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Study of Environmental Impact Analysis with Geospatial Technique in Newtown, Kolkata, India

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Abstract: The expansion in planned pattern occupies the north-eastern fringe of Kolkata by development of New Town area due to development of human settlement. It has led to the rise of temperature along with impervious surface, important in analysing the Urbanization and present day environmental condition. The Geospatial Technique helps in analysing the land use change pattern. It incorporates Landsat8 OLI of 2018,Landsat 7 ETM+ of 2010 satellite data. Software modelling is done followed by interpretation. The Built-up area Index (BI), Land Surface Temperature (LST) Index on temporal and spatial scale can justify the rate of increase in urbanized area along with rise of temperature. Urban Heat Island condition is analysed. It can predict probable impact on future climatic condition of Newtown location in Kolkata.

Keywords: Urbanization, Built-up area Index, Impervious Index, Land Surface Temperature Index, Urban Heat Island

INTRODUCTION

The continuous increase of temperature in urban areas along with increase percentage of impervious cover due to human encroachment, have been taking toll on the environment and climate. The rapid conversion of natural vegetative cover and wetland by development of transport and communication system from the city towards peri-urban areas by construction of metro railways, major arterial roadways, recreation centres, commercial and residential complexes also disturbing the balance of ecosystem. This scenario is prominent by expansion of the Kolkata City towards the eastern fringe by the conjunction of Rajarhat, Newtown and its surrounding areas in North 24 Parganas district Map of West Bengal of India. This phenomena fulfils the condition of Urban Heat Island (UHI) study which was initiated by Nieuwolt (1966) to analyse the scenario of southern Singapore. Later on many research and studies were conducted on UHI as well as the vertical and horizontal expansion of urban areas by putting importance on temperature change in specific area over the years Cao et al. (2008).The land-use classification system also plays a pivotal role by segregation of unit of land for particular type of - with areal coverage. These land-use classes provides a clear picture of spatial as well as temporal change through conversion of natural land by anthropogenic processes from the past to present years. This change adversely impacts the climate, environment and ecology of an area which justifies the reason of decrease rate of evapotranspiration, increase in temperature and degradation of vegetal cover as well as wetland.

In the above leading up to the consolidation of land use, NDVI, NDBI, LST the decision can be followed that Rajarhat and the surrounding area may have started to be expanded through a specific implementation plan by The Govt. of West Bengal. But this expansion poses a serious threat to the environment and the climate. The sharp air temperature extends from within an eight-year period and the random migration of people from the centre of the city to the open space, uncontrolled migration to the peri-urban region by the element of drainage is an indication of the uncontrolled use of space. The heterogeneous relationship of the NDVI with the NDBI and the NDVI with the LST completely satisfies the state of Rajarhat and its surroundings on the continuation of the Urban Heat Island within a very short period of time.

Geospatial technology is an integral part of the Environmental Impact Assessment (EIA) process, as environmental resources are directly affected by changes in the nature and extent of the proposed disturbance. By using local techniques such as remote sensing, Geographical Information Systems, and Global Positioning Systems, the EIA developed greater visualization, motion, query, and mapping capabilities. However, one of the biggest challenges is gaining access to geospatial data and relevant data. With the emphasis on using geospatial data in particular, the amount of data source is higher than usual with text and numeric data. Interdisciplinary work in science has been carried out in recent years by at least new technologies that meet the requirements of several disciplines at the same time. India is a huge country of global diversity and natural resources. Despite its wealth of natural resources, India is still considered a developing country. The increase in population and the conflicting needs of their basic needs have resulted in a large portion of the natural resources being used in a sustainable way. India's rural environment is experiencing rapid degradation of vegetation, leading to reduced soil fertility, soil erosion, and greater impact of drought due to lack of ground water and basic services required for human and animal growth.

The Geospatial Technology along with its sound data Landsat ETM+ and Landsat OLI and modelling through the analysis of thermal band over specific period of time clearly highlights the temperature change in urban area by application Land Surface Temperature Index. The application of Normalized Difference Built-up Index also states the spatial and temporal change by extraction of built-up areas over the years with Shortwave Infrared Wavelength Band and Infrared Band. The Normalized Difference Vegetation Index indicates the health of vegetation cover over the years with the application of Infrared and Red Wavelength. The comparative study between Vegetation Index and Surface Temperature Index, Built-up Area Index indicates provides clear picture of Urban Heat Island. The empirical analysis by statistical calculation justifies the outcome of Geospatial analysis. The findings of the study can be offset by the fact that Rajarhat and the surrounding area require immediate measures and policies by the Government to protect the environment and climate from further degradation. The development of Haphazard from above and beyond is in line with the plan initiated by Government. Environmental awareness is absolutely necessary to plan for sustainable development in order to save our nature from adverse effect.

Study Area

The study area Rajarhat and surrounding is The Block Development Community which belongs to Barasat Sadar Subdivision of North 24 Parganas, which is located at 22°36′37″N 88°31′37″E. The area is situated at the eastern part of The Hooghly River in Gangetic Delta plain. The soil type is dominated by Gangetic influence and mostly alluvial in nature.The elevation of the area is approximately 9 m. . The monsoonal climatic change affects the rainfall variation throughout the area. The maximum rainfall occurs during the month of August. Maximum temperature exceeds 40 °C (104 °F) during May–June and Winter prevails from the month of December to early February. The area is influenced by Tropical wet to dry climate. According to 2011 Census the population density is 2,700/km^2 and approximated area 69.09 km^2.The Newtown is a planned city in satellite pattern which has occupied the north-eastern area of Rajarhat. The area is considered as Information Technology hub and was planned since 1990s by conversion of cultivable land and water bodies into built up land.

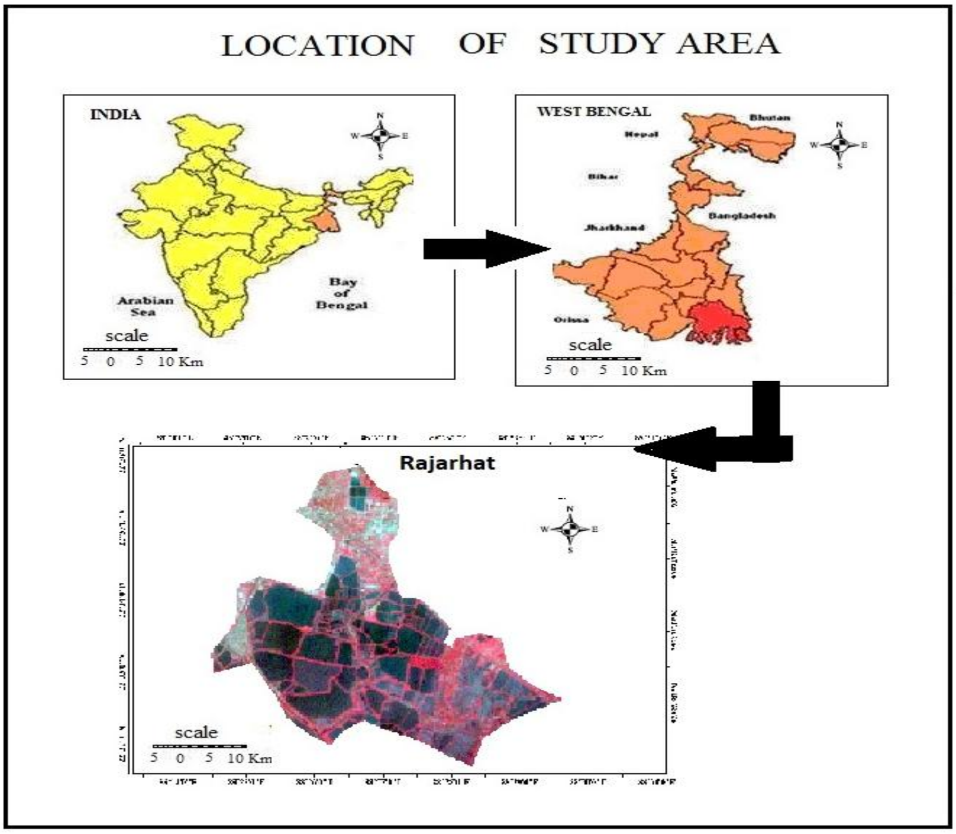


Fig.1: Location Map Of The Study

DATA AND METHODOLOGY

The study has been carried out based on the both primary and secondary data collected from different government authorities. The different software and data uses are given in the tabulated form (Table 1):

Table 1: Data & Software to be Used

	Type of Data & Software
Data to be Used	**Landsat ETM+ satellite data of year 2010 from Earth Explorer(USGS Glovis)**
	Landsat OLI satellite data of 2018from Earth Explorer(USGS Glovis)
	Google Earth Data of 2018
Software to be Used	Arc GIS 10.4
	Erdas Imagine 2014
	Statistical Software
	Global Positioning System

Methods

The methodology developed in this study is pertaining to analysis based on various operations on graphic and non-graphic data. The entire process is summarised in the explanation.

The Land use Classification System

Classification over the Multi temporal images of Landsat ETM+ of the year 2010 and Landsat OLI of 2018 were run on Image processing software Erdas Imagine 2014 with maximum likelihood classifier and training set were provided on real field knowledge of land use over the study area. The conversion of area from natural land to built up area were marked from the raster attribute table. The northern part of Rajarhat near Newtown and western part and eastern margin shows the expansion of urbanized area from the year 2010 to 2018.The change is significant on temporal and spatial scale.

Indices Analysis

Normalized Difference Vegetation Index

This index deals with the Reflectance of green cover in Near Infrared Band based on structure and water content present in the cover and absorption of Red band due to presence of chlorophyll in the vegetation. The vegetation health degradation was prominent due to encroachment of urban land from the year 2010 to 2018.

NDVI= NIR – R / NIR+ R (1)

(+1 = Good condition of vegetation health)

(-1 = Poor Condition in Vegetation Health)

Normalized differential built up index (NDBI)

The NDBI was used to extract the built up area over the study area and have indices range from -1 to 1.In the Landsat ETM+ and Landsat OLI false colour imageries, the high reflectance were observed at Band 5^{th} (1.55-1.75 µm) and Band 7^{th} (2.09-2.35 µm).In the OLI image Band 5 (0.85 - 0.88 µm) and band 6 (1.57 - 1.65 µm) are alike. The Builtup landuse of the study area were heighted with high spectral reflectance. Zha et al. (2003)

NDBI = (SWIR – NIR)/(SWIR + NIR) (2)

Land Surface Temperature Index(LST) for Landsat 8 OLI Satellite image

Land Surface Temperature indicates the temperature of the ground surface. Sometimes it is considered as the mixture of vegetation and bare land temperature due to change in diurnal variation in illumination and other climatic effect. The LST represents surface air temperature of the study area. The modelling of LST were generated on Landsat ETM+ satellite data of 2010 and Landsat OLI 2018 satellite data to mark change in temperature variation due to urban land expansion over the study area. The process can be simplified as:

a) LST Calculation for Landsat 8 OLI Satellite image

Step.1: Conversion of DN value to Radiance

DN of Band 10 and 11 of Landsat OLI 2018 satellite data were respectively converted to TOA Reflectance. The Radiance values were collected from the Meta data of the satellite image.

$L_\lambda = M_L Q_{cal} + A_L$ (3)

where:

L_λ = TOA spectral radiance (Watts/(m2 * srad * μm))
M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)
A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)
Q_{cal} = Quantized and calibrated standard product pixel values (DN)

Step.2 Conversion of Reflectance to Brightness Temperature Values

The reflectance values were converted to Brightness temperature. The values of K1_CONSTANT_BAND_10, K2_CONSTANT_BAND, K1_CONSTANT_BAND and K2_CONSTANT_BAND_11 were collected from Meta data of the satellite image.

$$T = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)} \quad (4)$$

where:
T =Top of atmosphere brightness temperature (K)
L_λ =TOA spectral radiance (Watts/(m^2 * srad * μm))
K_1 =Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)
K_2 =Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

The final results were derived by showing Maximum and minimum range of temperature. The temperature were converted to degree Celsius from Kelvin

b) LST Calculation for Landsat 7 ETM+ Satellite Image

Step.1: Conversion of DN values to Radiance

The DN values were collected from meta data file and converted to radiance values.

$$L_\lambda = ((LMAX_\lambda - LMIN_\lambda)/(QCALMAX - QCALMIN)) * (QCAL - QCALMIN) + LMIN_\lambda \quad (5)$$

Where:
L_λ is the cell value as radiance
QCAL = digital number
$LMIN_\lambda$= spectral radiance scales to QCALMIN
$LMAX_\lambda$ = spectral radiance scales to QCALMAX
QCALMIN = the minimum quantized calibrated pixel value (typically = 1)
QCALMAX = the maximum quantized calibrated pixel value (typically = 255)

Step.2.Radiance to Satellite Brightness Temperature

The emissivity was corrected by Artis and Carnahan (1982).and calculation was followed by

$$T = \frac{K2}{\ln\left(\frac{K1}{L_\lambda} + 1\right)} \quad (6)$$

TB=At-satellite brightness temperature (K)
Lk= Spectral Radiance in W.m2.sr1.lm1
K1 and K2 =K2 and K1 are two pre-launch calibration constants.
(For the Landsat 7 ETM+6.2 band, these compute to 1282.71 K and 666.09 W.m2.sr1.lm, respectively).

The Land Surface Temperature was calculated Artis and Carnahan (1982).

$$LST = T_B/[1 + \{(\lambda * TB/\rho) * \ln \epsilon\}] \quad (7)$$

where St = land surface temperature (LST) in Kelvin, k = wavelength of emitted radiance in meters (for which the peak response and the average of the limiting wavelengths (k = 11.5 lm) (Markham and Barker, 1985) is used, q = h * c/r (1.438 * 10^{-2}m K), r = Boltzmann constant (1.38 *10^{-23} J/K), h = Planck's constant (6.626 * 10^{-34} J s), and c = velocity of light (2.998 *10^{8}m/s) and e = emissivity (ranges between 0.97 and 0.99)

The Land Surface Emissivity was calculated as:

Land surface emissivity = 0.004*Pv+0.986 (8)

Where Pv was calculated from NDVImin and NDVImax. The LST result was converted to degree Celsius from Kelvin.

Statistical Analysis of Surface Temperature by Empirical Method

The surface temperature was derived statistically by applying mathematical formula by derivation to check analysis or fluctuation of Temperature over the year from satellite derived information.

RESULTS AND DISCUSSION

Landuse Classification and Change Detection of Rajarhat Area and surrounding

The Land use Classification was generated with six classes on the study area like: Wetland with Vegetal Cover, Roadways, Densely Populated Area,, Dispersed Built-upland, Fallow Land and Water bodies/Canal. The change of spatial extent over temporal period were visible in the attribute table of supervised classification by application of maximum likelihood classifier. From the year 2010 to 2018, 86% of the wetland with vegetal cover was converted to built up area the wetland with vegetal cover were converted to built up area huge percentage such as 86%, Densely populated area expanded by 3.4%,Fallowland decreased by 9.4%. The dispersed settlement occupied in the south-eastern part of the study area. The northern side and western side of the area is dominated by high concentration of residential and as well as commercial, industrial buildings.

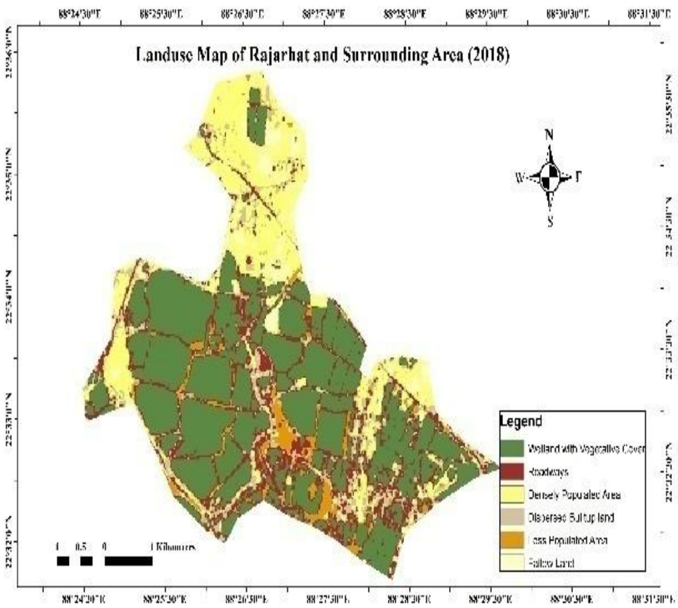


Fig.2(a): Landuse Classification Map of year 2010

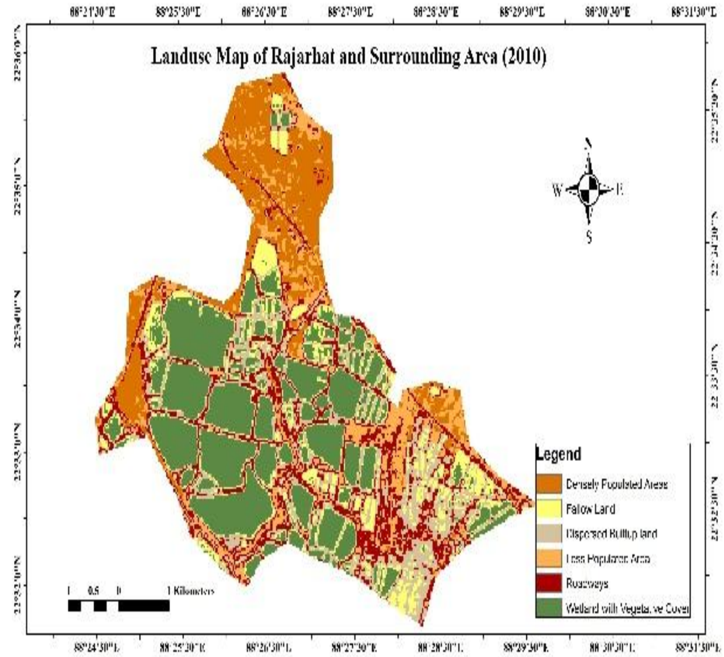


Fig.2(b): Landuse Classification Map of year 2018

Normalized Difference Vegetation Index

NDVI Index shows vegetal heath condition over Rajarhat and surrounding area. From the spectral reflectance of vegetation, the NDVI range for the year 2010 was derived on Arc GIS software - poor health 0.183 to good health up to 0.84.The high reflectance was noticed at the central to southern part of the area. Whereas in comparison the NDVI range for 2018 was derived as -0.083 to 0.35.The degradation of health was clearly marked over the years on the multi temporal satellite images. .

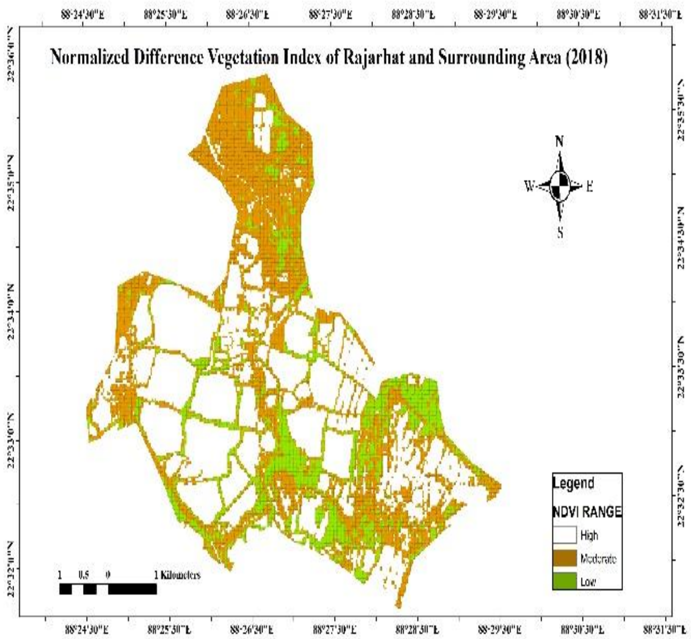


Fig.3a: Normalized Difference Vegetation Index of 2018

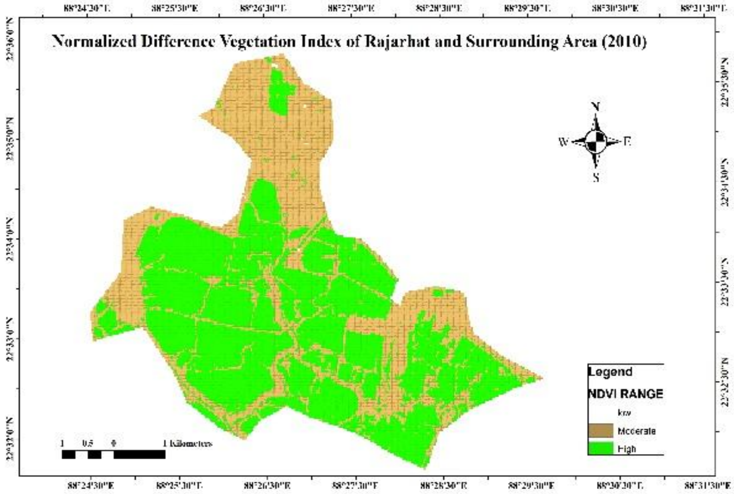


Fig.3b: Normalized Difference Vegetation Index of 2010

Normalized Difference Built-up Index

The NDBI Index spectral reflectance shows moderate reflectance in the northern and western part of the study area whereas low reflectance is visible near southern part. Comparison of NDBI of 2010 and 2018 clearly shows the expansion of the built up area over the study region. .NDBI was used to extract the built up area by using Shortwave Infrared wavelength in satellite images. This derived result of NDBI justifies the derived range and condition with NDVI on the study area. Both are indicating inverse relation with each other.

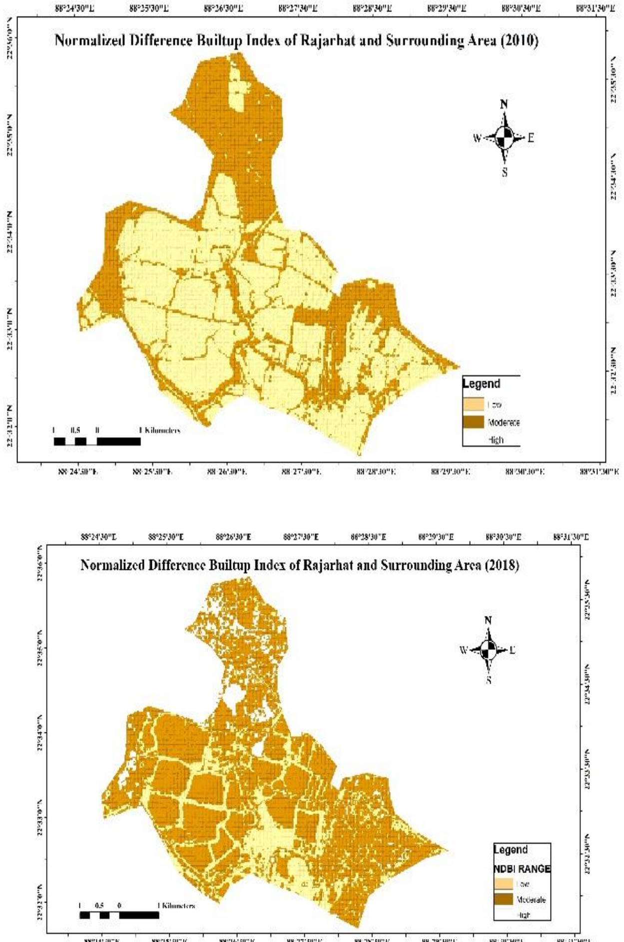
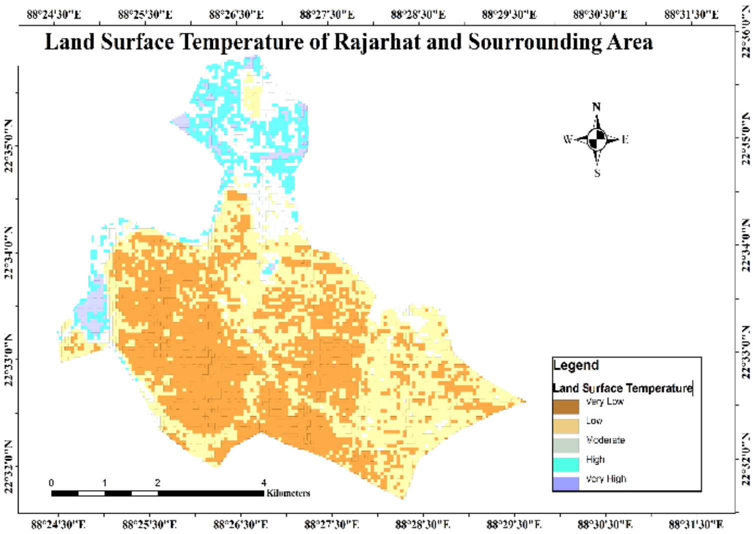


Fig.4: Normalized Difference Built-up Index in (a) 2010 and (b) 2018

Land Surface Temperature

Land Surface Temperature of year 2010, November shows maximum air temperature is 26°C and minimum is 21°C in the study area. Whereas the 2018,February satellite image LST reflects maximum air temperature is 36°C and minimum temperature 14°C.The blue colour in both 2010 and 2018 LST indicates high temperature. These derived temperature from the LST calculation was justified in comparison with change in Land use pattern from the year 2010 to 2018.Apart from the land use, rapid fluctuation in LST over the years established positive correlation with NDBI and negative with NDVI.



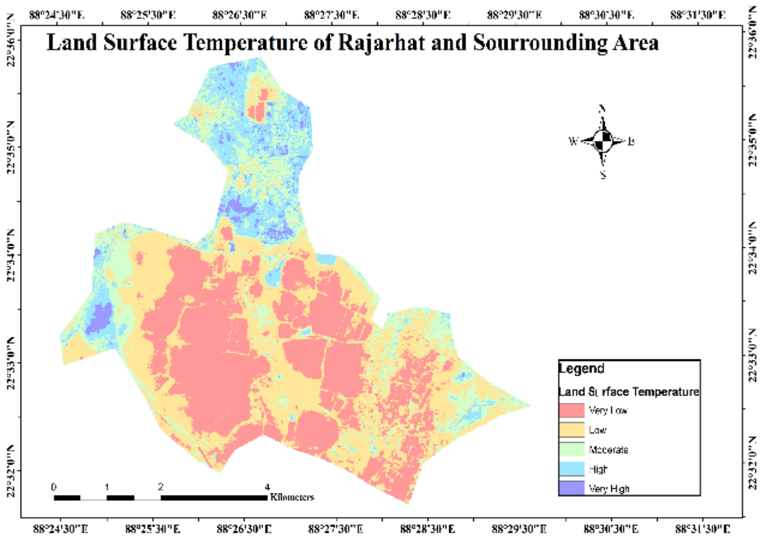


Fig.5: Land Surface Temperature of from 2010 to 2018

Statistical Analysis of Surface Temperature by Empirical Method

The surface temperature were derived empirically to match Software modelling of Land Surface Temperature which was presented through Table.2

Table 2: Empirical Analysis of Land Surface Temperature of 2018 and 2010 by using Thermal Band Information

	Landsat 8 OLI of 2018		**Landsat 7 ETM+ of 2010**	
Parameter	BAND 10	BAND 11	BAND 61	BAND 62
LMAX	0.18488	0.18488	17.04	12.65
LMIN	0.1	0.1	0.1	3.2
QCALMAX	255	255	255	255
QCALMIN	1	1	1	1
K1 (in	774.8	480.9	666.09	607.76

$Wm^{-2}sr^{-1}\mu m^{-1}$)				
K2(in K)	1321.08	1201.14	1282.71	1260.56
Radiance multiplier (m)	0.0003342	0.0003342	0.0671	0.0372
Radiance add(c)	0.1	0.1	-0.0671	3.1628
Radiance leaving earth (Lλ)	0.0003342DN+0.1	0.0003342DN+0.1	0.0671DN-0.0671	0.0372DN+3.1628
Land Surface Temperature (T)(in K)	$\frac{1321.08}{\ln(774.8/ L\lambda +1)}$	$\frac{1201.14}{\ln(480.89/ L\lambda +1)}$	$\frac{1282.71}{\ln(666.09/ L\lambda +1)}$	$\frac{1260.56}{\ln(607.76/ L\lambda +1)}$
Land Surface Temperature (T)(in ^{O}C)	T - 273	T - 273	T - 273	T - 273

From the above resulted parameter of Land use Classification, NDVI, NDBI, LST the decision could be followed that Rajarhat and its surrounding area might have started expansion with specific plan implementation by The Govt. of West Bengal. But this expansion is imposing serious threat to the environment and as well as the climate. The sharp air temperature increase during a span of eight years along with random encroachment of human population from the core of the city towards the fringe area, uncontrolled migration at peri-urban region by pull factor are the indicator of non-judicial use of natural space. The inverse relation of NDVI and NDBI and NDVI with LST clearly satisfies the condition for Rajarhat and its surrounding area in progression of Urban Heat Island within very short span of time.

CONCLUSION

The study finding could be concluded on the note that Rajarhat and its surround area requires immediate measures and policies by The Government to safeguard the environment and climate from further degradation. Haphazard vertical and horizontal development is going against the plan which was initiated by The Government. Environmental awareness is much in requirement to plan a sustainable development and save the balance of ecology in near future.

In order to plan land use in Rajarhat area properly there is a need to synchronize economy and resources of land with it. There should be optimum and balanced development of appropriate areas of Rajarhat. To ease the burden of any sorts of developmental issues, one can implement inclusive economic growth. In this regard, new ideas can be generated by brainstorming for imbibing future metropolitan growth in this area by controlling growth of its adjacent areas. Of course unplanned growth of settlements in the barren areas should be prohibited and sustainable growth of infrastructure facilities, residential activities, business activities and other facilities can be implemented. Moreover an environment-friendly and aesthetically attractive new urban settlement functionally integrated with the future metropolitan structure can be provided.

Adequate green zones can be set up so as to minimize the effect of pollution in the residential and other public activity areas. Balanced and eco-efficient development without putting much stress on the natural resources is the order of the day. Within an ecologically sustainable framework in Rajarhat area, government can incorporate social amenities (culture, health, education, recreation, law and order, postage and courier, fire fighting etc) along with improved state-of-the-art infrastructure facilities (drainage, water supply, solid waste disposal, biomedical waste disposal, sanitation, electricity, telecommunication, transportation, street-lighting, repair and maintenance etc.).

Residential and Commercial areas combined together should ideally be less than 40% of total area of land use zone. Regional, local street system and pathways can be implemented for good connectivity. Effluent treatment plant should be implemented in commercial zones. Power supply and water supply should be adequate. Sanitation system should be hygienic. Proper landscaped canal system should go vis-a-vis efficient drainage. No permission for encroachment in any form should be granted at open spaces, water bodies, roads and utilities.

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