# Impact of Urbanisation on Surface Temperature of Bangalore City

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**Summary**

The city of Bangalore in India is well known for its IT industries and has certain geographical advantages that help maintain a pleasant climate throughout the year. At the same time, it is a rapidly growing city, with a decadal population growth rate of 47% between 2001 and 2011. Bangalore is also recognised for its greenery, lakes, and focus on sustainable development. In this study, we explored how the city's geographical features and sustainable practices contribute to maintaining a favourable climate using GIS techniques. We analysed the growth of urbanisation and land surface temperature from 2016 to 2022 during both summer and winter. The results show that the increase in urbanisation has not significantly affected the city's climate and this finding is interesting compared to existing studies.

**KEYWORDS:** Land Surface Temperature (LST), Surface Urban heat Island (SUHI), built-up percentage.

## 1 Introduction

The rapid growth of the global population has accelerated urbanisation in many cities worldwide (Abd-Elmabod et al., 2022). Today, over half of the world's population resides in major cities like India, China, Pakistan etc. (McNabb and McNabb, 2019). Seto et al. (2012) projected that urban land cover will rise by 1.2 million km$^2$ by 2030, nearly tripling the worldwide urban land area from its 2000 levels. If current population growth trends persist, cities with high development potential will experience significant urbanisation growth (Seto et al., 2012). This rapid urban expansion increases environmental strain, leading to the loss of biodiversity hotspots, accelerating climate change, and significantly affecting land surface temperature (LST). Urban development and deforestation, which replace natural land surfaces with concrete, drive temperature variations. These changes intensify the temperature differences between urban and rural areas (Chakraborty et al., 2015). Additionally, vegetation, a key source of moisture, is often replaced by built-up zones, causing a significant drop in humidity. Reduced moisture, combined with heat-retaining materials, results in excessive heat retention in urban areas, increasing LST (Hidalgo-García and Arco-Díaz, 2022). Seasonal and diurnal variations in surface temperatures can be analysed using LST data,

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which is efficiently captured through thermal remote sensing via satellite and aircraft sensors. The term "surface urban heat island" describes the variation in LST between urban and suburban areas, as measured by remote sensing, and was first introduced by Peng et al. (2012).

This study aims to explore how the expansion of built-up areas influences the Surface Urban Heat Island (SUHI) effect, thereby highlighting on the impact of urban growth on regional climate conditions. While similar investigations have been conducted on major cities in Japan and China, this study focuses on Bengaluru, India, a city with unique geographical advantages compared to those previously studied. The analysis is based on Land Surface Temperature (LST) data from 2016 to 2022, utilizing GIS techniques. A reference point located approximately 10km from the city is selected to compare temperature differences between urban and suburban areas, providing a benchmark for understanding these variations.

## 2 Methodology

NASA's Land Processes Distributed Active Archive Center (LP DAAC) has processed the Moderate Resolution Imaging Spectroradiometer (MODIS) MOD21A2 dataset, which generates 8-day composites of land surface temperature (LST) and emissivity from the Terra satellite. To assess seasonal temperature fluctuations and diurnal variations, day and night data from May and December 2016, 2018, 2020, and 2022 were analyzed. The data are appropriate for comprehensive regional and global assessments of temperature and emissivity because it has a sinusoidal projection and a spatial resolution of one kilometer. The Land Use and Land Cover (LULC) data used in this investigation was derived from Landsat 8 imagery downloaded via the USGS Earth Explorer portal.

ArcGIS was used to reproject the area to UTM, extract the area of interest as a subset, and evaluate Land Surface Temperature (LST) separately for summer and winter seasons during both day and night.The following formula is used to convert LST values from Kelvin to Celsius:

$$LST_{celsius} = (LST_{kelvin} \times Scale\ Factor) - 273.15 \tag{1}$$

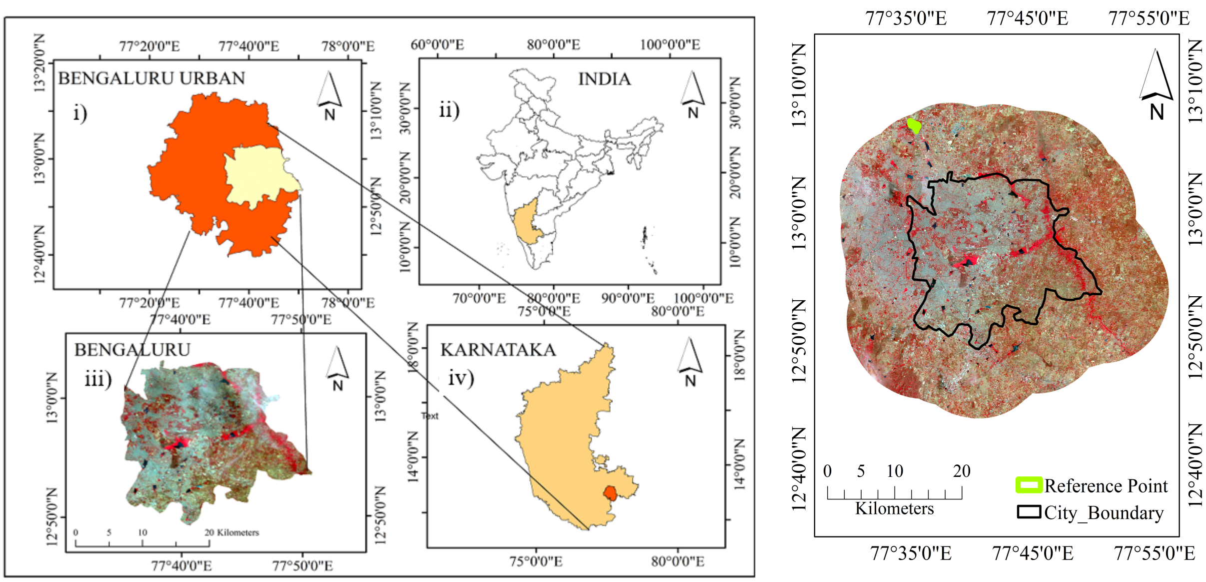
The mean temperature differential between urban and rural areas, known as SUHI, was calculated using LST values derived from the average pixel values outside the urban region, with a reference area identified as unchanged across 2016, 2018, 2020, and 2022. In Fig.2 the reference point is identified. The following formula (Hidalgo-García and Arco-Díaz, 2022) is used to calculate the

$$SUHI = LST_{urban} - LST_{rural} \tag{2}$$

## 3 Results

### 3.1 Expansion of Built-up Areas from 2016 to 2022

Bengaluru, a city renowned for its rapid industrial and urban expansion. Land Use and Land Cover (LULC) maps are helpful for visualizing the amount of urbanization over time and can be used to identify changes in built-up regions. A constant rise in built-up areas as a result of continuing



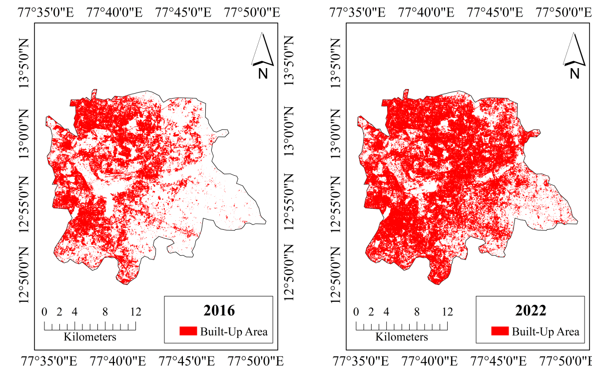

(a) (b)

Figure 1: (a.i) Show the maps of the study Area, Bengaluru (highlighted in yellow) and it's surrounding (highlighted in orange); (a.ii) shows the state of Karnataka (highlighted in yellow) where the city of Bengaluru belongs to. (a.iii) shows a Landsat image of the Bengaluru city and (a.iv) show the Karnataka state highlighting the Bengaluru city in red. (b) The figure shows the Landsat image of Bangalore city and its periphery. The reference point for calculation of SUHI is taken 10 km away from the city which is highlighted with green in the figure.

urbanization and industrialization is apparent in the data that was taken from these maps. Built-up areas have grown significantly in the last few years, from 144.62 km$^2$ in 2016 to 230 km$^2$ in 2022 as shown in figure 2. This pattern shows a yearly increase in urban development that is correlated with Bengaluru's continued landscape modification.

### 3.2 Surface Urban Heat Island

Figure 3 shows the impacts of day and night on summer and winter temperatures. The figure highlights a clear pattern of significant heat retention at night during both summer and winter. Additionally, during summer day-time, the northern part of the city is hotter, while during winter day-time, the southern part has the hotspots. A fixed reference point was used to study the Surface Urban Heat Island (SUHI) effect for the years 2016 and 2022. Furthermore, Bengaluru often experiences heavy evening rains in May, which enhance the cooling effect. According to Kumar and Mishra (2019), extensive irrigation systems that cool the environment are responsible for the temperature drops observed across India during heat waves.




(a) (b)

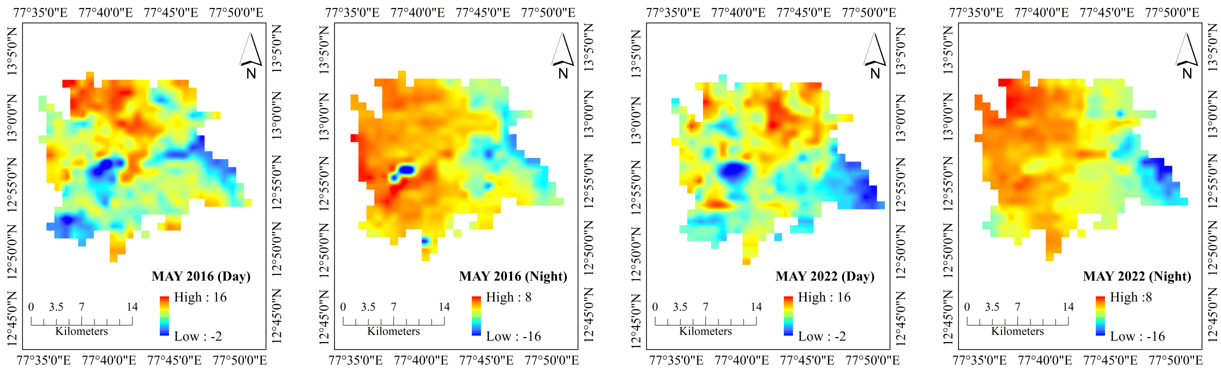
Figure 2: Show the built up area for a) 2016 b) 2022. The map shows that the built-up area has increases significantly from 2016 to 2022 towards south east.

### 3.3 Effect of builtup area on SUHI

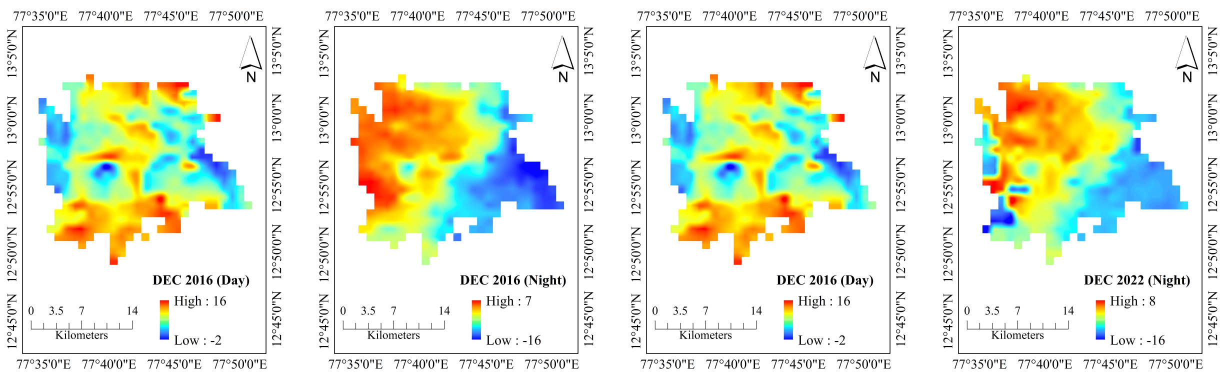
In Figure 4, the SUHI is shown against the percentage of built-up area for both day and night. Over seven years, there has been no major change in temperature during summer (May) or winter (December), even though the built-up area increased significantly between 2016 and 2022, as seen in Figure 2. During summer nights, the SUHI values are mostly around $0°C$, and during winter days, they also stay close to $0°C$. This is because the SUHI is calculated using a reference point, a lake about 10 km from Bangalore city. In the daytime, the temperature difference between urban and suburban areas is small. However, at night, urban areas cool faster because concrete, which is common in cities, has a higher emissivity than water. In summer, the opposite happens; the temperature difference is greater in the daytime as concrete heats up faster than water. In all cases, the SUHI does not change much as the built-up areas increase which is the most interesting finding of this study. This result might be due to the geographical location of Bangalore on a plateau, which helps to maintain moderate temperatures throughout the year. Since temperature decreases with altitude, Bangalore benefits from cooler air flowing in from the surrounding lowlands, allowing the heat from the land surface to dissipate more rapidly than in non-elevated cities. Furthermore, Bangalore frequently experiences evening rainfall, which accelerates the cooling of concrete surfaces. Another factor mitigating the impact of urbanization on land surface temperature is the city's sustainable urban planning, which preserves green spaces and helps regulate temperature effectively.

## 4 Conclusion

In this study we investigated the impact of urbanization on land surface temperature for Bangalore city, India. Bangalore was chosen because of its fast growth in urban areas and industries. The results show that the temperature difference, measured as the Surface Urban Heat Island (SUHI),




(a) (b) (c) (d)




(e) (f) (g) (h)

Figure 3: The map shows seasonal and diurnal temperature variation of a) day-time on May 2016 b) night-time on May 2016 c) day-time on May 2022 d) night-time on May 2022 e) day-time on Dec 2016 f) night-time on Dec 2016 g) day-time on Dec 2022 and h) night-time on Dec 2022. The colour gradation from blue to red represents low to high values of temperature.

stays the same even as built-up areas increase. This pattern is consistent across the years studied, from 2016 to 2022. Despite Bangalore's rapid urbanisation, the increase in built-up areas does not lead to higher surface temperatures. While this may seem surprising, it can be explained by the city's location on a plateau. The elevated position improves air circulation, which helps disperse heat from the land more effectively than in cities at lower altitudes. Additionally, frequent evening rainfall helps cool concrete structures like roads and buildings, keeping temperatures relatively stable throughout the year.

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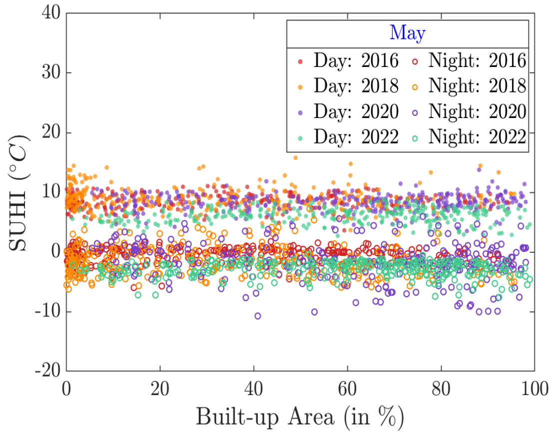
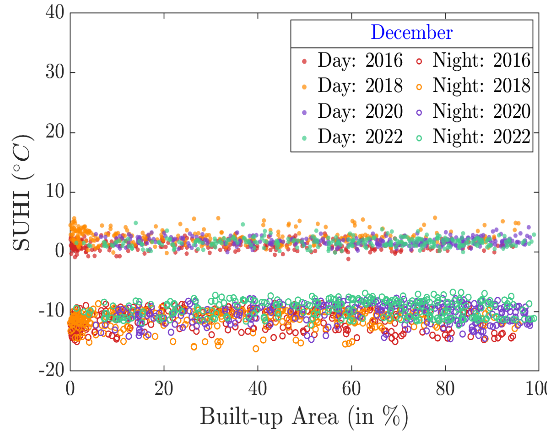



(a)




(b)

Figure 4: (a) shows the Surface Urban Heat Island (SUHI) for differnt percentage of builtup area in the month of May (summer time) (b) shows the same plot for the month of December (winter time).

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