMIN) * QCAL]$$

where  $QCALMIN = 1$ ;  $QCALMAX = 255$ ;  $QCAL = \text{DN of each pixel}$ ;  $LMAX_\lambda$  and  $LMIN_\lambda$  are the spectral radiance for the band 6 at DN. [The value of  $LMAX_\lambda = 15.303$  and  $LMIN_\lambda = 1.238$ ].

For Landsat OLI TIRS image, the following formula has been used in this context:

$$L_\lambda = (M_L * QCAL) + AL$$

where  $L_\lambda$ : spectral radiance of top of the atmosphere (TOA) ( $\text{W sr}^{-1} \text{m}^{-3}$ );  $M_L$ : band-specific multiplicative rescaling factor (0.0003342);  $QCAL$ : quantified and calibrated standard product pixel values (DN); and  $AL$ : the band-specific additive rescaling factor (0.1).



The extracted spectral radiance was then converted to At-satellite brightness temperature ( $BT$ ) using the following equation:

$$BT = \frac{K_2}{\ln\left(\frac{k_1}{L_\lambda} + 1\right)} - 273.15$$

where  $K_1$  and  $K_2$  are calibration constants of the Landsat 5 TM and Landsat 8 OLI TIRS images i.e.  $K_1 = 607.76$  and  $774.89$  ( $W/m^2$  sr  $\mu m$ ), while  $K_2 = 1260.56$  and  $1321.08$  Kelvin respectively,  $L_\lambda$ : spectral radiance.  $273.15$  help to convert the temperature from Kelvin to Celsius.

Then, proportion of vegetation has been extracted through the equation below:

$$P_v = \left[ \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}} \right]^2$$

where  $NDVI_{max}$  and  $NDVI_{min}$  are the maximum and minimum values of NDVI.

Land surface emissivity was corrected using the following equation (Valor and Caselles 1996):

$$\varepsilon = 0.004 * P_v + 0.986$$

where  $P_v$ : vegetation proportion.

Finally, the land surface temperature was computed by using the following formula:

$$LST_C = \frac{BT}{1 + \left[ \frac{\lambda * BT}{\rho} \right] * In\varepsilon}$$

where  $LST_C$ : Land surface temperature in Celsius;  $BT$ : brightness temperature,  $\lambda$ : wavelength of emitted radiance i.e.  $11.5 \mu m$ ;  $\rho = h * c / \sigma$  ( $1.438 \times 10^{-2}$  m K) [ $h$ : Planck's constant ( $6.626 \times 10^{-34}$  J s);  $c$ : Velocity of light ( $2.998 \times 10^8$  m/s);  $\sigma$ : Boltzmann constant ( $1.38 \times 10^{-23}$  J/K)] and  $\varepsilon$ : emissivity (ranges between 0.97 to 0.99).

## Results and discussion

An account of urban green space: some international statistics

Globally available information suggests that the cities in developed countries have more trees compared to cities in developing countries which often fall below

the minimum standard of WHO ( $9 \text{ m}^2$  green space/city dweller) (Kabisch et al. 2016). An inclusive study across 386 European cities reports that average proportion of green space is 18.6%, which witnesses variation from 1.9% (Reggio di Calabria, Italy) to 46% (Ferrol, Spain) (Fuller and Gaston 2009). Availability of per capita green space ranges from 3 to 4  $\text{m}^2$ /person (Cádiz, Fuenlabrada and Almeria in Spain; Reggio di Calabria in Italy) to more than 300  $\text{m}^2$ /person (Liège in Belgium, Oulu in Finland and Valenciennes in France).

Urban tree cover in the United States ranges from 0.4% (Lancaster, California) to 55% (Baton Rouge, Louisiana), occupying an average canopy cover of 27% (Nowak et al. 2001). A study of 439 cities in China noted that the overall green space was 20.1% of the urban areas in 1991. Almost 40% of the Chinese cities had more than 30% green cover in 1991 (Ming and Profous 1993). The green cover and per capita green space was 23% and 6.52  $\text{m}^2$  respectively in 2000 (Wang 2009). By the end of 2006, green cover in the cities of China has increased to 32.54%. Beijing is rich with vascular plant diversity (2276 species) including 207 species of conservation concern such as endemic, threatened and protected species (Wang et al. 2007) (Table 2).

Cities of developing countries have lower green cover and less per capita availability of urban green space compared to that of the developed countries (Singh et al. 2010). Despite wide variations in coverage as well as per capita availability, cities global renowned for their urban greeneries have 20  $\text{m}^2$  per capita share of urban green space. Most of the Indian cities lag behind such share in comparison to the cities of Europe, Australia, USA and China with few exceptions like Chandigarh, Gandhinagar and Bangalore.

Availability of green space of Asansol in 2011: a comparative analysis in national level

Tree cover in most of the urban areas across the globe is declining to meet the demand of land for residential, commercial and infrastructural development (Singh et al. 2010)—the Indian cities are not exceptions. Green spaces across many cities of India had been conspicuously reduced and are continuously decreasing with rapid urbanization and steady population increase. Per capita availability of green space has

**Table 2** Account of urban green space: international level

Region/country/ City	Estimated area of urban green space and Per capita green space	Source
Urban areas in USA	Average green space: 27% (i.e. 32 m <sup>2</sup> /inhabitant)	Singh et al. (2010) and Chaudhry and Tewari (2011)
Washington, D.C (USA)	Average green space: 28.6% (about 1,928,000 trees)	
San Francisco, USA	13.81 km <sup>2</sup> (i.e. 16.92 m <sup>2</sup> /city dwellers)	Department of Recreation and Parks (2017) Community Report
Europe (26 large cities)	Average green cover: 18.5% (i.e. 104 m <sup>2</sup> /inhabitant)	Konijnendijk (2003)
Paris, France	Average per capita green space: 80 m <sup>2</sup> /inhabitant	Singh et al. (2010)
Great Britain	Average green cover: 14% of urban areas (120,000 ha. of park/garden space)	Singh et al. (2010) and Chaudhry and Tewari (2011)
Netherlands (22 large cities)	Average green space: 19% (i.e. 228 m <sup>2</sup> /inhabitant)	Singh et al. (2010) and Konijnendijk (2003)
Copenhagen, Denmark	Total green space: 22.61 km <sup>2</sup> (i.e. 42.44 m <sup>2</sup> /city dwellers)	EGC 2019
Canberra, Australia	About 2400 ha (about 80 m <sup>2</sup> /inhabitant) contains 400,000 trees belonging to some 200 species	Brack (2002 and Banks and Brack (2003)
Melbourne, Australia	Green space cover: 40% (i.e. 16.3 m <sup>2</sup> /inhabitant) in 1997	Carmona et al. (2003)
Wellington, New Zealand	Average per capita green space: 200 m <sup>2</sup> /person	
China	Average urban green space: 32.54%	Nowak and Greenfeld (2002) and Jim and Wendy (2009)
Hong Kong	Average green space: 1.81% (i.e. 3 m <sup>2</sup> /inhabitant)	Singh et al. (2010) and Chaudhry and Tewari (2011)
Seoul, South Korea	Green space cover: 25.2% (i.e. 14.57 m <sup>2</sup> /inhabitant) in 1996	Aldous (2010)
Kuwait, Malaysia	Average Green cover: 5% (i.e. 2.25 m <sup>2</sup> /inhabitant) in 1998	
Singapore	Average green space: 17.8% (i.e. 7.5 m <sup>2</sup> /inhabitant)	
Colombo, Sri Lanka	Green space cover: 4.4%	
Japan	Average urban green space: 26.74%	Jun (2003)
Tokyo, Japan	Average per capita green space ranges from 6.1 m <sup>2</sup> /person to 8.5 m <sup>2</sup> /person	Carmona et al. (2003)
Hannou, Japan	Average Green space: 84% in 1990	Uozumi (1995)
Curitiba, Brazil	Average per capita green space: 51.5 m <sup>2</sup> /person in 2003	Carmona et al. (2003)

been drastically reduced vis-a-vis increase in urban population and is expected to decrease further. A few numbers of state's capitals like Gandhinagar, Bangalore, Chandigadh, New Delhi, Guwahati, Dehradun, Bhubaneswar, and Shillong are a few green cites of India which have a significant tree cover (Chaudhry and Tewari 2011; Chaudhry et al. 2011). Ahmedabad, Nagpur, Bhavnagar, Vadodara, Thiruwantpuram and Jamshedpur also claim to be the green cites in the

country (Kumbhakar 2012; Imam and Banerjee 2016). Table 3 represents the status of urban green spaces of some large urban centers of the country. Bangalore has reported highest percentage of green cover of 66.37%, followed by Gandhinagar (41%) and Delhi (20.05%). Gandhinagar shows a higher per capita green space of 162.80 m<sup>2</sup>/city dweller, followed by Chandigarh (54.45 m<sup>2</sup>/city dwellers) and Bangalore (17.79 m<sup>2</sup>/city dwellers). On contrary, the other 3 large

**Table 3** Status of urban green spaces in Indian metros 2011

District/City	Total Area (km <sup>2</sup> )	Green Space		Total Population (Million) 2011	Per capita Green Space (m <sup>2</sup> )
		Area (km <sup>2</sup> )	Area (%)		
Delhi	435	90.74	20.85	16.31	5.5
Bangalore	226	150	66.37	8.43	17.79
Chennai	174	9	5.17	8.69	1.03
Mumbai	735	122	16.67	18.48	2.01
Hyderabad	172	3.87	2.25	7.74	0.5
Ahmedabad	469	21.8	4.65	6.35	3.9
Vishakhapatnam	11,161	3439	30.81	4.29	801.98
Surat	395	11.84	3.00	4.58	2.7
Jaipur	484.64	61.4	12.67	3.07	2.30
Gandhinagar	75	30.75	41.00	0.20	162.80
Chandigarh	114	16.78	14.72	1.05	54.45
Kolkata	185	8.99	4.86	14.11	2
Asansol City	125.23	0.15	0.12	0.5	0.27
Asansol (MC)	326.48	55.66	17.05	1.24	44.76

Source: Population of cities from Census of India (2011), geographical area taken from urbanindia.nic.in, and green cover of cities taken from Forest Survey of India report (2011). The per capita green space for cities of Ahmedabad, Surat and Gandhinagar were available in a report by Gujarat Forest Department (2011). The per capita green space for Jaipur is provided by Singh et al. (2010). Data for green space of Kolkata, Delhi, Chennai, Vishakhapatnam, Chandigarh, Mumbai was taken from Mukherjee (2016), Sinha (2013) and Friederich et al. (2011), whereas data on green space of Bangalore, Hyderabad has obtained from Govindarajulu (2014), Asansol city and Asansol Municipal Corporation green space has been measured by the authors

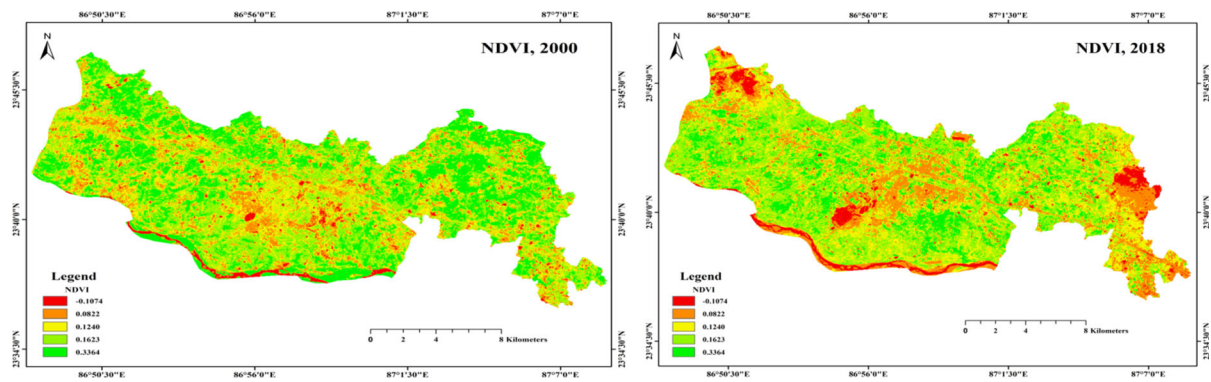
megacities i.e. Kolkata, Chennai and Mumbai have reported less proportion of land under green (8.99, 9 and 16.67% respectively) with trivial per capita green space (2, 1.03 and 2.01 m<sup>2</sup>/city dweller respectively). Hyderabad, Jaipur and Surat have also shown insignificant per capita green space of 0.5, 2.30 and 2.7 m<sup>2</sup> respectively.

It has been already mentioned earlier that three Municipalities—Raniganj, Kulti and Jamuria have been annexed to the AMC after 2011. If the geographical area after annexation is considered, the green cover measures for 55.66% of the Asansol Municipal Corporation area and per capita green space stands for 44.76 m<sup>2</sup>/city dweller (AMC 2018), which is significantly higher than the International Minimum Standard (9 m<sup>2</sup>) suggested by World Health Organization (WHO) and Food and Agriculture Organization (FAO) (Shanker et al. 2010). But in reality, prior to and after the annexation, the core area of Asansol city reports only 0.12% of green cover with a negligible amount of per capita green space of 0.27 m<sup>2</sup>/city dweller in comparison with other cities of the country.

Green spaces in fact are not always equitably distributed within the urban territory, both in developed and under developed countries for various reasons associated with their history of growth, traditional urban planning, philosophy of park design, embryonic ideas about leisure and recreation, and government policies (Byrne and Wolch 2009; Byrne 2012). Quite obviously, the older Asansol city (the core city at present) has recorded very less area under green space, whereas the adjacent areas, amalgamated in 2015 comprise significant proportion of vegetated land. As a result, the share of green covers as well as per capita availability of green space in 2011 measures high.

#### Temporal changes of green space in Asansol

The vegetation cover of the region is characterized with tropical deciduous trees. Sal forms the major tree species. Other important tree species are *Siris*, *Mahua*, *Simul*, *Palas*, *Bans*, *Shirisha*, *Arka*, *Kendua*, *Arjun* etc. Traditional chronicles and local popular beliefs



**Fig. 4** NDVI 2000 to 2018

subsume that the city's name 'Asansol' has been derived from the prevalence of 'Asan' (*Terminalia elliptica*) and 'Sal' (*Shorea robusta*), two indigenous tree species once found in abundance (Peterson 1910). But the attendance of trees at present, especially in the city core, is difficult to found. Temporal study reveals that the extent of vegetation cover has gradually been reduced with the rapid increment in built up area. Nearly 22% of its geographical area (71.84 km<sup>2</sup>) was under the green cover in 2000, which has been reduced to 55.66 km<sup>2</sup> (17.05%) in 2010. Hence, nearly 16.18 km<sup>2</sup> (4.5%) green space has been vanished during the first decade of the present century. Since the onset of mining activities deforestation was done on a massive scale to mine the underground resources. The process of devegetization gets intensified after that period. Nearly 30.68 km<sup>2</sup> area, occupying only 9.39% of the total geographical area of the city, is under the green cover at present (2018). Hence, nearly 24.98 km<sup>2</sup> (7.64%) of vegetation cover has been cleared during last 8 years to implement various development plans. Per capita availability of green space is 24.67 m<sup>2</sup>/city dweller, which is much higher than the International Minimum Standard (9 m<sup>2</sup>), suggested by World Health Organization (WHO) and Food and Agriculture Organization (FAO) (Kabisch et al. 2016) but much lesser than the standard (40 m<sup>2</sup>) suggested by the experts of Germany, Japan and other countries in 20th century (Wang 2009). The figure stands very close to the 'general standard' of green space of 20 m<sup>2</sup> per capita as recently adopted by the developed countries of the World (Wang 2009). In fact, the proportion of urban green space is much lesser in the city core area, the older Asansol city in particular, whereas the adjacent areas of the city

recently annexed to the city shows a higher percentage of green cover.

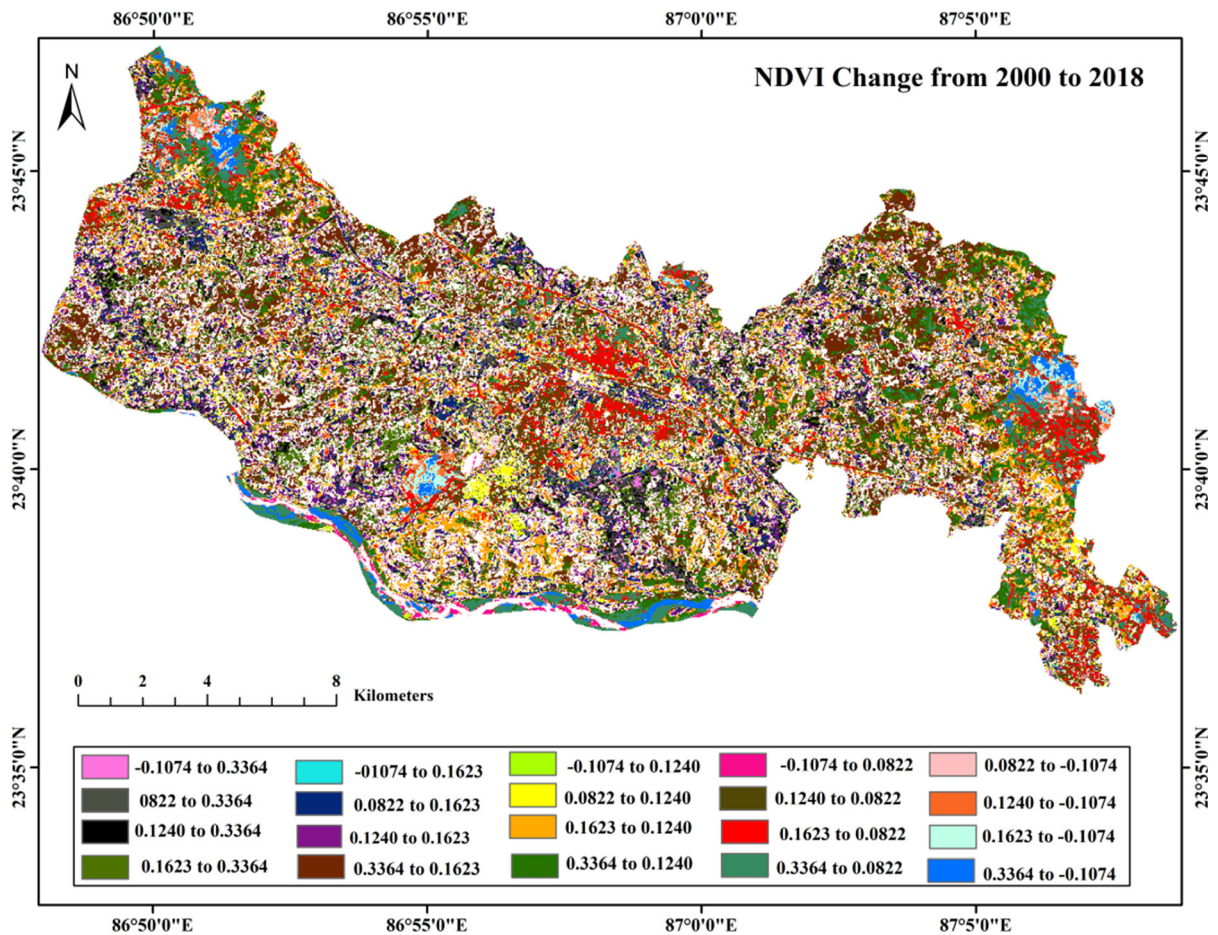
#### NDVI analysis: 2000 and 2018

The vegetation cover of the city has been deteriorated in terms of both quality and quantity and density through transformations of thick, lushly vegetation into dispersed one. The extracted result shows that nearly 38.62 km<sup>2</sup> vegetation area has been vanished within the observation period of 2000–2018 (Fig. 4). Nearly 24.16% area of the urban center was covered under abundant vegetation and 38.34% area was under sparse and scanty vegetation in 2000. Rapid transformation of land has removed a significant quantity of healthy vegetation cover of the area, whereas the sparse vegetation has also been decreased to 12.59% in 2018. Expansion of coal mining activities in *Jamuria-Raniganj* area and large scale mining and quarrying activities along with rapid industrialization in *Kulti*, *Niyamatpur* and *Sitarampur* area in the western part of the study area have destroyed a substantial part of the green spaces of the city (Fig. 5).

#### Land use and land cover change

LULC change is an obvious outcome of urbanization. Located within the coal belt area, the city had experienced gradual industrialization during British colonial time, which in turn has intensified the process of urbanization. Expansion of mining and industrial activities at the stage of inception creates a flow of migrants towards the city. Huge influx of poor rural immigrants as mining and industrial labor force from the adjacent states like Jharkhand, Bihar, Uttar





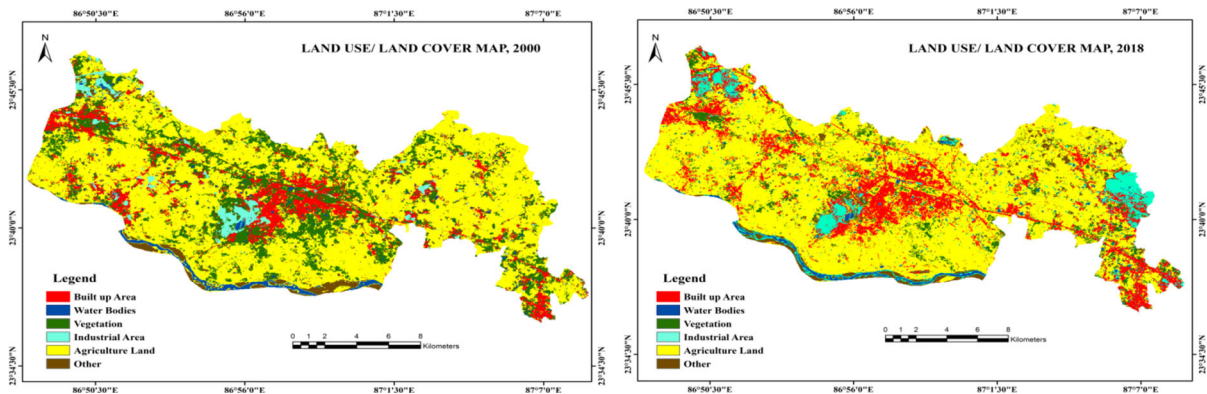
**Fig. 5** NDVI changes from 2000 to 2018

Pradesh lead to the rapid and unplanned expansion of Asansol city during the colonial days. Even today, the flow of immigration still continues which has encouraged the process of urban sprawling around the core city areas with substantial changes in the landscape composition within the past few decades. Incassant increase in urban population has become instrumental to transformation of land and has created an immense demand of land for various purposes. Rapid increment in impervious built-up space has reduced the green cover as well as its per capita availability.

Six LULC classes i.e. built-up area, industrial area, agricultural land, vegetation cover, water bodies and others areas are identified for the present study. LULC map of 2000 reveals that 33.77 km<sup>2</sup> (10.40%) is under built-up area, whereas industrial zone occupies 9.87 km<sup>2</sup> areas (3.04%). Besides, agricultural land, vegetated land, water bodies and others have occupied

201.29 km<sup>2</sup> (62.01%), 66.25 km<sup>2</sup> (20.41%), 7.21 km<sup>2</sup> (2.22%) and 6.22 km<sup>2</sup> (1.92%) respectively. The proportion of area under different LULC categories in 2018 stands for: built-up area 53.60 km<sup>2</sup> (16.51%), industrial zone 20.15 km<sup>2</sup> (6.21%) agricultural land 213.18 km<sup>2</sup> (65.67%), vegetation cover 21.55 km<sup>2</sup> (6.64%), water body 5.47 km<sup>2</sup> (1.69%) and others 10.67 km<sup>2</sup> (3.29%) (Fig. 6). The overall accuracy of the classified images is 87.59 and 89.63% for the respective years with Kappa coefficient of 0.80 and 0.88, which indicate ‘almost perfect agreement’ (Landis and Koch 1977).

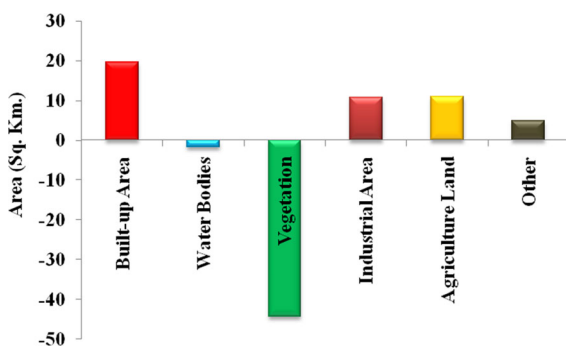
Hence, drastic changes in the composition of LULC have occurred in the area during the period 2000–2018 with rapid increment of built-up and industrial areas (including areas of mining and quarrying) at the expense of vegetated areas. The above diagram clearly reveals the changing trends of different LULC classes.



**Fig. 6** Land use/land cover map 2000 and 2018

The built-up area has sharply increased from 10.40% in 2000 to 16.51% in 2018, whereas the vegetated land has decreased nearly 13.77% during the observation period. The expansion of economic activity (both agriculture and industry) activities coupled with infrastructural development and urban sprawling (Auddya 2019) has cleared nearly 44.70 km<sup>2</sup> of green cover from different parts of the area (Fig. 7).

Significant alterations in LULC mosaic has been observed due to anthropogenic interventions, in which natural land covers especially vegetation areas has enormously been transformed into economic and residential spaces in the study area over recent past years (Fig. 8). The LULC change matrix (Table 4) reveals that 37.95 and 9.52 km<sup>2</sup> vegetated area has been converted into agricultural land and built-up spaces to meet the growing demand of commerce and settlement. Similarly, 3.11 km<sup>2</sup> of green spaces has been removed for industrial activities. The agricultural activities in the study area have been increase at the cost of destruction of green spaces especially in the



**Fig. 7** Areal changes in land use/land cover classes 2000 and 2018

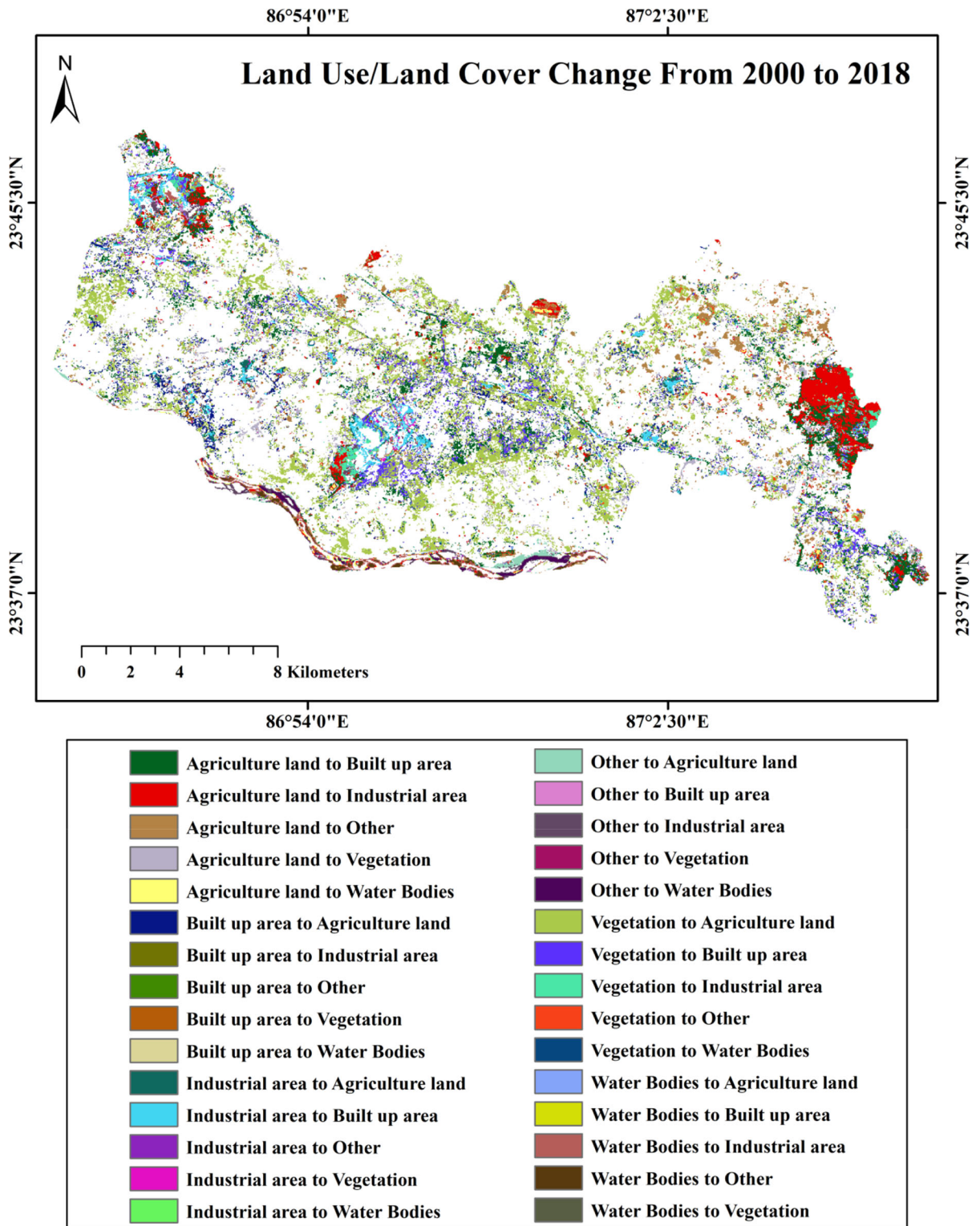
newly added part of the city within this stipulated period of 18 years (2000–2018).

Impact of declining green spaces: relation with land surface temperature

Impact of urbanization on the thermal condition of the environment is a major concern in today's world (Pal and Ziaul 2017). The material composition of the present urban space has increased the absorption of solar radiation, thermal capacity and conductivity (Ranagalage et al. 2019). The concrete impervious urban surface with higher heat conductivity absorbs heat during the day time and releases the same at night. This thermal variance shows a rise in urban sphere in comparison to the surrounding rural counter parts (Balogun and Daramola 2018). Urban green space behaves like shield that prevents solar radiation from heating up the immediate surface directly (Li et al. 2012) and reduces the temperature of the area through reflectance, shading and evaporative cooling effects (Georgi and Dimitriou 2010). The reduced temperatures in the green areas compared to the surrounding urbanized parts create a situation known as Park Cool Island (PCI) (Chen and Wong 2006). This phenomenon is observed around the urban parks with the presence of park surface, vegetation and water bodies. The cooling effect extended by the urban green areas has great importance in keeping the urban areas cool.

Several studies (Xu et al. 2017; Anjos and Lopes 2017; Yang et al. 2017; Wang et al. 2018) have revealed the cooling effect of green spaces in the urban thermal environment. Most efficient approach for





**Fig. 8** Land use/land cover change from 2000 to 2018

**Table 4** Land use/land cover change matrix

2018(km <sup>2</sup> )	2000 (km <sup>2</sup> )						
	Agriculture land	Built-up area	Industrial area	Other	Vegetation	Water bodies	Grand total 2018
Agriculture land	<i>164.60</i>	7.70	1.66	0.83	37.95	0.44	213.18
Built-up area	16.03	<i>23.49</i>	3.95	0.30	9.52	0.32	53.60
Industrial area	8.93	1.22	<i>3.33</i>	1.51	3.11	2.05	20.15
Other	6.08	0.12	0.22	2.73	0.59	0.93	10.67
Vegetation	5.07	1.13	0.52	0.03	<i>14.62</i>	0.18	21.55
Water bodies	0.59	0.12	0.19	0.82	0.46	<i>3.30</i>	5.47
Grand total 2000	201.29	33.77	9.87	6.22	66.25	7.21	<b>324.61</b>

Italics has been used to show the relation between the LULC Class

urban heat island mitigation is to increase green space as it reduces absorption of solar radiation with provision of shades to the land surface (Doick et al. 2014). Rao and Puntambekar (2014) has argued that 'vegetation has been shown to lower wall surface temperatures by 17 °C which led to a reduced use of air conditioner on an average of 50%' (Rao and Puntambekar 2014). The study of Bardhan et al. (2016) reveals that the older parts of Kolkata city are most vulnerable to heat, whereas the area surrounded by green areas and wetlands are characterized with relatively low heat (Bardhan et al. 2016).

The effect of the PCI around the green spaces and surrounding built-up zones is well understood from this study. Recorded surface temperatures were low at the green areas but high at the outer boundaries. The field data reveals that the temperature of the concrete built up surfaces is noticeably higher than the adjacent areas under tree. There is a minimum average difference of nearly 6 °C of temperature between the green space and adjacent road space (Primary Survey 2019). The following map (Fig. 9) prepared on the basis of the noon-temperature shows the spatial distribution of surface temperature. The distribution pattern of temperature has pictorially shown a quite symmetry with the spatial distribution of green spaces as shown in Fig. 4 (2018).

It has asserted that reduction in green spaces has caused the enhancement of the land surface temperature of the area. The temporal variation in land surface temperature conditions of the study area during 2010–2018 has been examined through the spectral radiance model and split window algorithm methods by using the satellite imageries of the study

area for the month of May of 2000 and 2018. A sharp rise both in maximum and minimum temperature have been experienced during the study period. The maximum temperature of the area has increased from 38.18 to 42.99 °C, whereas, the minimum temperature has also increased from 19.24 to 22.66 °C (Fig. 10). The study of Das et al. 2020 also shown that the summer and winter surface temperature of the area has been increased at a rate of 0.15 and 0.19 °C/year respectively from 1993 to 2018 (Das et al. 2020).

Radical modifications in LULC mosaic are undoubtedly responsible for such changes in temperature to a greater extent. As urbanization replaces the natural land cover to cultural land with higher thermal properties, it brings obvious modification of temperature in the urban environment. Thus notable alterations in natural land covers into anthropogenic surfaces with massive removal of green space in the study area definitely have enhanced the average temperature of the area. The following figure (Fig. 11) illustrates the negative relationship between the green space and LST in 2000 and 2018, which clearly depicts the role of decreasing green cover behind the increasing surface temperature.

Urban green spaces are often regarded as determinants of sustainability in the rapidly urbanizing world (Bardhan et al. 2016). Conservation and further extension of green areas help to sustain the physico-ecological balance of the city as well as to improve the quality of life of the urbanites with its complex ecosystem services and benefits. Studies with ecological perspectives have suggested that a realistic target of 10% of tree cover throughout urban areas is essential to create an ecologically sustainable city

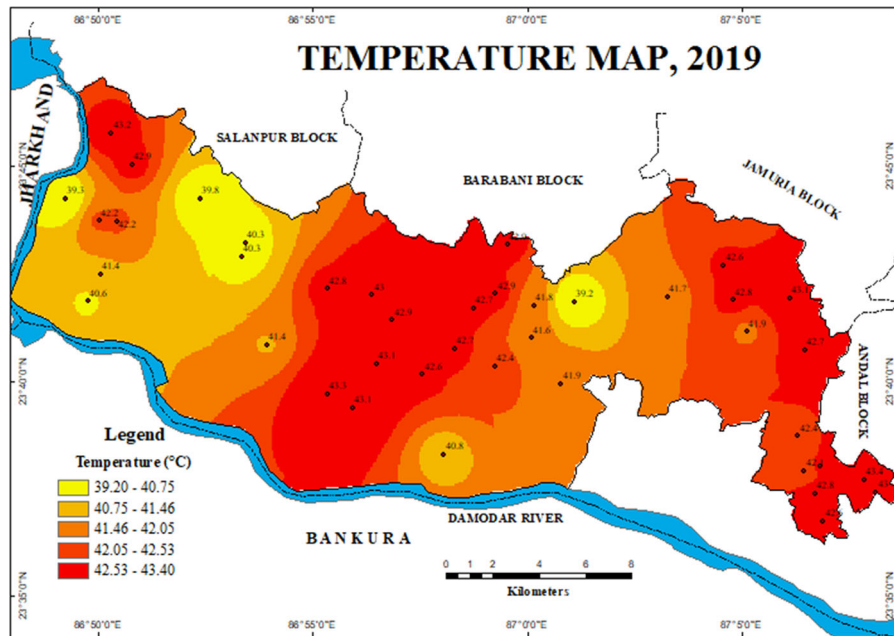


Fig. 9 Temperature map 2019

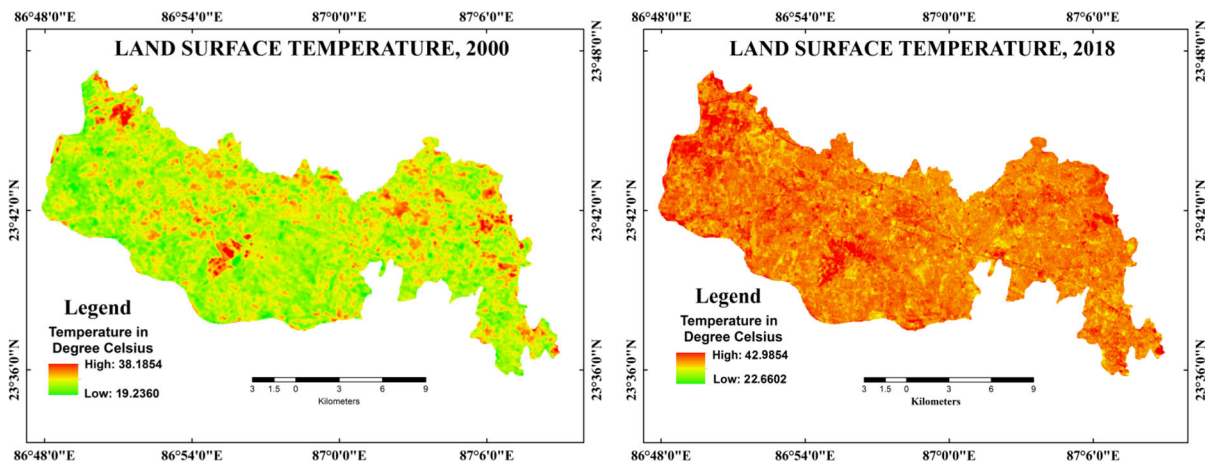
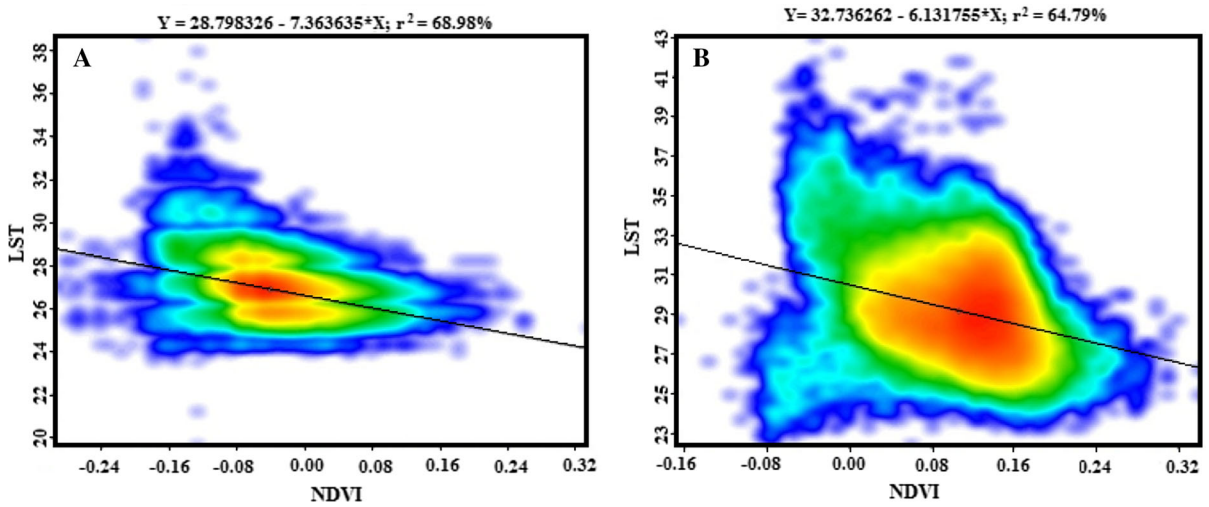


Fig. 10 Changes in land surface temperature 2000 and 2018

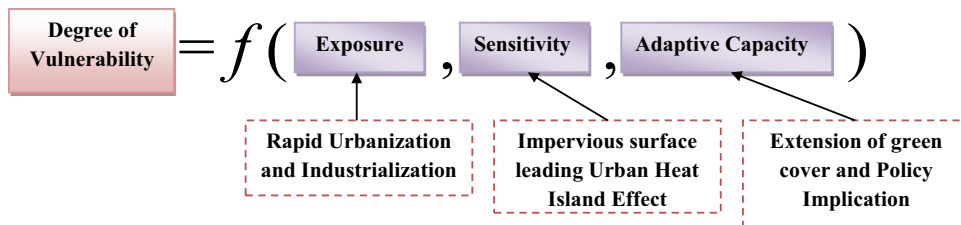
(Hashimoto et al. 2005). But the urban centre under review possesses less green cover than the prescribed level and has crossed the threshold limit. Several studies have explained vulnerability of city in different contexts. Chief components of such vulnerability are Exposure, sensitivity and adaptive capacity (Cutter et al. 2003; Füssel 2007). Exposure is the extent to which a system is in contact with a changing stimulus, sensitivity is the extent to which the area/community is distressed by the exposure and adaptive capacity is the

system’s capacity to survive or recuperate from the changed phenomena (Pandey et al. 2014; Mukherjee and Siddique 2019).

The above diagram (Fig. 12) theoretically analyzes the vulnerability of the city. Increase in impervious paved surfaces and urban heat island effect of rapid urbanization along with industrial and mining activity increase the degree of vulnerability. But proper implication of policies with more emphasis on preservation and expansion of green cover will



**Fig. 11** Relationship between NDVI and LST **a** 2000 and **b** 2018



**Fig. 12** Conceptual framework assessing degree of vulnerability. *Source:* Modified from Bardhan et al. 2016

increase the city’s strength to cope up with such severe changes. The study of Reddy and Ruj (2003) has revealed that coal mining operations and allied industrial activities contribute to pollution in the form of gaseous and dust particles in the ambient atmosphere of the Raniganj-Asansol area (Reddy and Ruj 2003), whereas Das et al. 2020 have assessed that the surface temperature of the area may increase at a rate of 0.21 °C/year in near future (Das et al. 2020). The ‘green lungs’ of the urban centre could combat the situation more amicably. But, the unscientific land transformations of the city with declining green cover and increasing concrete impervious space, have obstructed the efficiency of the ‘green solution’ offered by nature at free of cost.

**Conclusion**

It appears from the above discussion that gradual decline of green space in Asansol city has definite

effect on the physical environment of the city, especially in its core area where concentration of population is higher as urban function is more active compared to its peripheral zones. Diurnal as well as average temperature in core area in long run may invite definite ecological effects on water budget and heat island effects with direct impact on the health of the greens and put more demand on power and water supply that may take more on economy and urban functions. It is also revealed with the study that though the areas annexed after 2015 may apparently show the proficiency of share in average green cover but it will not be sufficient to mitigate the recharge of ground water and cooling the city core area. Almost all the studies on city sustainability cited in the study recommend that urban greens extend great ecological effects on the physical and social ambience of city. Asansol city with its meagre presence of per capita share of green cover lag far behind the capacity and degree of sustainability. Plantation with indigenous deciduous tree and shrub species adaptive to the soils



of the area, roof top gardening, open green space in private and corporate complexes and road side afforestation may enhance the sustainability of the city.

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#### Compliance with ethical standards

**Conflict of interest** The author declares that there is no conflict of interest.

**Ethical approval** This research does not involve individual participants in the study, and thus ethical approval is not required.

**Informed Consent** There is consent to publish this chapter of the book, if accepted.

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