LAND SURFACE TEMPERATURE STUDY OF WEST TRIPURA DISTRICT, INDIA

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ABSTRACT

Land surface temperature is a crucial factor that affects many ecological and environmental processes, such as the urban heat island effect, the health of the plants, and the effects of climate change. An increase in global temperature and erratic rainfall has been observed as a result of the weather's change during the recent past. Understanding the Spatio-temporal change of the land surface temperature can provide us with insights for sustainable land use management, urban planning, and also aid in planning and formulating plans to combat climate change. The present study area is the most populated district in Tripura and has experienced some of the fastest transformation in urban infrastructure. This study's objective was to investigate at how the land surface temperature (LST) varies across space and time in the West Tripura District. Landsat- 8 OLI and Landsat-5 ETM was the source of data to investigate the purpose of the study. Until the year 2020, steady rise in built up areas was observed with a decline in land cover until 2010. However, the year 2020 witnessed an increase in vegetation cover. Similarly, the land surface temperature revealed higher values till 2010 may be attributed to loss of vegetation cover and subsequent decrease in values of land surface temperature after 2010 may be attributed to afforestation and growing popularity of plantation schemes.

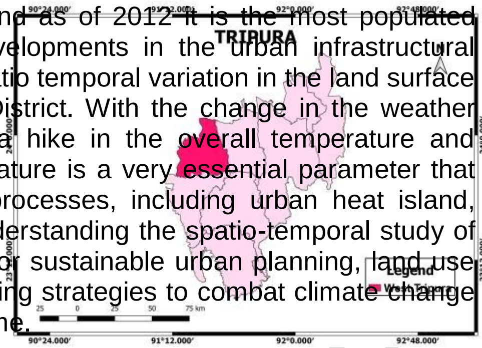
Keywords: *Land use land cover change, land surface temperature, Spatio-temporal, Normalized difference vegetation index.*

1. INTRODUCTION

The temperature of the earth's land surface, more especially the temperature of the ground or the top layer of soil, is referred to as land surface temperature (LST). It serves as representation of the thermal energy emitted by the land surface and is essential for comprehending the climate pattern [1] and determining how human activities affect local climate. LST may help us to better understand how land surface and atmosphere interact on a global and regional scale [2], as well as offer a useful surface state statistic for a variety of uses. LST has thus been acknowledged as a significant Earth surface parameter by the National Aeronautics and Space Administration, the United States (US) Climate Change Science Programme, and one of the 10 crucial climatic variables in the terrestrial biosphere named by the Global Climate Observing System [3,4].

Spatio-temporal study refers to the analysis and understanding of phenomena or process that varies in time and is an important aspect in understanding the dynamic relation between the earth's surface and its surrounding. In spatio-temporal study of the present work, it involves examining land surface temperature (LST) pattern in the designated area over a period of time using satellite imagery. This can be done by analyzing satellite imagery with thermal sensors that capture thermal variation. Temporal dimension of the study focuses on analyzing LST values over time and identify areas with higher and lower temperature and identify the hotspots and observe the impact of land cover on temperature distribution.

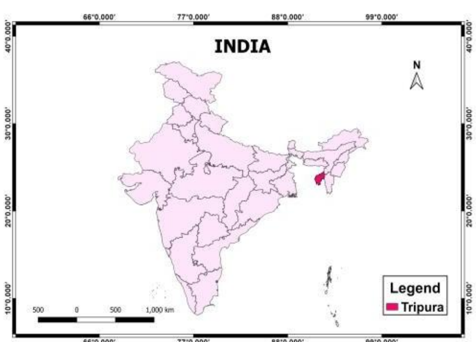
West Tripura is an administrative district and as of 2012 it is the most populated district of Tripura with one of the most rapid developments in the urban infrastructural changes. The aim of this study is to examine the spatio temporal variation in the land surface temperature (LST) in the region of West Tripura District. With the change in the weather conditions over the past decades there is seen a hike in the overall temperature and irregular rainfall pattern hence land surface temperature is a very essential parameter that influences various ecological and environmental processes, including urban heat island, vegetation health, and climate change impacts. Understanding the spatio-temporal study of the land surface temperature can give us insights for sustainable urban planning, land use management and also help us in planning and making strategies to combat climate change by adapting sustainable measures to protect our home.



2. MATERIAL AND METHODS

2.1. Study Area

Tripura is a hilly state in northeast India and is bounded on 3 sides by Bangladesh. The study area, West Tripura district is located between 23.899° N latitude and 91.4048° E longitude and the most populous district in the state as of 2012 with its geographical area of 983.63 sq. km. West Tripura provides an interesting area for spatio-temporal studies due to its diverse landscape, forest cover, agricultural field, urban areas and water bodies. Geographically, West Tripura district is classified by diverse topography comprising of plains, hills and river valleys. With an average elevation of 12 to 30 meters above sea level, the terrain is undulating. Various rivers and their tributaries cross the region. The district experiences sub-tropical humid climate and has four distinct seasons i.e., summer (March to June), monsoon (June to September), (October to November), winter (December to February). The study area comprises of diverse forest cover types such as natural forest, agricultural land, plantation and riverine vegetation. There are both urban and semi-urban areas in the district. With significant population and infrastructure growth, Agartala, the capital of West Tripura, is the largest urban centre in the region. Jirania, Mandwi, Mohanpur, and Melaghar are a few other major towns that make up the district's urban built-up areas and function as vital economic, social, and cultural hubs that offer locals access to services, amenities, and employment opportunities. With its mixture of hills, forests, rivers, and urban centres, the study region of West Tripura offers a varied and dynamic terrain.



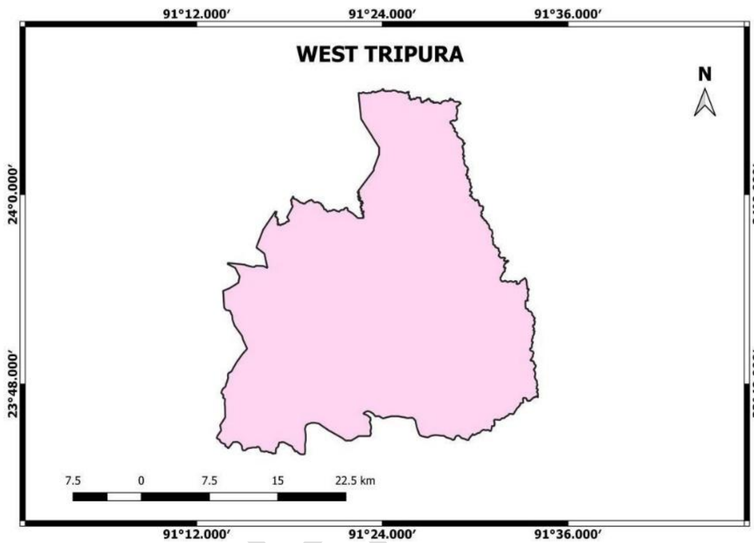


Fig.1. Location of Study Area

2.2. Database and methodology

For the present study, secondary source of data is used to draw the analysis. These secondary data include articles, online journals and satellite imagery (Landsat-8 OLI) for the year 2020 which consist of total eleven bands, (Landsat 4-5) for 2010 and (Landsat- 5 ETM) for 2000 which consist of seven bands in total that were obtained from USGS Earth Explorer with cloud cover less than 20% for performing the task for the study.
To examine the spatio-temporal change of the land surface temperature of the study area, NDVI, retrieval of land surface temperature, correlation analysis and additional LULC maps for the year 2000, 2010 and 2020 with maximum likelihood classification was performed in the Arc GIS software 10.8.

Normalized Difference Vegetation Index (NDVI) is a standardized vegetation index which iscalculated using Near Infrared band and Red band. For (Landsat- 8 OLI) (Band 5) Near Infraredand (Band 4) Red and for (Landsat- 5 ETM) (Band 4) Near Infrared and (Band 3) Red was used topreparethemaps.

NDVI=(NIR-RED)/(NIR+RED)

Landsurfacetemperatureof(Landsat-8OLI)wasobtainedby the followingstepsandtheradiance bands 10.

Step1:ConversionofTopof Atmosphere(TOA)Radiance:Usingtheradiancerescalingfactor,ThermalInfra-RedDigitalNumberswasconvertedtoTOAspectralradiance.

$L\lambda = ML * Q_{cal} + AL - O_i$

Where,

$L\lambda$= TOAspectralradiance(Watts/(m^2*sr*μm))

ML= RadiancemultiplicatedBand(No.)

AL=RadianceAdd Band (No)

Q_{cal}= Quantized and Calibrated standard product pixel values (DN)

O_i= correctionvalueforband10is0.29

Step 2: Conversion to Top of the Atmosphere (TOA) Brightness Temperature (BT): Spectralradiancedatawasconverted totopofatmosphere brightnesstemperatureusing thethermalconstantvaluesinMeta datafile.

Kelvin (K) to Celsius (°C) Degrees $BT = K2 / \ln (k1 / L\lambda + 1) - 273.15$

Where,

BT= Topofatmosphere brightness temperature(℃)

$L\lambda$=TOAspectralradiance(Watts/(m^2*sr*μm))

K1=K1ConstantBand(No.)

K2=K2ConstantBand(No.)

Step 3: Normalized Difference Vegetation Index(NDVI): The Normalized Difference Vegetation Index(NDVI)isastandardizedvegetationindexwhich was calculatedusingNearInfra-red(Band5) andRed(Band4)bands.

NDVI=(NIR-RED)/(NIR+RED)

Where,

RED=DNvaluesfromtheREDband

NIR=DNvaluesfromNear-Infraredband

Step 4: Land surface Emissivity (LSE): Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth calculated from NDVI.

$PV = ((NDVI - NDVI\,min)/(NDVImax - NDVImin))^2$

Where,

PV = Proportion of Vegetation

NDVI = DN values from NDVI image.

$NDVI_{min}$ = Minimum DN values from NDVI image

$NDVI_{max}$ = Maximum DN values from NDVI image

Step 5: Land Surface Temperature: LST is a radiative temperature which was calculated using Top of atmosphere brightness temperature wavelength of emitted radiance, Land Surface Emissivity.

$LST = BT/(1+(\lambda * BT/c2) * \ln(E))$

Here, c2 = 14388μm K

The value for Landsat 8 Band 10 is 10.8.

Where,

BT = Top of the atmosphere brightness temperature (℃)
λ= Wavelength of emitted radiance
E = Land Surface Emissivity
c2 = h*c/s=1.4388*10-2 mK = 14388 mK
h = Plank's Constant = $1.38*10^{-34}$ j s
s = Boltzmann constant = $1.38*10^{-23}$
c = velocity of light = $2.998*10^{8}$ m/s
QCAL = Quantized calibrated pixel value in DN

LMAXλ = Spectral radiance scaled to QCALMAX in (Watts/(m^2*sr*μm))
LMINλ = Spectral radiance scaled to QCALMIN in (Watts/(m^2*sr*μm))
QCALMIN = Minimum quantized calibrated pixel value (corresponding to LMINλ) in DN
QCALMAX = Maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN = 255

Land surface Temperature of (Landsat 5 ETM) was obtained by the following steps:

Step 1 Conversion of DN to radiance

$L\lambda=(LMAX\lambda - LMIN\lambda / QCALMAX - QCALMIN) (QCAL - QCALMIN) + LMIN\lambda$

Where,

Lλ = Spectral Radiance
QCAL = Quantized calibrated pixel value in DN
LMAXλ = Spectral radiance scaled to QCALMAX in (Watts/(m^2*sr*μm))
LMINλ = Spectral radiance scaled to QCALMIN in (Watts/(m^2*sr*μm))
QCALMIN = Minimum quantized calibrated pixel value (corresponding to LMINλ) in DN
QCALMAX = Maximum quantized calibrated pixel value (corresponding to LMAXλ) in DN = 255

Step 2 Conversion of Radiance into BT (in Kelvin)

$T = K2IN(K1L\lambda+1)$

Where,

T = Effective at satellite temperature in Kelvin
K2 = Calibration constant 2
K1 = Calibration constant 1
Lλ = Spectral radiance in (Watts/(m^2*sr*μm))

Step 3 Conversion of degree kelvin to degree celcius

C = k-273.15

3. RESULTS AND DISCUSSION

3.1. Land Use Land Cover(2000-2020)

Land use land covermap provides a visual representation and helps us to understand and analyze the current landscape. From 2000 to 2020, there was a fascinating shift in the changes in LULC over the two decades (Fig. 2.). Vegetation cover of 2000 was at 59% and it reduced to 55% in 2010 which was because of deforestation and in 2020, the vegetation cover has increased to 61% because of the popularity in the rubber plantation and other plantations and also the Tripura government's scheme has boosted the forest cover of the district (Fig. 3). West Tripura has gained 5.93 kha of tree cover region wide from 2000 to 2012 which equals to 35% of all tree cover gain in Tripura [5]. The built up areas had increased over the years and the agriculture land was reduced subsequently because of the pressure on land. During the years 2000, 2010 and 2020, the built up area accounted for 11%, 15% and 18% and the agriculture land was 14%, 14% and 13% respectively (Table 1). Barren land showed a 9 percent decrease from 2000 to 2020 due to increase in the infrastructural development and popularity in plantations which led to the significant reduction in the area of barren land over the years. Area under water body was 3% in the year 2000 and it showed 1% increase during 2010 and 2020 which may be because of the government's initiative to protect the wetlands in the city.

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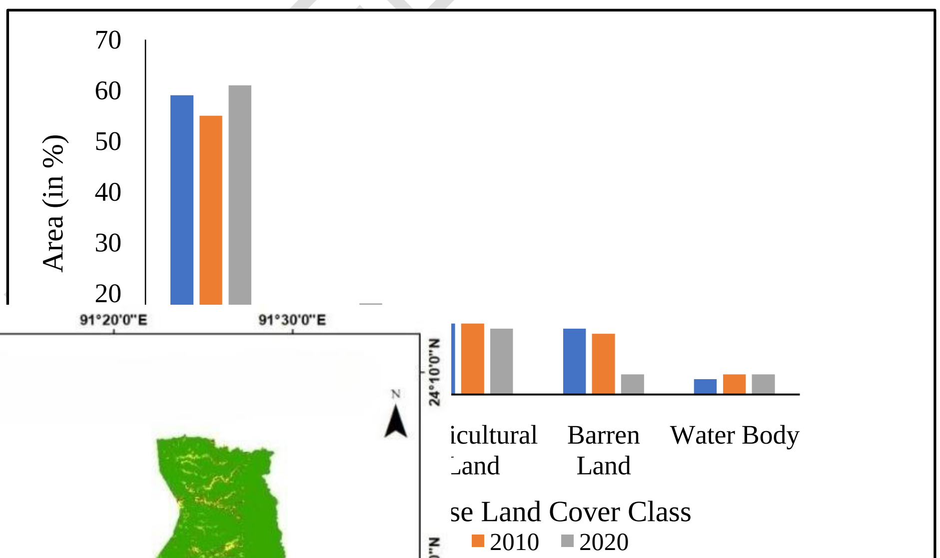
Table 1. Decadal change in Land use land cover of West Tripura

Land Use Land Cover Class	2000		2010		2020	
	Area (Sq. Km)	Percentage	Area (Sq. Km)	Percentage	Area (Sq. Km)	Percentage
Vegetation	552.08	59%	514.84	55%	575.38	61%
Built up	106.88	11%	133.77	15%	168.45	18%
Agricultural Land	133.19	14%	135.84	14%	122.5	13%
Barren Land	126.29	13%	121.77	12%	37.63	4%
Water Body	24.42	3%	37.67	4%	38.89	4%



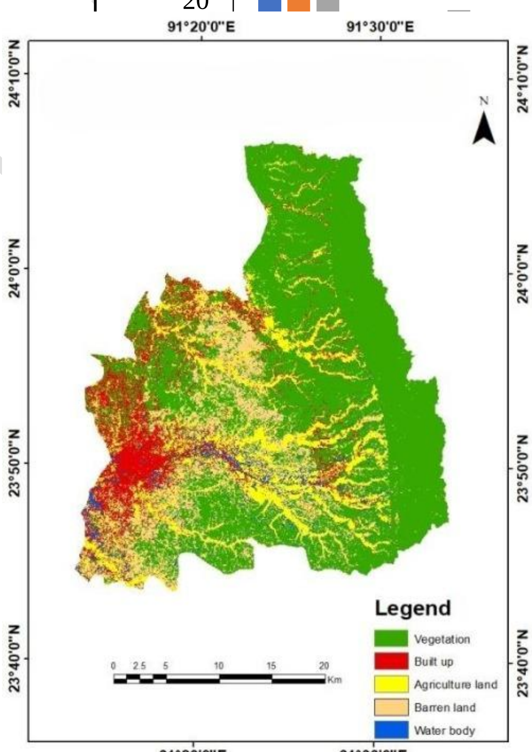
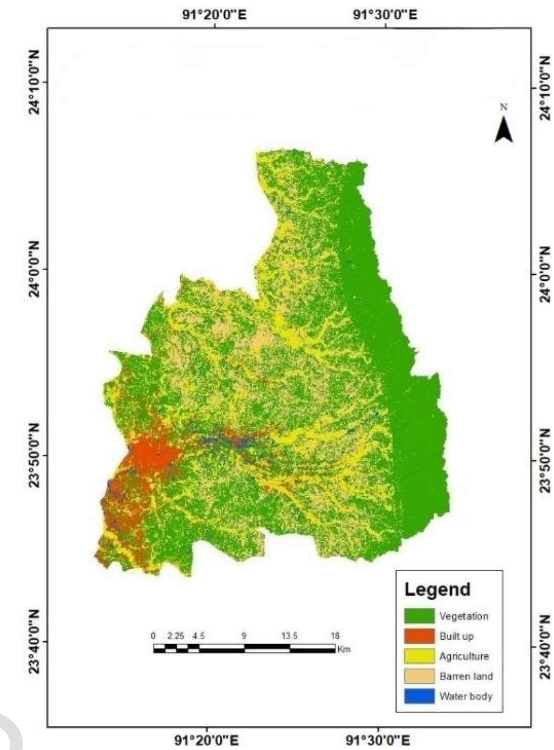
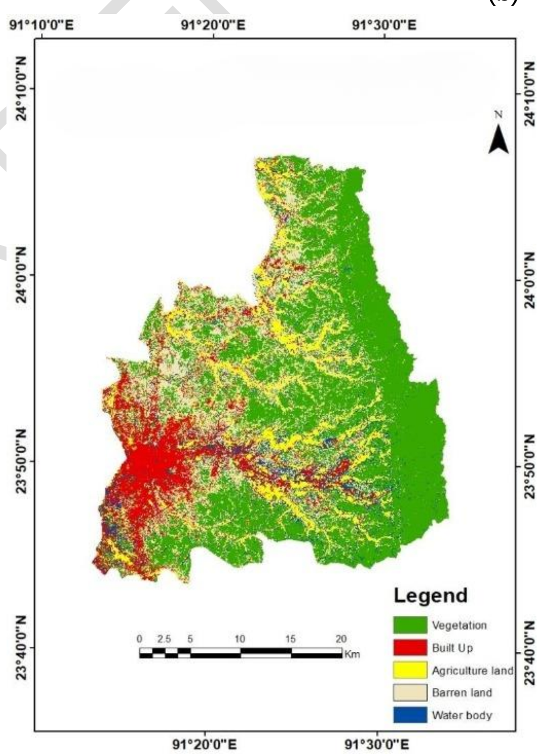


Fig. 2. Decadal wise percentage change in area of Land use land cover

(a)



(b)



(c)

Fig. 3. Land use land cover map of West Tripura (a) 2000 (b) 2010 and (c) 2020

Growing rubber plantations through the World Bank- backed India Rubber Project had become one of the key initiatives for rehabilitation of jhumias by the time of the ninth five-year plan [6]. The increase in the forest cover can also be attributed to the restoration of degraded forest land primarily caused by jhum cultivation through commercial rubber plantation and implementation of rubber based rehabilitation programme to elevate the marginalized section and land less farmers to earn their daily wages sustainably through this scheme. And various other efforts by the Tripura government such as Agriculture and Farmer's Welfare Department which engage in arecanut plantation, banana, mango and jackfruit plantation, roadside plantation and afforestation programme initiated by the Forest Department, River bank plantation by Water Resource Department and tea estate managed by Industrial Department and Public Sector promoted the overall vegetation growth of the district.

3.2. Spatio-temporal Change of Land Surface Temperature (LST)

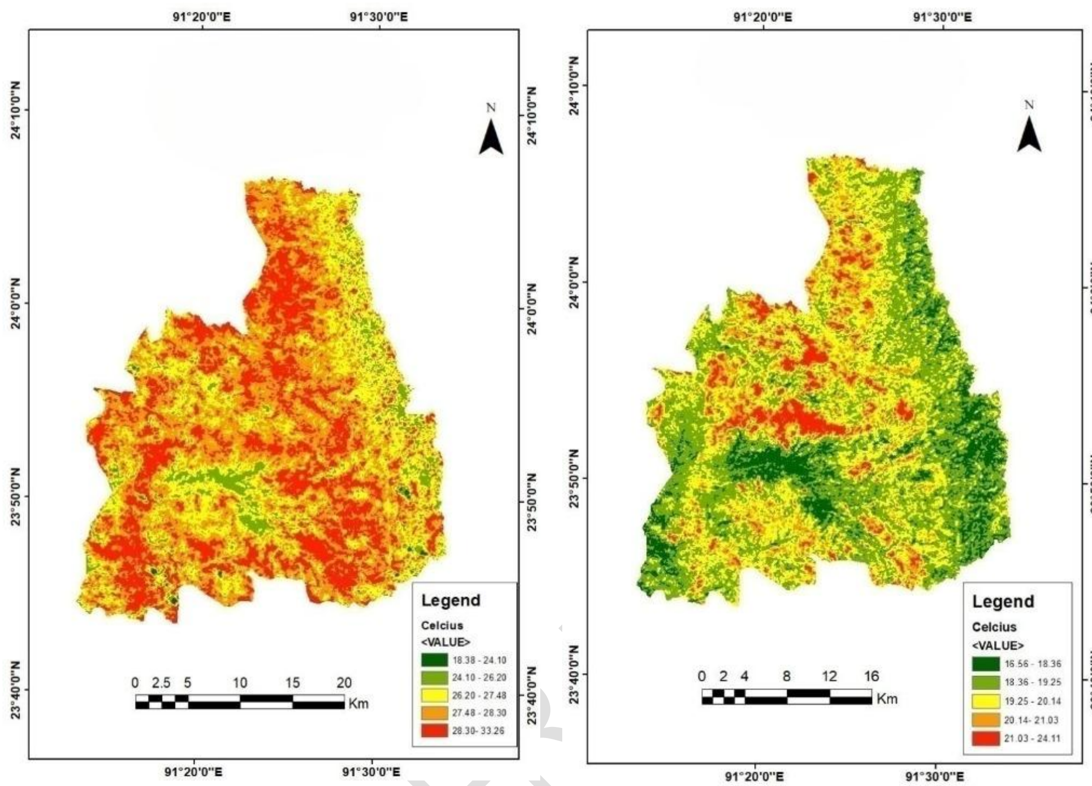
The dynamic transformation or evolution of events, patterns or processes through both space and time is referred to as spatio-temporal change. Land surface temperature of West Tripura district was subjected to various changes such as changes in the forest cover, urbanization, agricultural practices which have potential impact in the alteration of local climate. In spatio- temporal study, it involves examining land surface temperature (LST) pattern in the designated area over a period of time using satellite imagery. This can be done by analyzing satellite imagery with thermal sensors that capture thermal variation. Temporal dimension of the study focuses on analyzing LST values over time and identify areas with higher and lower temperature and identify the hotspots and observe the impact of land cover on temperature distribution.

3.2.1.Spatial pattern of LST of different Land Use Land Cover (LULC)

One significant component influencing LST is land use land cover change [7]. Different land use types have varied surface reflectivity and roughness, which causes variations in LST. [7,8]. The spatial pattern of LST of different land use land cover has varied differently in all through the season over the years from 2000 to 2020. In the present study, land use land cover was categorized into 5 classes that is vegetation, agricultural land, built up, barren land and water body.

3.2.1.1. Summer and winter (2000)

In 2000, the summer season saw the highest average LST in the highly concentrated areas, or built-up areas; summer temperatures peaked at 33.2°C with an average temperature of 26.7°C, while winter temperatures peaked at 23.2°C with an average temperature of 18.9°C. The highest temperature recorded in agricultural land was 32.4°C with an average temperature of 27.1°C, and winter temperatures averaged 23.2°C with an average temperature of 18.9°C. In the barren land, summertime highs reached 32°C with a mean temperature of 28°C, and wintertime highs reached 24.1°C with a mean temperature of 19.7°C. During the summer, the vegetation cover recorded a maximum temperature of 31.2°C with a mean temperature of 26.5°C, while in the winter, the greatest temperature was 23.1°C with a mean temperature of 17.2°C. The water body's highest recorded temperature in the summer was 25.8°C, with a mean temperature of 25°C, and the highest temperature in the winter was 19.3°C, with a mean temperature of 17°C.

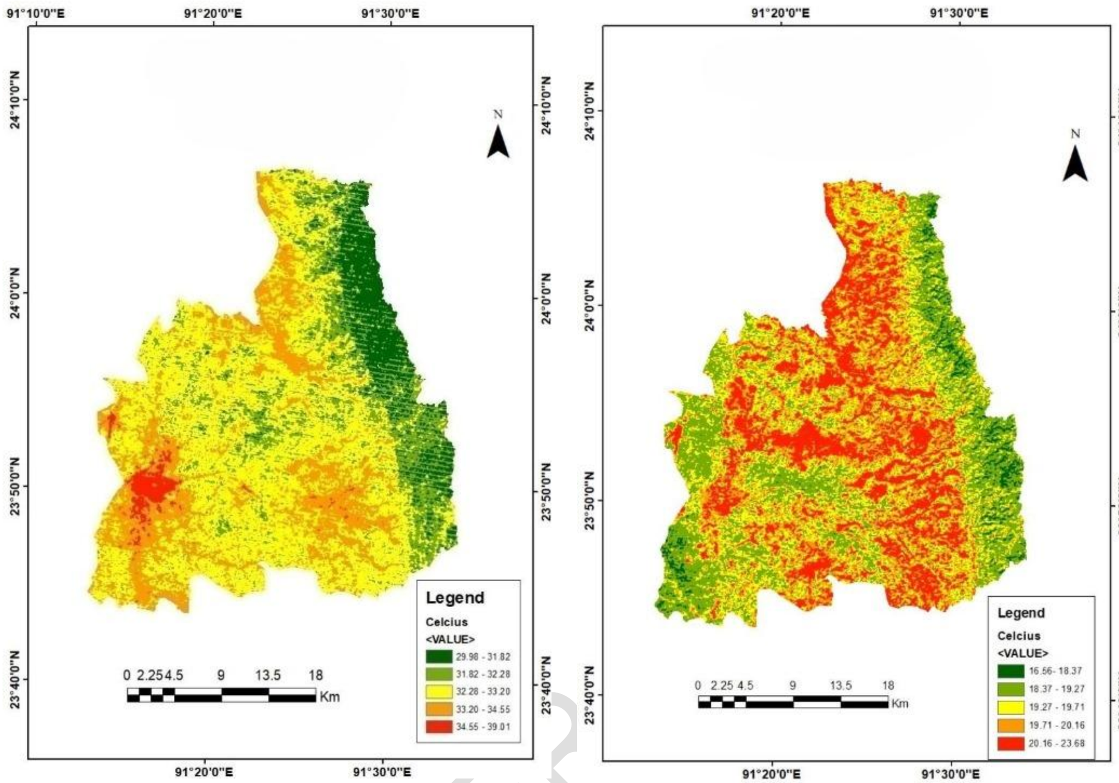


(a)(b)

Fig. 4. Land surface temperature of West Tripura(a) 2000, summer and (b) 2000, winter

3.2.1.2. Summer and winter (2010)

During the 2010 summer, the highly concentrated areas, or built-up areas, experienced the highest temperature among all land use and land cover groups. Summer temperatures reached a maximum of 39°C with a mean of 33.3°C, while winter temperatures reached their greatest point of 23.6°C with a mean of 19.1°C. In agricultural land, the highest recorded temperature was 37.2°C with a mean temperature of 33°C. In winter, the lowest recorded temperature was 23.6°C with a mean temperature of 19°C. For barren land, the highest recorded temperature in the summer was 36.8°C with a mean of 32.8°C, and the highest recorded temperature in the winter was 23.2°C with a mean of 20°C. In contrast, the highest recorded temperature in the summer for vegetated areas was 35.2°C with a mean of 29.6°C, and the highest recorded temperature for vegetation in the winter was 22.3°C with a mean of 19.3°C. In the summer, the water body recorded a maximum temperature of 28.2°C with a mean temperature of 26.7°C, while in the winter, the maximum temperature recorded was 21°C with a mean temperature of 19°C.

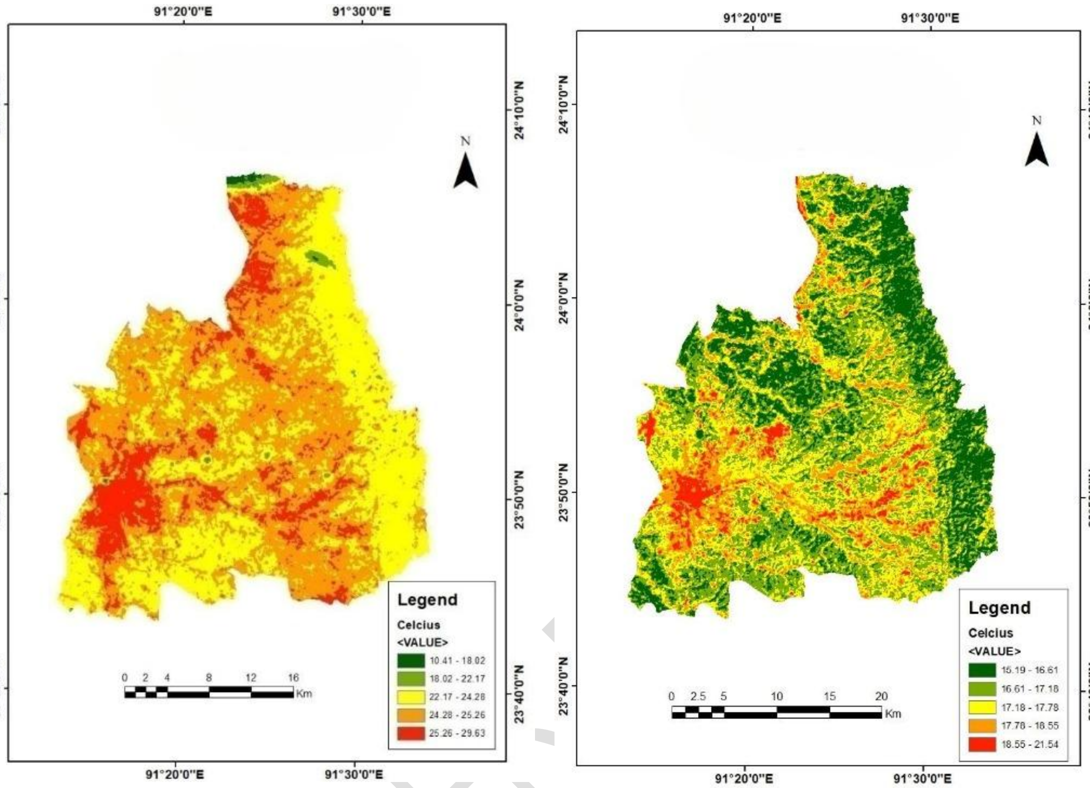


(a) (b)

Fig.5. Land surface temperature of West Tripura(a) 2010, summer and (b) 2010, winter

3.2.1.3. Summer and winter (2020)

Among all land use and land cover classes in 2020, the highest recorded summer temperature was 29.6°C, with a mean temperature of 25.2°C; the highest recorded winter temperature was 21.5°C, with a mean temperature of 17.8°C. The built-up areas experienced the highest temperatures during the summer season. The highest recorded temperature on agricultural land was 28.7°C, with summer and winter mean temperatures of 24.7°C and 21.2°C, respectively, and mean temperatures of 17.7°C. Barren land was found in the summer and winter seasons, with 28.1°C having a mean temperature of 24.6°C and 20.9°C and a mean temperature of 17.2°C, respectively. For the vegetated area, the highest recorded temperature in the summer was 27.4°C with a mean temperature of 24°C, and the highest recorded temperature in the winter was 20.6°C with a mean temperature of 16.7°C. Water body's maximum summer temperature was 28.3°C with a mean temperature of 23°C and the maximum winter temperature was 20.2°C with a mean temperature of 16.2°C.



(a) (b)

Fig.6. Land surface temperature of West Tripura(a) 2020, summer and (b) 2020, winter

Built-up areas had the highest mean temperature across all LULC types during the course of two decades, regardless of the season. The typical summer temperature of built-up land dropped by 2.4°C over this period, reaching 27.6°C, 33.3°C, and 25.2°C in 2000, 2010, and 2020, respectively. The equivalent winter LST readings were 18.9°C, 19.1°C, and 17.8°C in 2000, 2010, and 2020, respectively. There was a recorded 1.1°C dip in temperature. 2010 had a higher mean temperature due to reduced vegetation cover.

Over the years, agricultural land has consistently had a lower LST than built-up regions. In the summer, when it was 0.2°C in 2000, 0.3°C in 2010, and 0.9°C in 2020, the average land surface temperature (LST) difference between these two land use categories is much higher than in the winter, when it is just 0.2°C in 2000, 0.2°C in 2010, and 0.1°C in 2020.

The average temperature of barren land was 28°C in the summer of 2000, 32.8°C in 2010, and 24.6°C in 2020, indicating a 3.4°C drop in temperature between 2000 and 2020. Over the same period, the average temperature during the winter was 19.7°C in 2000, 23.6°C in 2010, and 17.2°C in 2020 representing a 2.5°C reduction.

Throughout the year, in every season, the water body's mean temperature behaved quite similarly to the vegetation. In 2000, the average summer temperature of a water body was 25°C, and the average winter temperature was 17.2°C. In 2010, the average summer temperature of a water body was 26.7°C, and the average winter temperature was 19°C. In 2020, the average summer temperature of a water body was 23°C, and the average winter temperature was 16.2°C. During the summer months, there was a 1.7°C rise in temperature from 2000 to 2010 and a 3.5°C drop from 2010 to 2020. Comparably, the temperature increased by 1.8°C between 2000 and 2010 and fell by 2.6°C between 2010 and 2020's winter season.

3.3. Relationship between LST and NDVI (2000 to 2020)

In environmental research and Earth observation, the link between land surface temperature (LST) and the Normalized Difference Vegetation Index (NDVI) is crucial [9]. The relationship between LST and NDVI is frequently inversely proportionate, meaning that when one parameter increases, the other usually decreases [10]. There is an inverse relationship between plant and bare soil (or impermeable surfaces) because of the differences in how they absorb and release heat energy.

3.3.1. Correlation between LST and NDVI (2000)

The graph of 2000 (Fig. 7) shows a declining trend, with the greatest LST temperature being 33.2°C and the minimum being 18.3°C. Additionally, the maximum NDVI value is 0.87 and the minimum value is -0.11. The maps below (Fig. 8) show us that the built-up areas, or areas with high temperatures, have low NDVIs due to a lack of vegetation cover. The eastern part of the map and certain patches in the central, southern, and western regions of the map have lower NDVIs and temperatures due to vegetation cover.

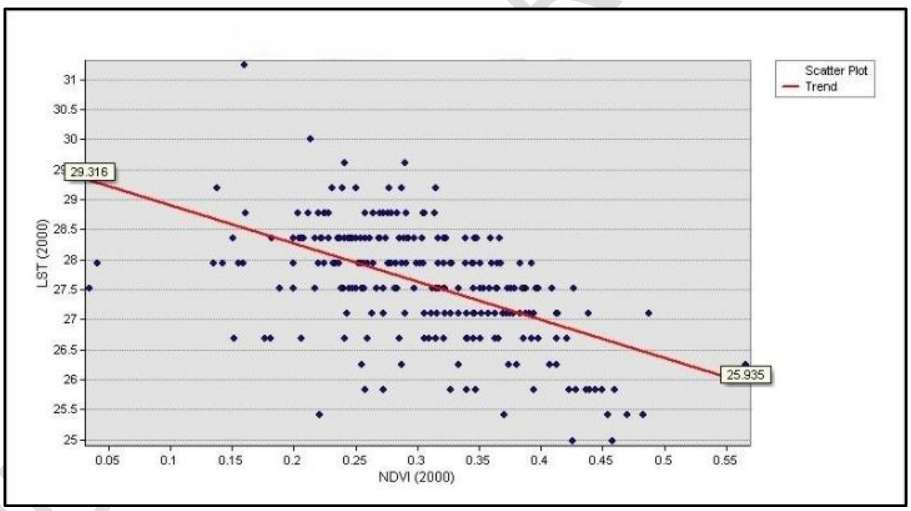
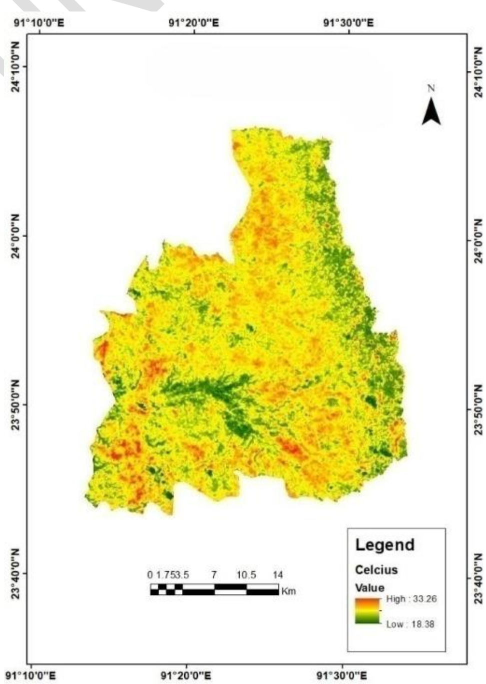
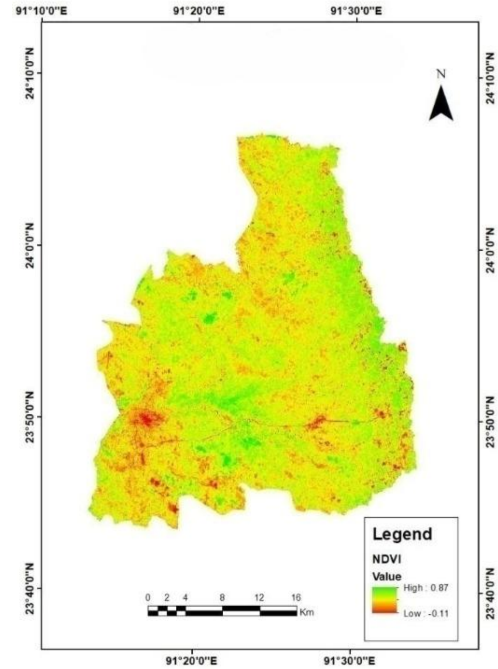


Figure 7. Correlation between LST and NDVI, 2000





(a) (b)

Figure 8. LST and NDVI map of West Tripura (a) LST, 2000 and (b) NDVI, 2000

3.3.2. Correlation between LST and NDVI (2010)

The graph shows a downward trend, with 2010's maximum and lowest LST temperatures being 39°C and 29.9°C, respectively (Fig. 9). The NDVI values range from 0.65 to -0.10, at the highest and minimum, respectively. The map below shows the areas with the highest levels of built-up area and high temperatures. These areas are located in the south-central, east, and north-western regions of the map, respectively, and have lower NDVI values. It is evident from the maps that Agartala, the capital city of Tripura and a centre for infrastructure development, has the lowest NDVI value and the highest temperature (Fig. 10). Mostly in the eastern, central, and southern regions of the map, the area with comparatively lower temperatures has higher NDVI values.

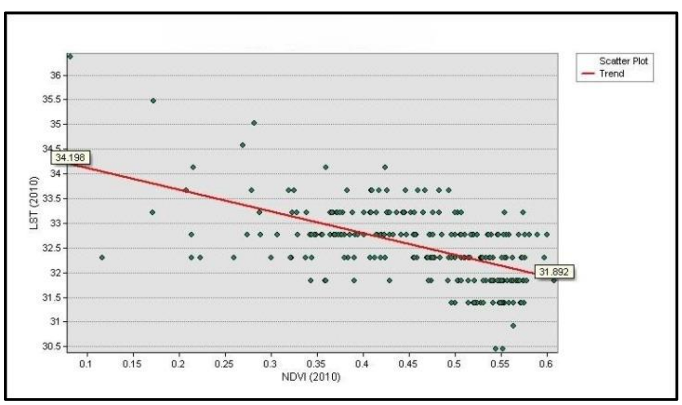
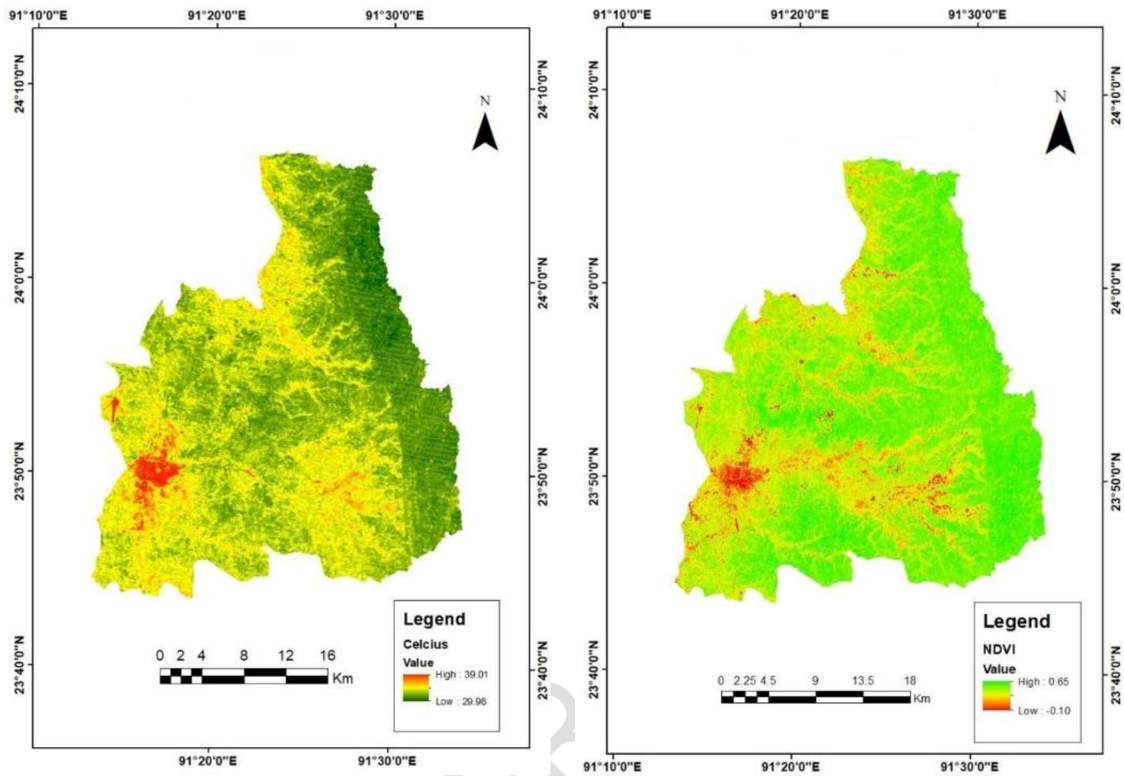


Figure 9. Correlation between LST and NDVI, 2010



(a) (b)

Figure 10. LST and NDVI map of West Tripura (a) LST, 2010 and (b) NDVI, 2010

3.3.3. Correlation between LST and NDVI (2020)

The maximum and minimum LST temperatures in 2020 are 10.4°C and 29.6°C, respectively (Fig. 11), whereas the maximum and minimum NDVI values are 0.53 and -0.04, respectively, as seen by the graph's negative trend line between LST and NDVI. The maps below make it clear that the high-temperature areas have low NDVI values because built-up areas retain heat and because ongoing infrastructure work reduces tree cover and denote poor vegetation. Agartala has the highest temperature, which causes it to have the lowest NDVI, or plant cover, as the maps make evident (Fig.12). The eastern and southern portion of the map depicts the locations with moderate to low temperatures.

The land surface temperature of the West Tripura district shows a decline in temperature across all land cover types over the 20-year period from 2000 to 2020. The land surface temperature (LST) exhibits a noteworthy trend over a two-decade period. From 2000 to 2010, the LST increased, a phenomenon that may be linked to continuous deforestation, growing land pressure due to urbanization, and population growth. These factors have all contributed to the 2010 loss of vegetation cover. Between 2010 and 2020, there was a drop in temperature, which can be linked to the government's efforts to enhance forest cover through policies and the growing popularity of plantations growing rubber, tea, bananas, and other crops.

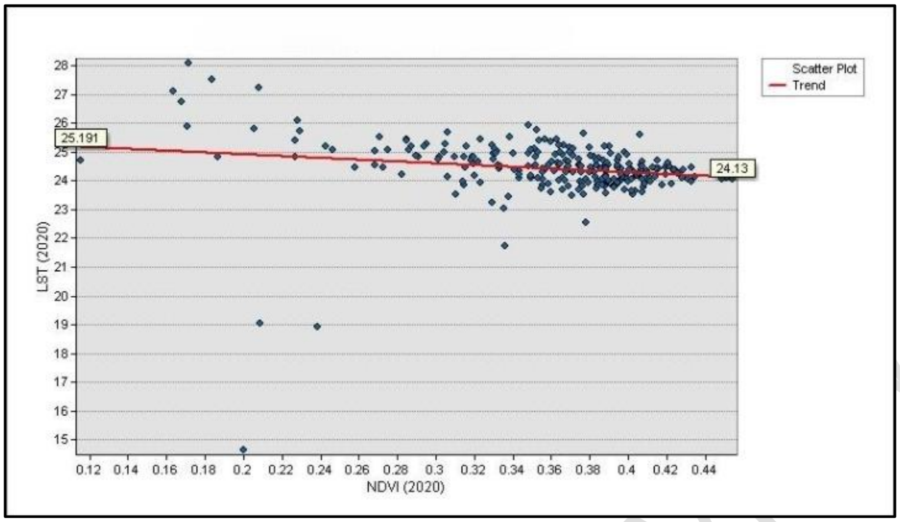
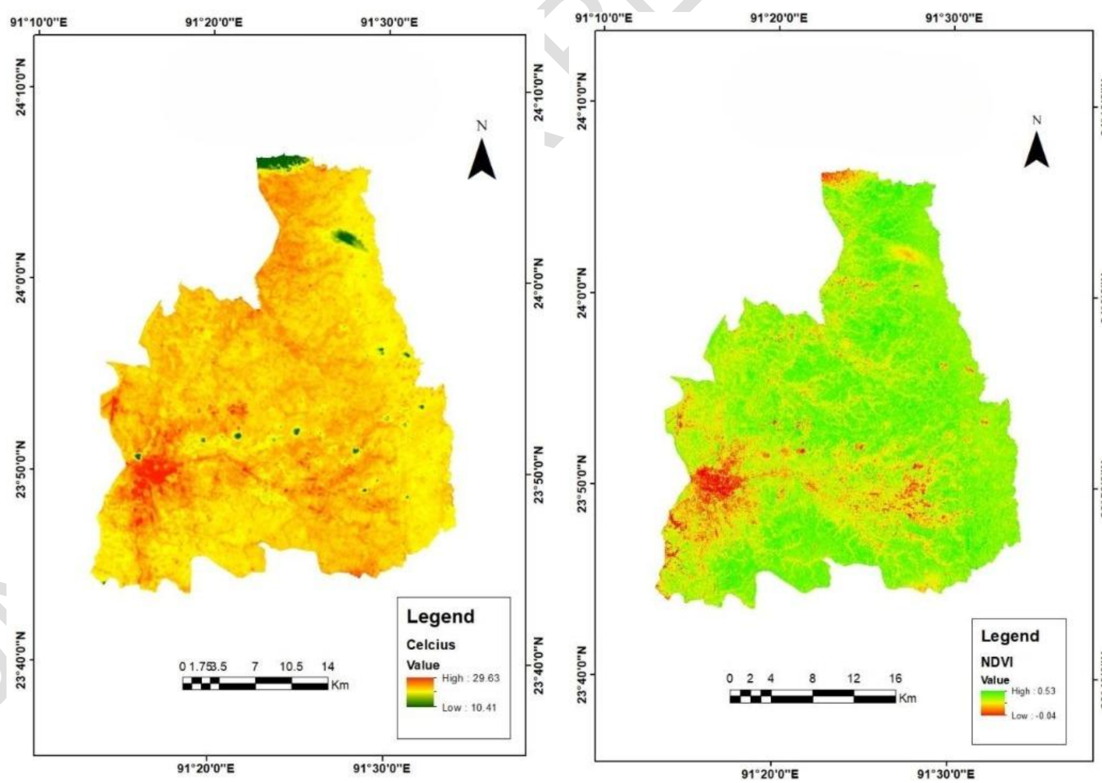


Figure 11. Correlation between LST and NDVI, 2020



(a) (b)

Figure 12. LST and NDVI map of West Tripura (a) LST, 2020 and (b) NDVI, 2020

4. CONCLUSION

In conclusion, the analysis of land use land cover and land surface temperature in West Tripura District from 2000 to 2020 reveals intriguing trends and outcomes over the two decades. The built-up areas, encompassing residential and commercial zones, displayed a steady growth rate of 11% in 2000, 12% in 2010, and 18% in 2020. In contrast, the vegetative cover initially experienced a decline from 59% in 2000 to 55% in 2010 due to factors such as deforestation, urbanization, and traditional jhuming practices by the indigenous communities. However, the implementation of Tripura government policies encouraging commercial rubber plantations by various agencies, along with other activities supporting agriculture and afforestation, allowed the vegetative cover to rebound to 61% in 2020.

Agricultural and barren land areas witnessed a decline over the two decades, mainly attributed to the increasing pressure from urban development and the rise in popular plantations like rubber, tea, and banana etc. Notably, the water bodies in the district saw a slight increase of 1% over the two decades, due to successful implementation of the Tripura Government's wetland protection scheme. This initiative played a crucial role in safeguarding and maintaining wetlands, which serve as cooling agents in urban areas and provide various social and ecological benefits.

The analysis of land surface temperature revealed that, over the course of the two decades from 2000 to 2020, the average temperature in the West Tripura District dropped for all land cover types. Notably, the LST displayed a greater value from 2000 to 2010, which can be linked to causes including population expansion, urbanization, and deforestation, which resulted in a decrease in the amount of vegetation cover by 2010. But between 2010 and 2020, the temperature started to drop, most likely as a result of government measures that increased the amount of forest cover and the rising popularity of plantations that produced rubber, tea, bananas, mangoes, and other crops.

Overall, these findings indicate that the district has undergone significant changes in land use and surface temperature, with efforts to promote afforestation and sustainable agricultural practices showing positive impacts on vegetation cover and temperature reduction. The Tripura government's proactive measures in protecting wetlands have also contributed to the preservation of valuable ecological resources. These insights are crucial for informed decision-making and future planning to ensure the sustainable development and environmental well-being of West Tripura District.

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