



Assessment of Land Surface Temperature (LST) & Urban Heat Island (UHI) Effect on Lucknow City, Uttar Pradesh, India

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ABSTRACT

Urbanization has significantly altered the thermal environment of many cities, leading to the emergence of the Urban Heat Island (UHI) phenomenon. This study investigates the spatial distribution of Land Surface Temperature (LST) and UHI intensity in Lucknow City, Uttar Pradesh, using Landsat 8 Thermal Infrared Sensor (TIRS) Band 10 imagery acquired on 12 February 2020. LST was estimated through radiometric and emissivity correction procedures, while z-score normalization was applied to standardize temperature values and identify UHI zones. The results reveal that urban and built-up areas exhibit substantially higher surface temperatures than surrounding agricultural lands, vegetated regions, and water bodies. The maximum, minimum, and average LST values were found to be 26.50°C, 13.75°C, and 20.12°C, respectively. Temperature profile analysis further confirms the existence of pronounced UHI effects within Lucknow's urban core. Rapid urban expansion, increasing impervious surfaces, reduction in vegetation cover, and anthropogenic heat emissions are identified as the major factors contributing to elevated surface temperatures and UHI development in the city.

KEYWORDS

Land Surface Temperature (LST), Urban Heat Island (UHI), Landsat 8.

INTRODUCTION

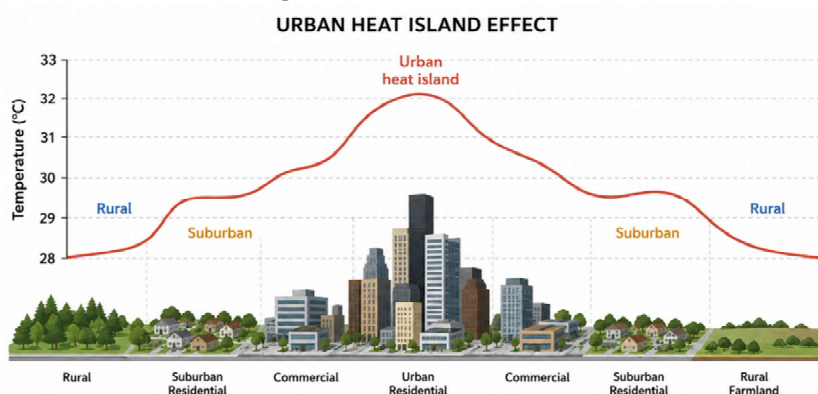
The temperature of our Earth is continuously increasing since Industrial period by various human induced activities. The IPCC Sixth Assessment Working Group I report has been pointed out that global average temperature has already risen by 1.07 Degree Celsius since pre-industrial times. Year 2024 was the warmest year since 1850. Earth's temperature has increased by an average of 0.11° Fahrenheit (0.06° Celsius) per

decade since 1850. Rising temperatures have affected every form of life on Earth.

Urban areas are also affected by these climate changes and has caused adverse impact on the urban environment, human health, infrastructure, energy, water, transportation, economic activities, livelihood, etc. Spatial extent of urban areas increases due to increasing population of urban centres which further induces urban sprawl. Urban material (concrete, asphalt, bricks, etc) absorbs solar radiation in great amount and release it slowly. Vehicles, air conditioners, kitchens, etc also release heat energy. Due to this phenomenon urban areas behave like as heat chambers. The temperature of the urban area remains greater than the surrounding areas. This phenomenon is known as Urban Heat Island (UHI). So, it can be said that urban sprawl directly contributes in the effect of UHI (Sultana & Satyanarayana, 2018).

The urban heat island (UHI) effect is a distinct phenomenon widely observed in cities across the world, where urban regions experience significantly higher temperatures than nearby rural or non-urban areas. This temperature difference, illustrated in Figure 1, results from the combined influence of several factors and human activities. These include the expansion of low-albedo concrete surfaces, repeated heat reflections from buildings, the dominance of impervious surfaces, reduction of vegetation, limited evapotranspiration, construction of asphalt-covered roads, and heat emissions from vehicles and air-conditioning systems. The warming effect is particularly pronounced during nighttime.

Figure 1: Urban heat Island



Urban Heat Island (UHI) develops due to several interconnected factors. One major cause is the urban built environment. In many Indian metropolitan regions, natural landscapes have increasingly been replaced by built-up areas because of rapid commercialization, population growth, and the rising need for housing. Structures such as buildings and paved surfaces absorb solar energy during the daytime and gradually release this stored heat at night, resulting in elevated urban temperatures. Another significant factor is the reduction of vegetation. Urban areas generally contain fewer trees and green spaces, limiting the cooling effect produced through evapotranspiration. Air pollution further intensifies the UHI phenomenon, as pollutants and suspended particles retain heat within the atmosphere, increasing local temperatures. Additionally, waste heat generated from human activities, including transportation, industrial operations, and energy use, contributes to urban warming. The albedo effect also plays an important role. Artificial surfaces such as concrete and asphalt possess lower albedo compared to natural vegetation, meaning they reflect less solar radiation and absorb more heat, thereby raising the temperature of surrounding areas (Amirtham, 2016).

In this study, the Urban Heat Island (UHI) effect on Lucknow City has been evaluated using Land Surface Temperature (LST) derived from Landsat 8 satellite imagery acquired on 12 February 2020. LST refers to the temperature of the Earth's surface estimated through remote sensing techniques. Although it does not represent the actual surface temperature, it is closely associated with air temperature (Kumar, 2018). In essence, LST reflects the brightness temperature of the Earth's surface. Due to this relationship, LST serves as an effective indicator of the Urban Heat Island phenomenon, where urban regions exhibit relatively higher temperatures than nearby rural surroundings. Consequently, spatial patterns of LST often reveal distinct "heat islands" represented as zones of elevated temperature on LST maps (Rinner, 2011).

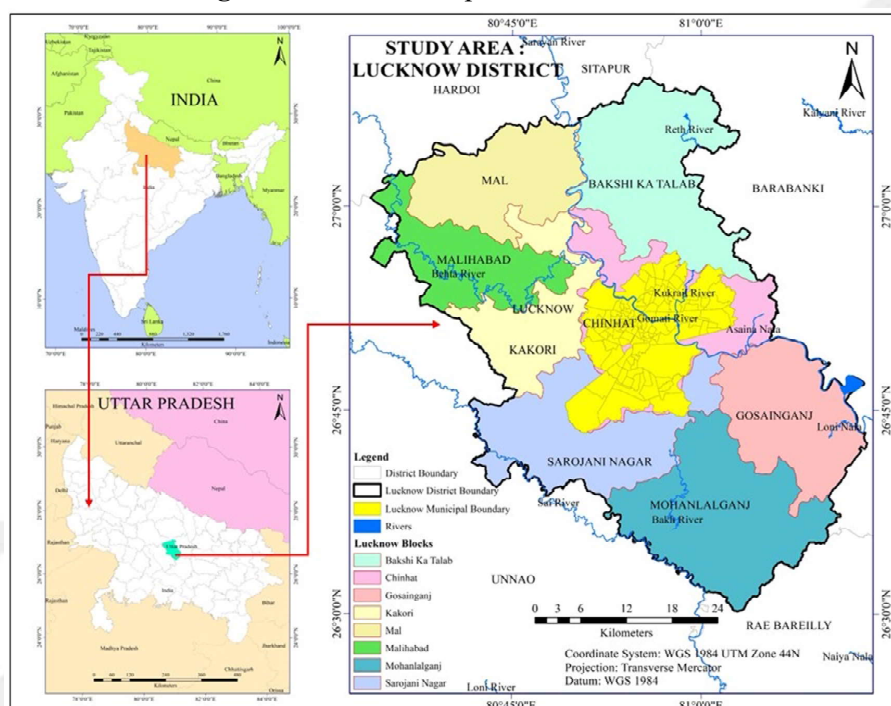
Study Area

Lucknow District has been selected as the study area for the present study. Located in the state of Uttar Pradesh, Lucknow serves as the state capital and is one of the most significant urban centers in northern India. According to the Census of India (2011), the Lucknow Urban Agglomeration had a population of 2.90 million, placing it among the country's major metropolitan regions and ranking 12th among urban agglomerations with a population exceeding 1 million. Owing to its status as the administrative capital, Lucknow has long functioned as a prominent center for political governance, economic development, cultural heritage, and social activities.

Geographically, the district is situated between 26°30' N and 27°09' N latitudes and 80°33' E and 81°13' E longitudes. The total geographical area of the district is approximately 2,528 square kilometers. It is bounded by Hardoi and Sitapur districts to the north, Barabanki to the east, Raebareli to the south, and Unnao to the west. The district stretches about 65 km in the north–south direction and nearly 51 km from east to west. The average elevation of the region is around 123 meters above mean sea level.

The Gomti River, an important perennial tributary of the Ganga River system, flows through the district and traverses Lucknow city. Situated within the fertile Indo-Gangetic Plain, the district is characterized by a predominantly flat topography with very limited relief variations. These physiographic conditions contribute significantly to the agricultural productivity and urban expansion of the region.

Figure 2: Location Map of Lucknow district



Methodology

Land Surface Temperature (LST) was estimated using Landsat 8 imagery acquired on 12 February 2020. The Thermal Infrared Sensor (TIRS) Band 10 (TIRS-1) was used for LST retrieval. The calculation of LST from Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) data involves a series of steps (Digavinti, 2017, Almeida, 2021).

1. Conversion of DN to at-sensor or Top of Atmospheric spectral radiance.
2. TOA Radiance is converted to Brightness temperature.
3. Calculation of NDVI (Normalised difference Vegetation Index).
4. Calculation of Vegetation Proportion.
5. Calculation of Land Surface Emissivity.
6. Calculation of Land Surface Temperature.

Normalization of LST Data

To facilitate comparison of Land Surface Temperature (LST) values across different locations and time periods, the LST data were normalized using the z-score standardization method (Dutta, 2021). This technique transforms the data to a common scale with a mean of zero and a standard deviation of one, thereby reducing the influence of differing units and ranges.

The z-score was calculated as:

$$Z = \frac{(x - \mu)}{\sigma}$$

where x represents the LST value, μ is the mean LST, and σ is the standard deviation of LST. The resulting z-score indicates the deviation of a particular LST value from the mean in terms of standard deviations. Positive values indicate temperatures above the mean, while negative values indicate temperatures below the mean.

The standardized LST values enable effective comparison of temperature conditions across different areas and help identify anomalously high-temperature zones. Areas with higher positive z-scores represent locations experiencing elevated surface temperatures and potential Urban Heat Island (UHI) effects.

Intensity-wise Urban Heat Island (UHI) Classification

Since LST data represent a continuous temperature surface, the normalized temperature values were classified into four categories using the mean and standard deviation approach (Dutta, 2021) to identify Urban Heat Islands (UHIs).

The classification scheme was as follows:

- **Category I:** $LST < \mu$
- **Category II:** $\mu \leq LST < \mu + SD$
- **Category III:** $\mu + SD \leq LST < \mu + 2SD$
- **Category IV:** $LST \geq \mu + 2SD$

Areas with temperatures exceeding the mean by one standard deviation ($\mu + SD$) were identified as Urban Heat Islands (UHIs), whereas areas exceeding the mean by two standard deviations ($\mu + 2SD$) were classified as extreme hotspots. These extreme hotspots are statistically uncommon and represent the most intense thermal environments within the study area. Regions with temperatures equal to or below the mean were not considered UHI zones, as they do not reflect elevated thermal stress conditions.

Result

Land surface temperature map (Figure 3) of the Lucknow district has been created using Landsat 8 (band 10) satellite data of February 2020. During this time maximum and minimum LST values are 26.50 to 13.75 degree Celsius respectively. Average land surface temperature of the whole district is 20.12 degree Celsius in the month of February 2020. It is evident from the map that the Lucknow urban area depicts the higher temperature than the surrounding areas. Even roads originating from the Lucknow show the high temperature. Gomti river and other waterbodies show less surface temperature than the outer built up areas. Forest area and other vegetated areas of Lucknow also exhibit less temperature than the surrounding. Urban areas and other non-vegetated area show maximum LST around 24 to 26 degrees Celsius. Regions just outer the urban areas where greenery in the form of trees or crops is available shows less surface temperature near the lower values of LST.

The LST map was normalised using the z score method and a new normalized LST map (Figure 4) has been created to compare temperature values easily. Areas showing higher Z Score values indicate higher surface temperature. These areas are the potential Urban Hear Islands. Three lines AA', BB' & CC' (Figure 5) are drawn to create temperature profile graph. Along these lines 3 Temperature profiles has been created (Figure 6). After looking theses 3 temperature profile graphs, it is clear that Lucknow urban area has higher land surface temperature as compared to surrounding vegetated agricultural land and plantation areas. It clearly implies the existence of effect of Urban Heat Island over Lucknow City.

Lucknow has experienced a significant increase in Land Surface Temperature (LST) and Urban Heat Island (UHI) intensity during recent decades due to rapid urbanization and extensive land-use and land-cover changes. As the capital city of Uttar Pradesh, Lucknow has witnessed substantial population growth, economic development, and infrastructure expansion, resulting in the conversion of natural and agricultural lands into built-up areas. The replacement of vegetation and open spaces with impervious surfaces such as concrete buildings, asphalt roads, parking areas, and commercial complexes has increased the absorption and storage of solar radiation, leading to higher surface temperatures.

The rapid expansion of residential colonies, industrial zones, transportation networks, and commercial centers has reduced the extent of green spaces and agricultural fields that previously helped regulate local temperatures through evapotranspiration. The decline in vegetation cover decreases the cooling effect provided by plants, thereby contributing to elevated land surface temperatures. Furthermore, dense urban structures create urban canyons that trap heat and restrict air circulation, causing the accumulation of thermal energy within the city.

Anthropogenic heat emissions from vehicles, industries, air-conditioning systems, power generation, and other human activities further intensify the Urban Heat Island effect. The growing number of motor vehicles and increasing energy consumption associated with urban lifestyles contribute additional heat to the urban environment. Moreover, the concentration of economic and administrative activities in Lucknow attracts continuous migration from surrounding regions, resulting in further urban expansion and increased pressure on land resources.

Climatic factors such as low wind speed, high solar radiation, and prolonged summer conditions in the Indo-Gangetic Plain also enhance heat accumulation in the urban landscape. The loss of water bodies and wetland areas due to urban encroachment further reduces the natural cooling capacity of the city. Consequently, Lucknow exhibits higher Land Surface Temperatures compared to its surrounding rural areas, making it a prominent example of Urban Heat Island development in rapidly growing Indian cities.

Figure 3: Land Surface Temperature (LST) Map of Lucknow district

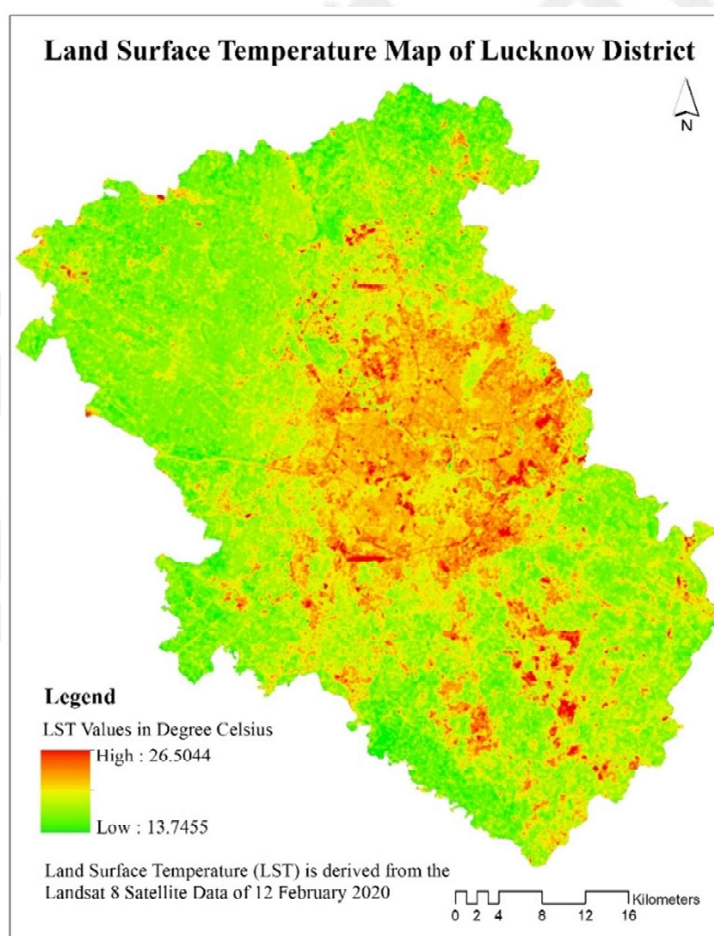


Figure 4: Normalised Values of Land Surface Temperature (LST) Map of Lucknow district

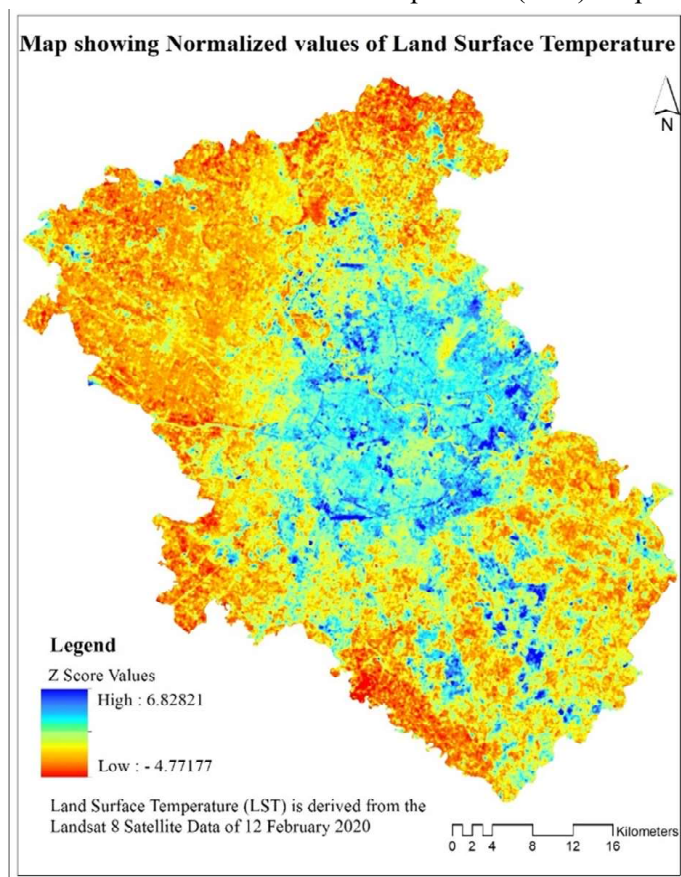


Figure 5: Map Showing Lines AA', BB' & CC' along which LST Profile was created

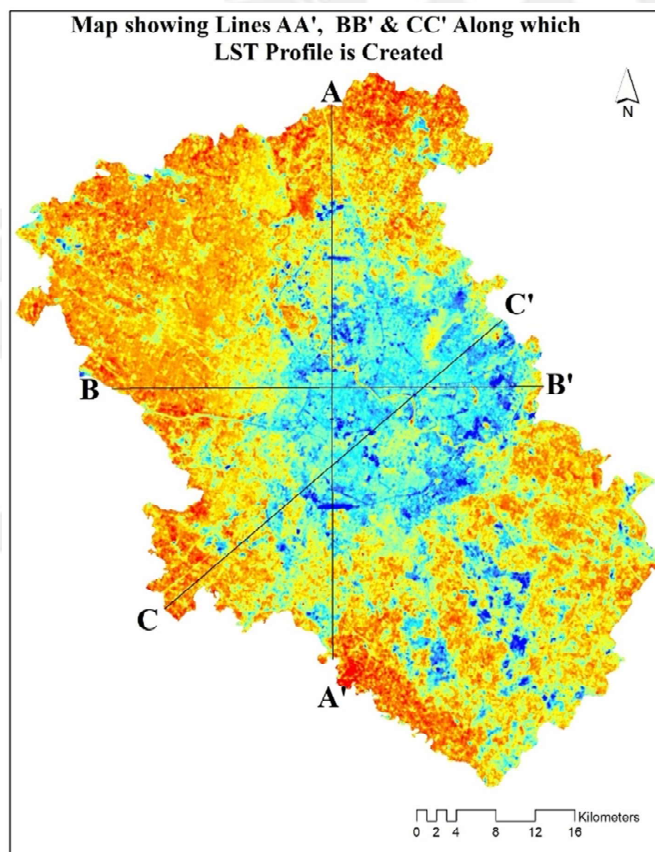
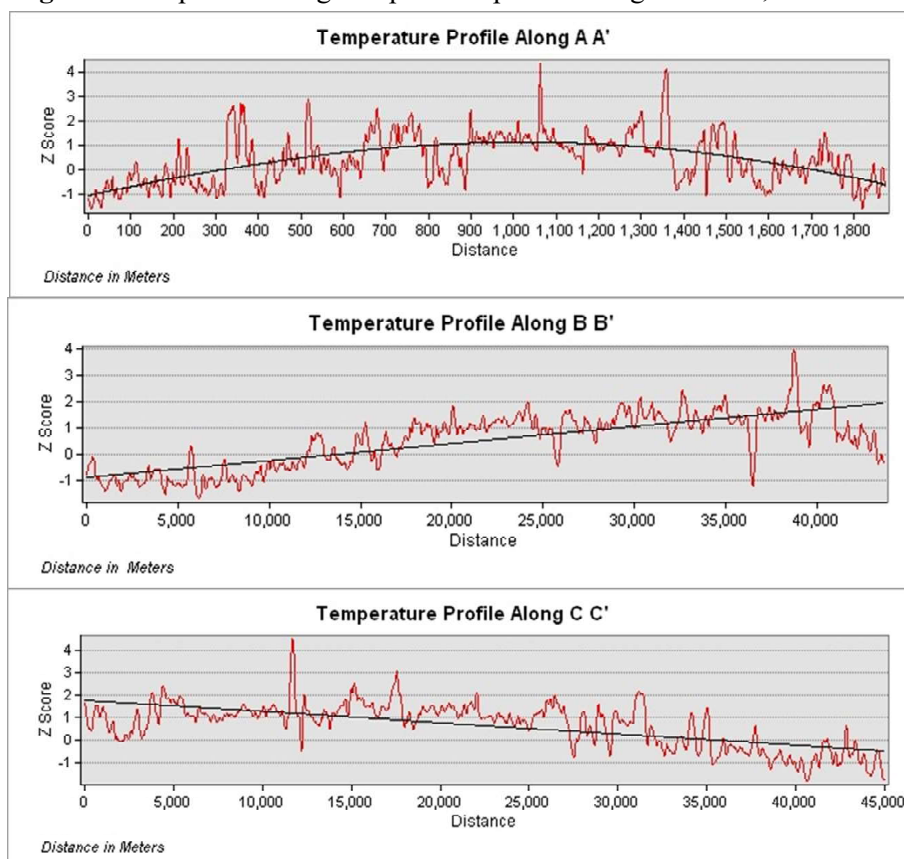


Figure 6: Graphs Showing Temperature profile along lines AA', BB' & CC'



CONCLUSION

Lucknow, the capital city of Uttar Pradesh, is one of the most important urban centers in northern India. As the administrative, political, economic, educational, commercial, and cultural hub of the state, the city attracts a large number of people from surrounding districts and other parts of Uttar Pradesh. The concentration of Government offices, educational institutions, healthcare facilities, industrial establishments, business centers, and employment opportunities has significantly enhanced its regional importance. Consequently, continuous rural-to-urban migration and population growth have accelerated the demand for housing, transportation, public services, and urban infrastructure.

In recent decades, Lucknow has experienced rapid urban expansion and urban sprawl, particularly along major transportation corridors and peripheral areas. The development of new residential colonies, industrial zones, commercial complexes, educational campuses, and infrastructure projects such as highways, expressways, metro rail networks, and ring roads has substantially transformed the urban landscape. The expansion of real estate activities and the conversion of agricultural land, open spaces, and peri-urban areas into built-up land have contributed to a significant increase in the city's spatial extent.

Furthermore, economic liberalization, rising income levels, population pressure, improved connectivity, and Government-led urban development initiatives have intensified land-use and land-cover changes across the city. These processes have resulted in the outward growth of the urban fringe and the emergence of new urban centers around the city. While such growth has enhanced economic development and urban infrastructure, it has also posed several environmental challenges, including the reduction of vegetation cover, loss of agricultural land, increased land surface temperatures, urban heat island effects, traffic congestion, and pressure on natural resources.

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