Comparative Study on the effects of Urban Heat Islands using Remote Sensing and Geographical Information System for the Salem district, India

Abstract - The Urban Heat Island (UHI) phenomenon causes cities to suffer a higher level of warmth than they would in an environment that is devoid of clouds and winds. A phenomenon known as an urban heat island is produced when surfaces that were originally permeable become impermeable, which results in a decrease in moisture and an increase in dryness respectively. These satellite data were obtained through the utilisation of LandSAT8 imagery, which was obtained through the utilisation of the United States Geological Survey (USGS) Explorer. For the purpose of carrying out a comprehensive investigation of Salem's Land Surface Temperatures (LSTs), the information was subsequently employed, with a particular emphasis placed on bands 10, 4, and 5. In the investigation, both geographical and temporal issues were taken into consideration. Because of the vast variety of adverse consequences that urban heat islands have the potential to have on our natural systems, this inquiry is centred on learning more about them. Following the conclusion of the investigation, it was discovered that the Salem region already possessed Urban Heat Islands (UHIs), and it proposed a feasible strategy to reduce the impact of these UHIs.
1. Introduction

The term “Urban Heat Island” (UHI) refers to an urban area that experiences significantly higher average temperatures compared to its rural surroundings. The primary cause of this is the existence of human settlements and other forms of urbanization. The use of remote sensing and Geographic Information Systems (GIS) has revolutionized the investigation and monitoring of Urban Heat Island (UHI) occurrences. The field of study referred to as “remote sensing” utilizes aerial or satellite imagery to collect data on surface temperatures, land cover, and urban characteristics, among the other topics. These data are integrated using geographic information systems (GIS) to enable spatial analysis and mapping, which are crucial for accurately detecting and evaluating the impacts of the Urban Heat Island (UHI) phenomenon. By utilizing techniques such as remote sensing and geographic information systems (GIS), policymakers and urban planners may make well-informed choices that will lead to the creation of cities that are both resilient and sustainable. By employing these measures, they effectively tackle the issues posed by the impacts of urban heat islands (UHI) on public health, energy usage, and overall urban climate management. We are able to assess the extent of temperature swings, evaluate patterns of land utilization, and design ways to ameliorate the effects of urban heat island syndrome (UHI) thanks to the utilization of these technologies by scientists. As the population of metropolitan areas steadily increases, cities are growing both in terms of physical size and the range of activities they encompass. Hence, it is imperative to take into account both the growth of the human population and the alterations in the environment when formulating future strategies.

Stakeholders, particularly urban planners, designers, and architects, can greatly benefit from the data gathered from the Urban Heat Island in the process of identifying critical areas of excessive heat in urban canyons and forecasting weather conditions that are likely to result in higher UHI values and subsequent thermal discomfort. When considering the possibly detrimental implications that future climate projections may have, it is imperative.

Sustainability is also a crucial element of urban development because it helps reduce the strain on the environment and existing urban...
2. Materials and Methods

Salem, a vibrant city in the southern state of Tamil Nadu, derives its name from its strategic location, which offers numerous benefits. The cultural and historical importance of it is tremendous. The city is well known for a wide range of fascinating attractions that go beyond its significance to the local economy. The Salem city is approximately located at a Latitude and Longitude of 11° 39’ 29.285” N and 78° 8’ 14.0478” E.
LandSAT8 series 2013 and 2022 is downloaded from the United States Geological Survey explorer website as per the proper procedure.

**Fig. 2 Methodology flow chart**

**Step 1:** The United States Geological Survey (USGS) Explorer supplied the Landsat 8 series images (LC08_L2SP_143052_20131218_20200912_02_T1 and LC08_L2SP_143052_20220922_20220929_02_T1) for the purpose of this investigation. An analysis was conducted for the years 2013 and 2022.

**Step 2:** The pre-processing phase involved the calculation of the Normalised Differential Vegetation Index (NDVI) utilising Bands 4 (Red) and 5 (Near-Infrared) from the Landsat 8 imagery. This was done to evaluate the condition and extent of the vegetation.

**Step 3:** To determine the Proportion of Vegetation (PV) in the research area, the NDVI was estimated by utilising Bands 4 and 5 from the index calculation section. During this stage, the understanding of vegetation density and distribution is enhanced. The Top of Atmosphere Radiance ($L_\lambda$) was calculated using Band 10, which corresponds to the thermal infrared spectrum. Consequently, the Brightness Temperature (BT) was defined as a measure of the Earth's surface temperature in degrees Celsius. Subsequently, the BT data was utilised to construct a mapping of land surface temperature (LST). The land surface temperature (LST) offers accurate information about the temperature of the ground surface when the influence of the atmosphere is removed.

The mapping of urban heat islands was accomplished by utilising the LST data. The urban heat island (UHI) is calculated by subtracting the mean land surface temperature (LST) from the actual LST, and then dividing the result by the standard deviation. This formula splits the difference between the study region's average Land Surface Temperature (LST) and each pixel's LST by the standard deviation. It measures the extent of urban heat islands compared to average temperature. Graphical representations of Urban Heat Island (UHI) stack profiles for a particular portion between 2013 and 2022 were the final step. This was done during the last step. This visualisation helps explain urban heat island (UHI) intensity changes across the study period. It also illuminates urban heat island dispersion.

The ArcGIS is used to prepare the map and arctoolbox spatial analyst extension raster calculator is used for the study. Changes in Land Use and Land Cover (LULC) brought about by urbanisation have a major impact on world average land surface temperature (LST). An increase in land surface temperatures has led to a phenomenon known as the urban heat island effect, or UHI.

A remarkable transformation of the urban environment and unparalleled levels of urbanisation have resulted from the country's tremendous progress. Due to urbanisation, distinct local urban climates have emerged, characterised by
higher land surface temperatures (LST) and more intense urban heat islands (UHI)

Urban heat island (UHI) detection equipment have been developed at a rapid pace, leading to their findings being widely accepted without regard to how accurately they measure the phenomenon's influence. Although the task of achieving urban sustainability is intrinsically difficult, there is a growing abundance of sophisticated computer tools and digital data that can aid in the tasks of planning and analysis.

3. Approaches adopted in general

Conventional methods: The conventional method for mapping Urban Heat Islands involves conducting field observations, utilising remote sensing techniques, doing GIS analysis, and employing statistical models. To accomplish the task of mapping the temperature of the land surface through the utilisation of geographic information systems (GIS) and remote sensing, it is necessary to employ a wide range of methodologies. In order to establish the Land Surface Temperature (LST) while taking into consideration the effects of the atmosphere, single-channel or split-window algorithms are utilised to make use of thermal infrared sensors such as MODIS and Landsat. This allows for optimal accuracy in the determination of LST. These kinds of sensors are able to detect and record heat radiation that is being discharged into the environment. Adjustments are made to account for differences in surface qualities, which results in an improvement in the accuracy of the measurement. The emissivity is compensated for in order to achieve this particular goal. The implementation of atmospheric correction processes makes it possible to collect climate data that can be relied upon completely. Land Surface Temperature (LST) data by eliminating the effects of the atmosphere.

A digital number (DN) ranging from 0 to 255 is used to store temperature data acquired and stored by the Landsat (TM, ETM, OLI) sensors. All of the photos that are being analysed were shot at the same time and during the same season. To study the urban green space distribution in Tehran, the researchers used multi-distance spatial cluster analysis and the closest neighbour approach. In addition to highlighting vegetation intensity, the 2017 Normalised Difference Vegetation Index (NDVI) photos offered an extra tool for finding pools that are partially or entirely covered by trees. Detecting priority areas to introduce multi-beneficial climate change adaptation measures is set to be a key task for the cities long-term strategies to improve climatic conditions across different urban structures and scales. The study's emphasis and widespread land use and land cover (LULC) were used to construct six classes. While it is possible to generate additional land use and land cover (LULC) categories, their proportion is negligible and not adequately represented. This introduces indeterminate pixels to the adjacent classes of the system. A developing issue in the field of environmental health concerns the effects of heat waves on human health. This assertion holds particular validity in the context of major metropolitan areas marked by substantial population densities due to the urban heat island effect. This study employs both qualitative and quantitative methodologies to examine the association between surface radiation temperature and NDVI. Researchers have examined the correlation between NDVI and surface radiation temperature in a geographical profile. Urban heat islands can facilitate the transmission of dengue disease by the Aedes aegypti mosquito due to elevated land surface temperature, low humidity, and sparse vegetation.

Modern methods: The progress in mapping UHI can be credited to the adoption of interdisciplinary approaches and the innovation of novel technologies. Contemporary technologies are employed in these processes to create appropriate measures for reducing...
the impacts of UHI and to gain a more comprehensive comprehension of its effects. Sensor networks and Internet of Things (IoT) devices have been deployed in metropolitan areas to collect and transmit real-time temperature data. To facilitate ongoing monitoring and analysis, these sensors are connected to platforms that are integrated with Geographic Information Systems (GIS). High-resolution remote sensing enables the employment of drones equipped with thermal cameras or satellites with advanced sensors to provide accurate recordings of land cover features and temperature distributions. By comparing areas with and without wind corridors, we were able to analyse eight aspects of the urban spatial landscape that contribute to variations in ventilation capacity and urban heat island intensity (UHII). Two elements related to the land surface, vegetative cover (VC) and impervious covering (IC), as well as six spatial morphological traits (BH, BD, FAR, SVF, FAI, and surface RL), were included in the parameters.

The “UHI Threat Rating” was established to identify temperature differences in a small urban population and explain the Urban Heat Island (UHI) effect's microclimate alterations. 4. Comparison of Land Surface Temperature between the year 2013 and 2022

Fig. 3 Land Surface Temperature_2013

Table.1 Showing the Latitude and Longitude values of the places in meters
As can be seen in Figure 3, the temperature of the land surface fluctuated from very high to extremely high, which presents an illustration of the impact that urbanisation has had on Salem over the course of nine years. Attur was situated in a region with temperatures ranging from moderate to high. In 2013, the temperature at Yercaud was documented to be the lowest ever recorded, which led to the discovery of the location as a cool place. The majority of the time, the surface temperatures in the Mettur and Omalur range from extremely high to extremely high.

Table.2 Showing the Land Surface Temperature in °C
Figure 4 illustrates that although the attur is affected by the LST to a relatively high degree in most places, the land surface temperature in Salem City has gone from high to medium. At various points around the Omalur area, you can find areas labelled as either medium category or high category.

Figure 5 is produced by subtracting LST_raster_2013 and LST_raster_2022, using the raster calculator. The modifications that took place between 2013 and 2022 are shown on the map. Rising land surface temperatures have had a significant impact on the area surrounding Yercaud and Attur, according to the available evidence. The tables labelled as No. 1 and No. 2 provide the sample values of the minimum and maximum land surface temperatures in the research region for the years 2013 and 2022, respectively.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Place_Name</th>
<th>LST_Min_Temp_ºC</th>
<th>LST_Max_Temp_ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Salem City</td>
<td>54</td>
<td>71</td>
</tr>
<tr>
<td>2</td>
<td>Mettur</td>
<td>50.38</td>
<td>65.55</td>
</tr>
<tr>
<td>3</td>
<td>Omalur</td>
<td>49.77</td>
<td>63.26</td>
</tr>
<tr>
<td>4</td>
<td>Attur</td>
<td>56</td>
<td>66.72</td>
</tr>
<tr>
<td>5</td>
<td>Yercaud</td>
<td>41</td>
<td>60.53</td>
</tr>
</tbody>
</table>
Fig. 6 Comparison of minimum LST and maximum LST 2013

Fig. 7 Comparison of minimum LST and maximum LST 2022

5. Urban Heat Island in major areas of interest in Salem district

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Figures 6 and 7 show that in 2013, Mettur, Salem city, and Omalur all experienced significant levels of the urban heat island effect. This is something that can be witnessed. On the other hand, within the year 2023, the cities of Salem, Attur, and Mettur are all going to see a considerable impact from the urban heat island effect.

6. Results and Discussion
Figures 10, 11, 12, and 13 depict the UHI stack profile, which depicts the change in temperature from the reference distance in both 2013 and 2022 with a distance ranging from 10 to 60 kilometres. This change in temperature can be either an increase or a decrease, depending on the circumstances. It was determined that Mettur, Salem city, and Omalur were the places that had the highest temperatures in 2013. This information was derived from the UHI for the year 2013. On the other hand, when compared to the temperatures at the other places, Attur reported the lowest temperatures. There is a site that can be classified as having low temperatures, and such an area is Yercaud, according to the statistics. This is due to the fact that the region has been impacted by the effects of the Urban heat island. As of the year 2022, it was noted that the temperatures in the cities of Mettur and Attur were significantly higher than those in the city of Salem. Yercaud, on the other hand, had a fall in temperature as a consequence of the urbanisation that took place there.
7. Conclusion

During the period of 2013 to 2022, the patterns of urban heat islands were studied, and the findings revealed that there were considerable temperature disparities between the various regions. Mettur, Salem city, and Omalur experienced higher temperatures in 2013, whilst Yercaud and Attur maintained more mild weather conditions throughout the year. Further, Mettur was subjected to temperatures that were greater. There was a decrease in the temperatures at Yercaud, which has traditionally been typified by a climate that is in the middle of the range. Mettur and Attur, on the other hand, demonstrated clear evidence of the urban heat island phenomenon, and it is projected that the major temperature increases will occur by the year 2024. The findings of this study make it clearly clear that the urban heat island effect (UHI) is a dynamic phenomenon that requires ongoing monitoring and activities that are flexible in order to lessen the effects of temperature swings in a range of locations. This is because the UHI is a phenomenon that is constantly changing. It is possible to reduce the amount of heat that is absorbed in metropolitan environments by the adoption of architectural modifications, the expansion of the presence of parks and green areas, and the incorporation of additional reflecting surfaces. All of these are effective solutions. It is possible that the development of this would be considered a step in the right direction.

References


20. ...
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