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Urbanization Effects on Land Surface Temperature in Shillong City

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Research Article

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Urbanization Effects on Land Surface Temperature in Shillong City

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Abstract :

The rapid urbanization has led to profound changes in the land surface temperature changes in the land surface characteristics of the Shillong urban agglomeration. The spatial characteristics of the cities are the expansion of built-up areas and the reduction of vegetation and open spaces. These changes can increase the land surface temperature of the thermal environment and development of the urban heat islands. The present study examines the relationship between urbanization and land surface temperature in Shillong City using a spatio-temporal approach based on remote sensing and Geographic Information System (GIS) techniques. Multi - temporal satellite data have been used to analyse changes in built-up areas , vegetation cover and surface temperature over the Shillong urban Agglomeration. LST is derived from Satellite data to examine the spatial distribution of surface temperature. Normalized Difference Vegetation Index are used to assess vegetation and built-up characteristics. The spatial analysis of the region is characterized by relatively dense built-up surfaces generally exhibit higher land surface temperatures (LST) , higher vegetation cover and open surfaces which is related to comparatively lower surface temperature. The findings emphasize the important relationship between urban growth, land cover transformation, and the thermal environment of Shillong city. The study provides useful information for sustainable urban planning, vegetation conservation and heat environment management in the rapidly developing hill city.

Keywords : Urbanization, Land Surface Temperature, Shillong, NDVI, NDBI, Remote Sensing , GIS , Urban Heat Island .

1 .Introduction :

The land surface temperature in Shillong has been on the rise over the past decades, primarily due to urbanization and changes in land use. Recent studies indicate that densely populated areas in Shillong has been on the rise over the past few decades, primarily due to urbanization and changes in land use. Recent studies indicate that densely populated areas in Shillong have experienced an average increase of 4.3 ℃ in LST from 1993 to 2024 , with temperature rising from approximately 17.45 ℃ to 21.75 ℃ during this period. This warming trend is attributed to the expansion of build up areas, which have grown by nearly 11% since 1993, often replacing green spaces and water bodies that naturally help in cooling the environment. The reduction in

vegetative areas has also contributed to the urban heat island effect, where urban regions become significantly warmer than their rural surroundings. Currently , most parts of Shillong exhibit land surface temperatures ranging between 17 ℃ and 23 ℃, a notably increase from previous decades. The rise in temperature not only affects the comfort of residents but also places additional strain on resources like water and electricity, and poses challenges to the city's delicate ecosystem. For real time weather updates, Shillong current air temperature is approximately 18 ℃ with clear skies. It's important to note that land surface temperatures, especially in urban areas with extensive concrete and asphalt surfaces. To monitor land surface temperatures in Shillong and other regions can utilize satellite based tools such as NASA's MODIS Land surface temperature maps , which provide global LST data.

2. Study Area :

Shillong is located at 25 °46' N latitude and 91° 48' E longitude , with the highest elevation of 6433 feet (1961 meters) above the mean sea level. Shillong urban agglomeration includes municipality, cantonment, and all areas under Mawlai C & RD Block including census town , Mawpat C& RD Block from umshyrpri Bridge upto 7th mile ,Upper Shillong including , Mawblei , Laitkor , Nongkseh , Umlyngka, Lawsohtun, Mawdiangdiang , Siejiong , (Govt of Meghalaya, Shillong master plan 2035).

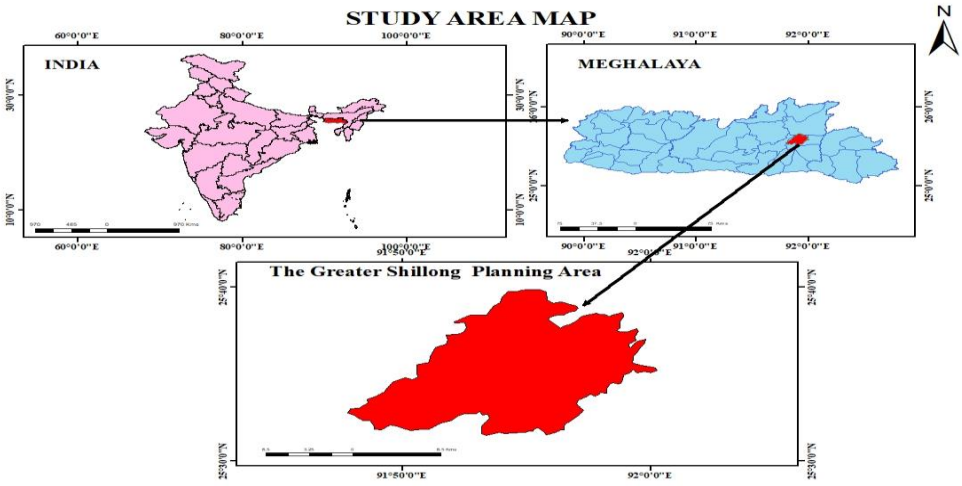


Figure 1. Background of the study area

The climate of Shillong is generally very humid and is directly influenced by the southwest monsoon and the northwest winter winds. Shillong experiences four main seasons ; spring (March to April), monsoon (May to September) ,autumn (October to November) ,winter (December to February). Temperature begin to warm at the onset of spring , peaking during the summer months. Winters are quite severe, with temperatures dropping to as low as 4℃ . April and May are the warmest months, while January is the coldest month.

3. Objective :

1 To investigate the land surface temperature of the study area.

2 To analyze the changes in vegetation and Built-up Area.

3. To examine the relationship between Urbanization and LST

4. Data Source and Methodology :

Data	Dataset	Data Sources
Satellite Imageries	Landsat 5,8 MODIS	USGS Bhuvan Geo -portal
Temperature Data	Microclimate variations in both Season (Summer and winter) Temperature data will be collected from several ground stations	Various ground stations
	Temperature data from individual roof top through appropriate sample survey (So as to understand the range of temperature at various locations	Infrared thermometer

5. Material and Methods :

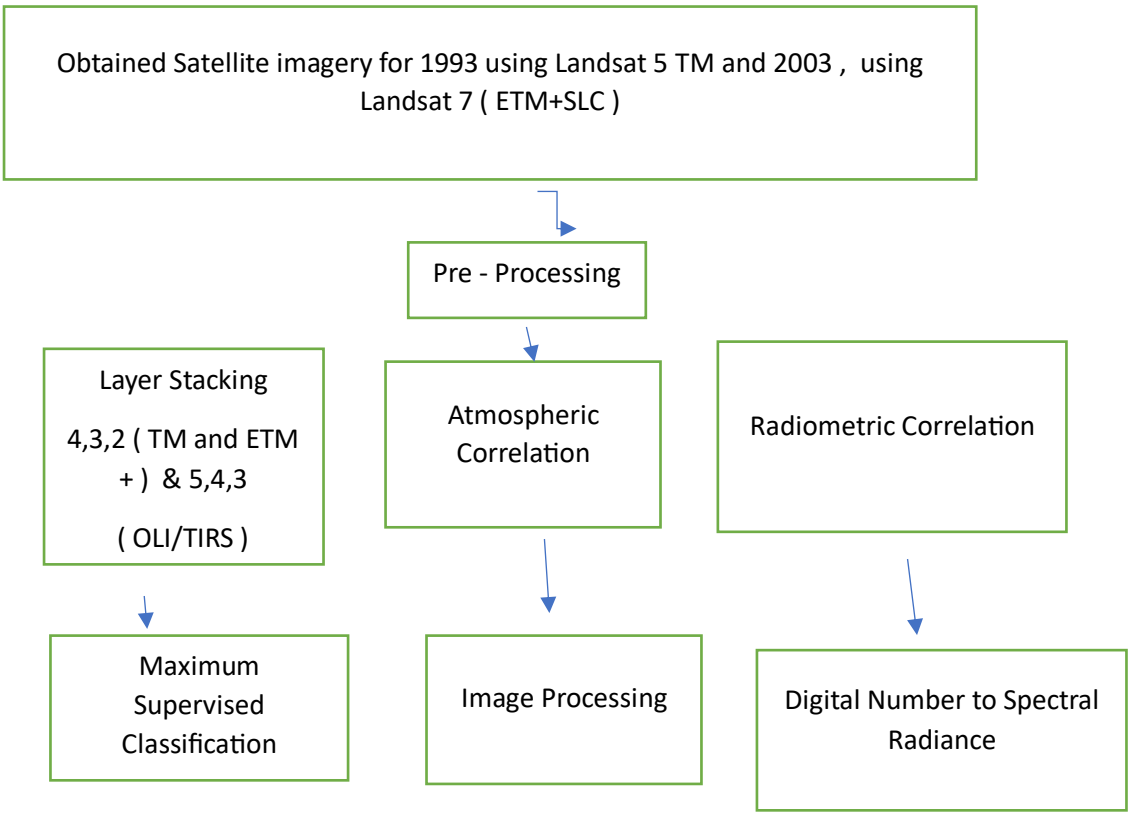
5.1. Acquisition of Satellite Imageries :

The USGS Earth Explorer website (https// earth explorer .usgs.gov/), viewed on March 15 , 2024 , provided the Landsat satellite data (USGS collection 2, Level 2 archive). The Landsat 5 Thematic Mapper (TM) (2003), Landsat 7 (ETM + SLC) Enhanced Thematic Mapper plus

Satellite	Sensor Type	Spatial resolution	Year
Landsat 5	TM	30	1992
Landsat7	ETM+	30	2007
Landsat9	OLI/TIRS	30	2024

(ETM +) and scanline collector (SLC) (2003), Landsat 8, Landsat 9 are among the datasets. The ground truth conditions have also been ascertained using field surveys and high resolution photos taken with Google Earth Pro 7.34.

The Greek alphabet



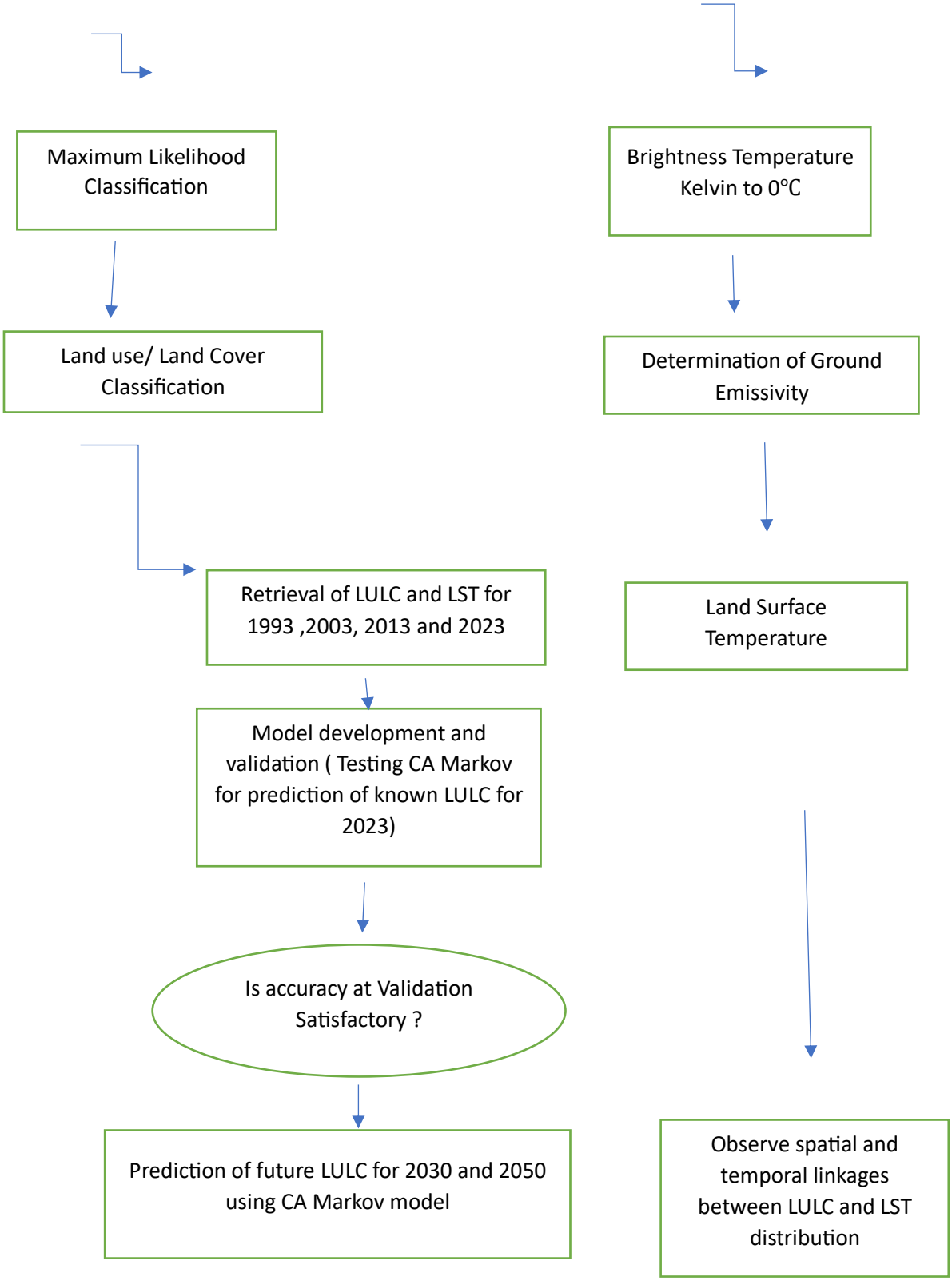


Figure 2. The overall methodological framework adopted in this study is illustrated

calculate the percentage of incoming solar energy reflected by the Earth's surface has been employed in this investigation. The USGS collection 2 , level 2 archive is replicated in the Landsat SR product , which is accessible in GEE. Level 2 scientific products are atmospherically corrected photos. The ecosystem disturbance adaptive processing system,

version 3.40 , is used to create the SR product of Landsat 5 and 7 NASA was initially responsible for developing the algorithm .

5.2. NDVI Analysis :

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

5.3 NDBI Analysis :

NDBI = (SWIR- NIR) / (SWIR + SIR)

5.4. Changes in LST over time in Various LULC classes :

The relationship between urbanization and LST is examined through a comparative interpretation of NDBI , NDVI and LST maps.

6. Results and Discussion :

6.1. Spatial pattern of Urbanization :

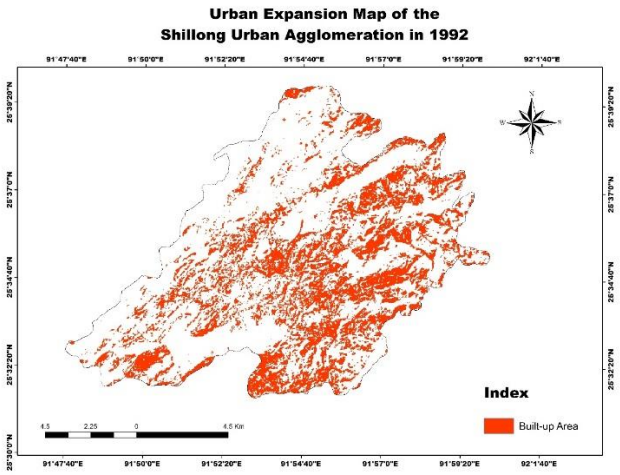


Figure 3. Urban Expansion Map of the Shillong Urban Agglomeration in 1992

The map shows the spatial distribution of built-up areas for the Shillong Urban Agglomeration in 1992. The red colour represents built-up areas, including residential, commercial, institutional, and transportation infrastructure , conversely the remaining white areas represents non built-up land such as forests , grassland , agricultural land , barren land , wetlands , and water bodies .

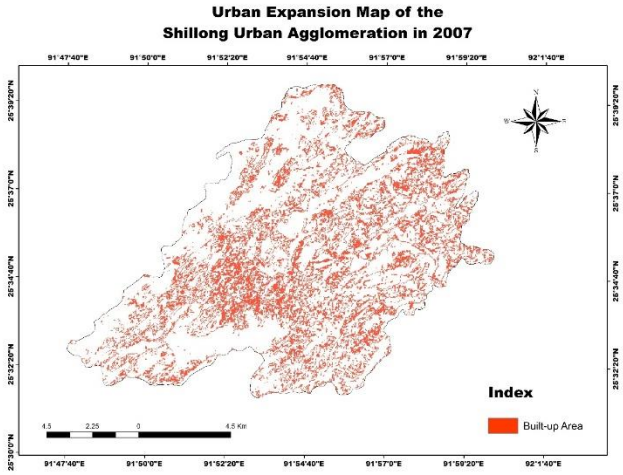


Figure 4. Urban Expansion Map of the Shillong Urban Agglomeration in 2007

The Urban Expansion Map (2007) indicates a significant phase of urban growth transforming from hilly city region within the Shillong Urban Agglomeration. Urban growth represents a continuous process which is the result of population growth, urban and institutional development transforming from the physical landscape. These zones function as a transitional zones between the urban city and surrounding rural regions.

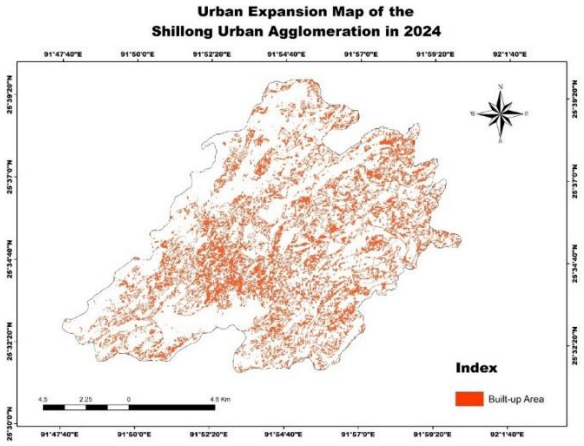


Figure 5. Urban Expansion Map of the Shillong Urban Agglomeration in 2024

The urban expansion map of 2024 shows the spatial variation in built-up areas and the density of the urban pattern within the Shillong urban agglomeration. Urban development is not evenly distributed thoughout the study area. The colour pattern indicates the transition zone between higher developed and lower developed regions.The red shades represents the higher density of urban development areas within the shillong urban agglomeration.

6.2. Spatial Distribution of Vegetation :

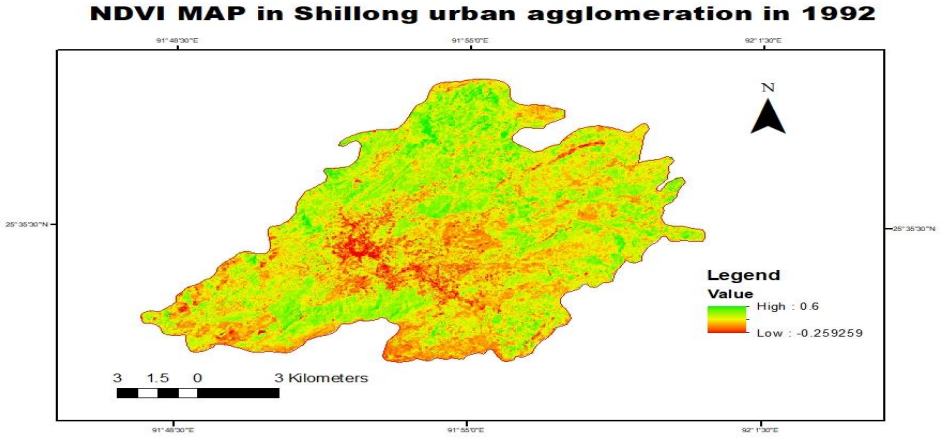
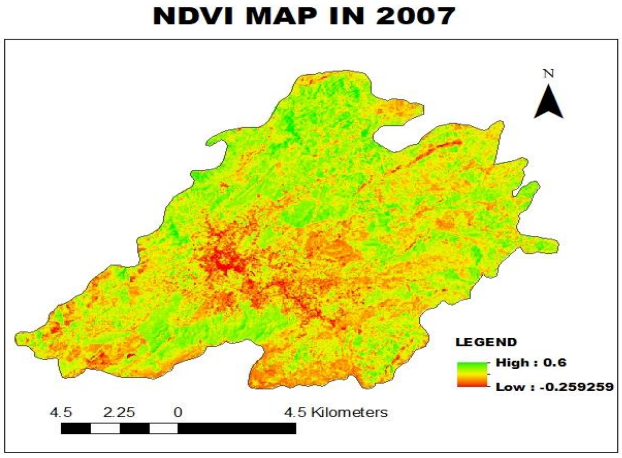


Figure 6. NDVI Map in Shillong Urban Agglomeration in 1992

The Normalized Difference Vegetation Index (NDVI) is the most important part for understanding the vegetation characteristics of the Shillong urban agglomeration in 1992.



The NDVI map in 2007 indicates a spatial variation of vegetation cover over the study area , with values ranging from -0.259 to 0.6.

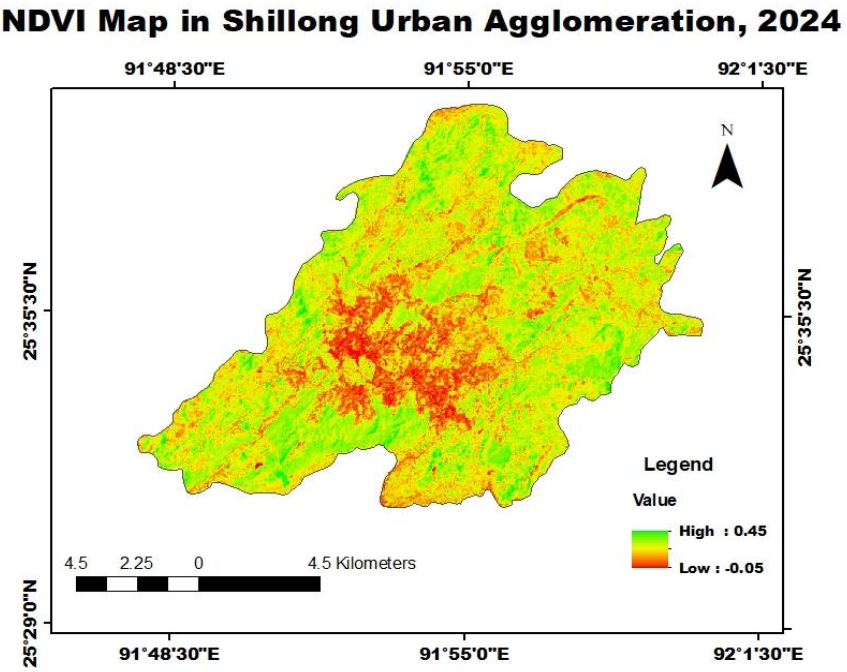


Figure 7. ***NDVI Map in Shillong Urban Agglomeration in 2024***

6.3. Calculation of Land Surface Temperature :

Information on Surface temperature emissivity can be obtained using thermal satellite sensors . Thermal Infrared (TIR) radiation measures are used to calculate the land surface temperature . Band 6 is utilized for surface temperature (ST) in Landsat 5 TM and Landsat 7 (ETM +) photos , while band 10 is used to transform the raw image into spectral radiance in Landsat (OLI) images. The formula below is used to determine the land surface temperature (LST)

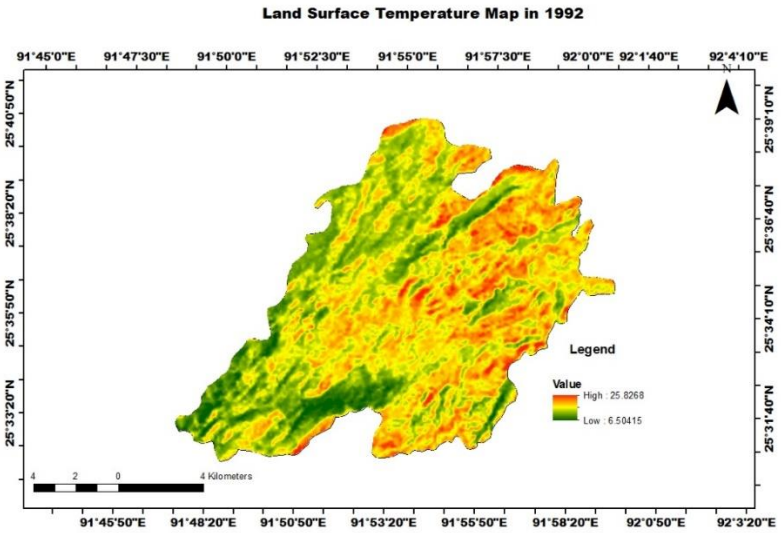
$$LST = \frac{BTS}{1 + (W+ BT) /14380 * In (E)}$$

Where ,

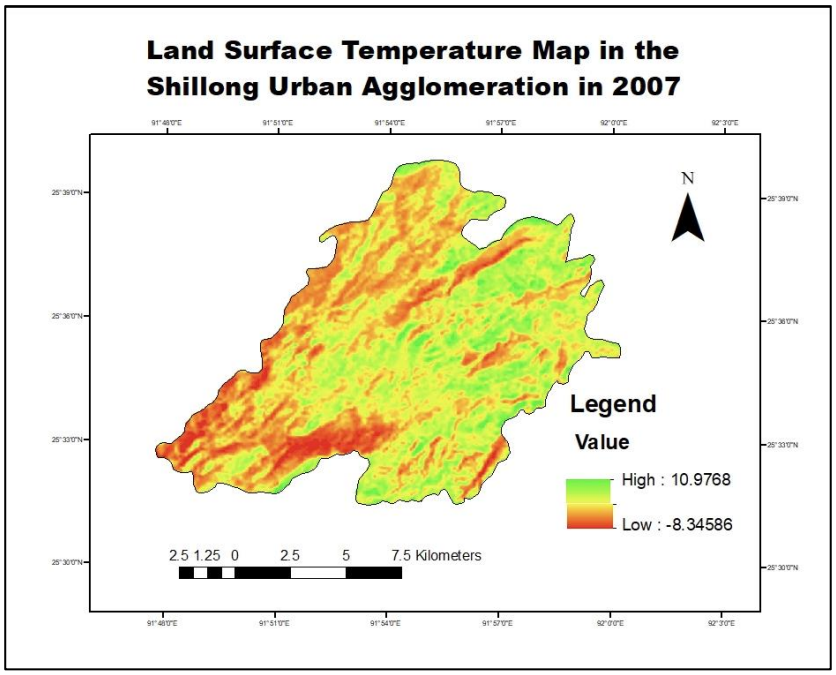
LST = Land Surface Temperature (Celcius) .

BT = Top of atmosphere brightness temperature (C).

E = Land Surface Emissivity .



The land surface temperature map of Shillong to 1992 indicates a spatio-temporal variation over the study area. The land surface temperature map is highly influenced by slope type, sunlight angle, and vegetation cover, which has a significant impact on local surface temperature over the study area.



The land surface temperature map from 2007 indicates the spatial thermal variation based on land use and land cover cover the study area.

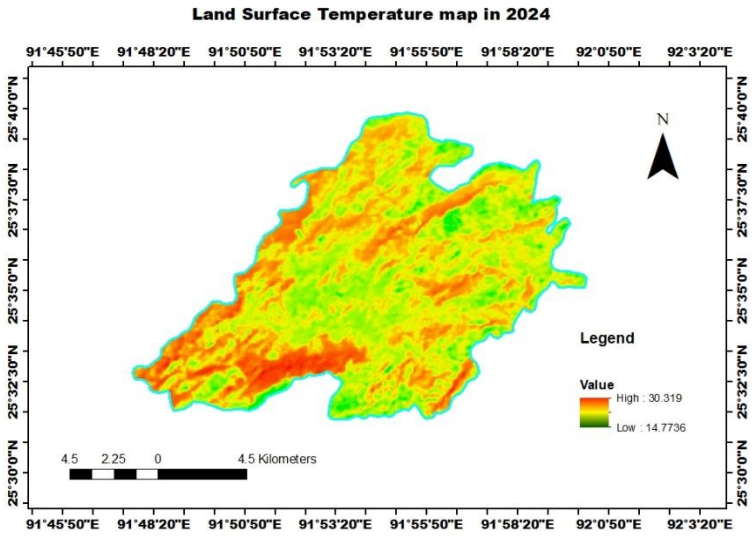


Figure 8. The variations in the temperature of the ground surface throughout time : (a) 1992 (b) 2007 , (c) 2024

The land surface temperature map for the year 2024 shows a significant spatial distribution of land surface temperature throughout the study area

Table 1. Land Surface temperature (LST) was determined by classifying satellite images across different years .

Year	Maximum (℃)	Minimum (℃)	Mean (℃)
1992	25.82	6.50	16.16
2007	10.97	- 8.34	9.67
2024	30.31	14.77	22.54

6.4. Changes in LST over time in Various LULC classes :

One of the most dynamic factors influencing LULC characteristics is urbanization, which also has a big effect on the environment. The highest average temperature are found in built -up areas and agricultural areas. The mean land surface temperature increased by 4.3℃ overall in urban areas. A larger standard deviation and wider minimum and maximum ranges accompany

this rise , suggesting dynamic volatility in land use characteristics . This variance is caused by the mix of various LULC classes brought about by the growth of industrial zones, build up region , and transportation networks.

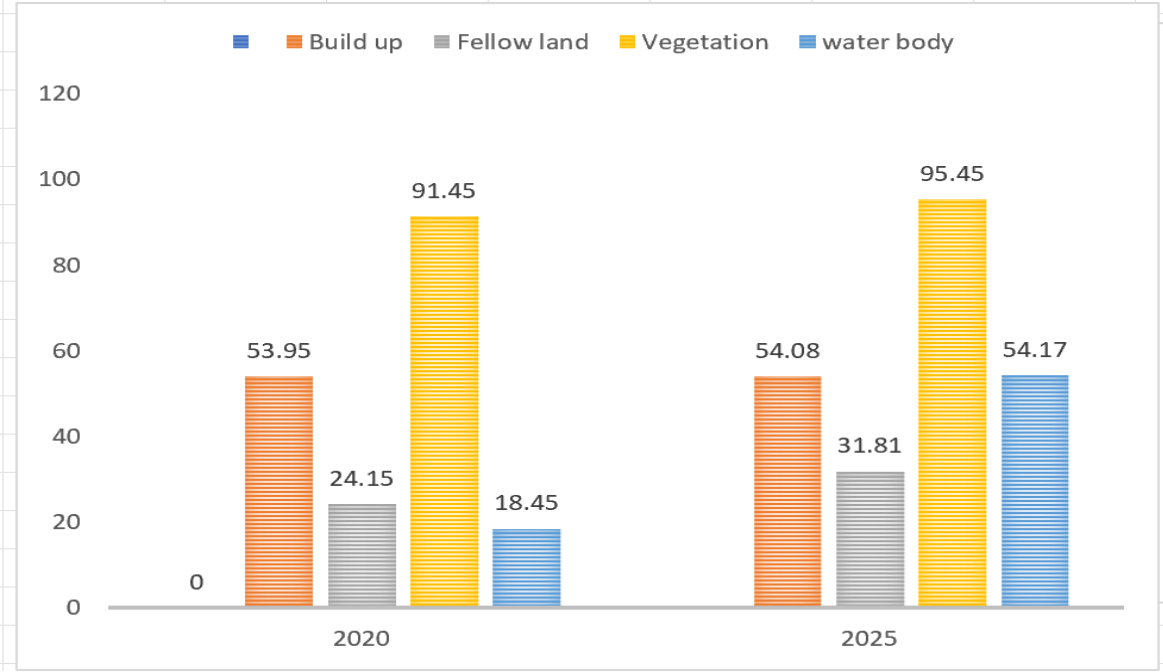


Figure 9. The bar graph illustrate the connection between LULC and LST in 2020 and 2025

Building construction and the expansion of urban infrastructure are linked to a notably increase in LST. Conversely region in vegetative cover show the least increase in LST. The main cause of this discrepancy is the significant evapotranspiration from plants, which cools the environment.

Table 2. Variations in LULC classes over the years

	2020 (%)	2025 (%)
Buildup Area	53.95	54.08
Fellow Land	24.15	31.81
Vegetation	99.00	95.45
Water body	18.45	54.17

6. Discussion :

Shillong's population has grown quickly as a result of its administrative and educational infrastructure. The city's grown picked in 2010 which resulted in the creation of new urban districts called New Shillong. Over the past three few decades , other LULC categories have stayed mostly unchanged in spite of this growth. During the research period , there have been no notable changes to the woodland area in particular. Since Shillong is a tribal town and careless tree cutting is strictly prohibited the forest area has remained largely stable. However, as the growth of additional urban areas is expected to raise LST in future, the anticipated changes in LULC feature could worsen UHI dynamics (Adnan et al , 2014).Therefore, while evaluating the effects of LULC and LST fluctuations on urban dynamics must be taken into account .

The natural cooling mechanism is adversely impacted by the expansion of build up regions, which is caused by factors like reduced transpiration and vegetation shade. Urbanization alters building methods , which increase surface run off and decreases soil penetration . Consequently, groundwater levels decrease. The decline of the water balance is made worse by climate change. Climate variables like daily maximum and minimum temperatures are greatly impacted by changes in land use . Furthermore , changes in land use lead to variations in surface albedo , which throw off the Earth radiation balance. In urban settings , a number of physical factors like as vegetation , land use and topography effect. The distribution of open terrain , water bodies , build up regions , and vegetation all have a significant impact on surface temperature. Places with high vegetation density and water features are often cooler than places with lower vegetation and fewer water features because vegetation and surface water bodies regulate temperature.

In recent years , Shillong , a well- known hill station in the eastern Himalayas , has been a sharp increase in population. This study provides important new information about the environmental effects of Shillong's urbanization , laying the groundwork for future urban planning and climate adaptation plans in the area and other places with comparable topography.

7. Conclusion :

This study investigate the relationship between LULC change and LST in Shillong city, India. In order to gain the critical spatial information and LULC features required for efficient land

resource planning and management , satellite data and GIS technology must be integrated. This study shows how well GIS technology and remote sensing data can be used to analyze LULC changes and forecast future events. Nevertheless, more investigation is required to include a variety of socioeconomic and environmental elements in the simulation , including the application of contemporary classification algorithms like RNN and LSTM. In order to lessen the effects of climate change, urban design and development should prioritize the creation of parks , green areas , and water bodies. In order to address growing thermal stress , green policies eeducation. The immediate impact of urbanization on LST and any lagged effects must be highlighted by a thorough quantitative investigation of these factors, which could yield insightful information for urban planning.

Declaration :

Data Availability Statement : . The datasets used and/ or analysed during the current study are available from the corresponding author upon responsible request. The publicly available remote sensing study .The remote sensing data and other spatial datasets used in this study have been obtained from publicly accessible sources.

Ethics Statement : Ethics approval was not applicable to this study because it involved the analysis of satellite imagery , remote sensing products , and other special datasets to investigate the urbanization on land surface temperature in Shillong City. The study did not involve human participants, the collection of personal data , or experiments.

Consent to Participate : This declaration confirms that no human participants have been recruited for the research.

Consequent for Publication :This study does not contain identifiable individual information or other requiring consent for publication .

Competing Interests : The authors declare that they have no competing interest .

Funding : The authors received no specific funding for this research

Authors Contribution : The author contributed to the conceptualization, methodology , data collection, remote sensing data processing , spatial analysis and interpretation results and revision of the manuscript . The author read and approved the final manuscript.

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