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Analysis of the micro Urban Heat Island effect

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Abstract

Urban areas worldwide are experiencing increase in temperatures due to urbanisation and, leading to the effect of Urban Heat Islands (UHIs), which threaten urban sustainability. Global research aims to identify UHIs and develop mitigation measures. Most existing studies rely on coarse-resolution satellite imagery, limiting the detection and characterization of heterogeneous urban surfaces and localized UHI effects. Advances in drone technology with multi-payload thermal sensors now allows LST mapping at finer spatial resolutions (<1 m), enabling detailed analysis of temperature variations across urban surfaces. Assessing the accuracy of these measurements is essential and typically involves comparing UAV-derived LST with ground-based or in situ temperature observations collected simultaneously during UAV flights. Proper calibration of the TIR sensors is necessary to minimize systematic errors. Accuracy is commonly quantified using statistical quantification like Mean Absolute Error (MAE), R squared and Root Mean Square Error (RMSE). UAVs offer much finer spatial resolution (<1 m) than satellites, enabling detection of localized UHI hotspots that coarse-resolution imagery may miss. Combining UAV, ground, and satellite data enhances confidence in LST estimates and supports precise analysis of urban heat patterns, providing critical insights for mitigation strategies and urban planning. These high-resolution datasets can support machine-learning tools for urban planners to predict localized UHI impacts, adopt mitigation strategies, and advance Sustainable Development Goals.

1. Introduction

Cities across the globe are, expanding both vertically and horizontally to meet the population growth (Yun et al. (2020). Overheating significantly impacts socioeconomic and environmental areas. "Land surface temperature (LST)" is a crucial parameter in urban overheating. Understanding LST and its driving factors is essential for mitigation and adaptation. As an important environmental aspect, LST affects urban ecosystems, influencing energy consumption, air quality, and public health. (Eshetie, 2024). Globally, the In 2019, over half of the global population—55.70%—resided in urban areas. In Asia, this proportion reached 57% and continues to grow rapidly. India, is undergoing rapid urbanisation, resulting in highly dense urban regions (Paramita et al., 2022) s, (Mohammad Harmay & Choi, 2023). Unplanned urban growth can change the microclimate and create environmental problems. This is mainly due to the spread of buildings, changes in land use, and more people living in cities. As a result, all Indian cities—where more people and economic activities are concentrated than in surrounding areas—will be more vulnerable to health risks caused by extreme temperatures. (Li et al., 2020), (Wang & He, 2023). Urbanization is a key trend of the 21st century. By 2050, most of the people in the world will migrate to cities. "Cities are going to be central in achieving various global goals, particularly those related to sustainability and climate resilience". At the inauguration of the Urban Studies and Research Centre at Miranda House, a captivating speech was delivered, by the minister for Housing and Urban Affair highlighting the significance and potential impact of this new initiative. He said that "more than 50% of India's population, or 877 million people, will live in our cities and towns by 2050"According to the UN (*Press Release:Press Information Bureau*, n.d.). As per SDG goals índex of 2025 india is ranked 99th out of 193 countries in the world (*Sustainable Development Report 2025*, n.d.). SDG 11, emphasises to "Make Cities and Human Settlements Safe, Inclusive, Resilient and Sustainable." India's performance in Sustainable Development Goal 11 is getting worse. This decline is due to issues such as the poor quality of life, poor disaster preparedness, poor air quality, and water shortages.(Kumar Goyal et al., 2023). Heat waves caused by high land surface temperatures are common in many Indian cities. They affect city dwellers by reducing work productivity due to stress, lack of water, and air pollution. Urbanization leads to large areas of concrete and asphalt, which change the local landscape and impact weather and water conditions.(Goyal et al., 2023) . The major factor to aggravate the situation is that Heat waves which significantly impact urban areas in India and across the globe, driven by the UHI, substantial human influence, and change in climate. To tackle this issue, we need high-quality atmospheric measurements in complex environments, especially in urban areas. It is important to collect data over wide areas and long periods while ensuring high resolution in both space and time. This will help us accurately identify Land Surface Temperature (LST) and understand its behaviour. Using conventional manned aircraft in urban areas is impractical and unsafe for many reasons. Meteorological towers can be set up in these locations to provide accurate and timely measurements, but they require a lot of effort to install. They also cannot capture high-resolution data and are limited in height, often falling below the height of urban structures. Tethered balloons can only provide limited vertical measurements, and untethered balloons lack precise control. Surface-based remote sensing methods also have height limits and lose clarity at greater altitudes. (Adkins et al., 2020). Also, crowdsourcing weather services are important for combining public feedback and data sources. They help both government agencies and individuals by providing affordable and accessible information. Unlike traditional weather methods that depend on physical sensors and complex models, crowdsourcing uses data collected from the public. This approach offers a new way to gather, analyze, and use weather information that benefits everyone.(Adkins et al., 2020; Zhu et al., 2020). Consequently, embedded sensors and social data sources struggle to capture the varied surface heat in urban areas, leaving an observational gap. Consequently, these strategies do not offer a complete understanding of urban surface characteristics or their vertical extent. "Urban development and policy circles prioritize strategies to control microclimatic variables influencing UHIs, given the dynamic factors and diverse microclimates created by complex urban heterogenous topography The variability of microclimates within the same city necessitates detailed investigation into the spatial–temporal variations arising from local architecture, human activity, urban planning, and fluctuating weather conditions”. (Alonso & Renard, 2020) leading to warmer temperatures in cities. Further, understanding urban heat islands is important for creating smart and sustainable cities. We need to study Land Surface Temperature (LST) and how it affects the temperature in urban areas. It is also important to explore how Land Use Land Cover (LULC) relates to LST. Numerous case studies have been conducted worldwide to estimate land surface temperature, employing a diverse range of datasets and methodologies derived from advanced thermal sensors. These studies utilize innovative techniques and data sources to provide a comprehensive understanding of temperature variations across different landscapes and regions. (Li et al., 2013) This study examines land surface temperature (LST) and its development. It highlights recent improvements in how LST is estimated and processed using satellite data information. In recent years, people have developed many ways to measure land surface temperature (LST) using satellite thermal infrared data. However, few studies have checked how accurate these satellite measurements are. The main difficulties in confirming satellite-derived LST come from two sources. First, it's hard to take ground measurements that truly match what the satellite sees in a specific area. Second, LST can change a lot over time and in different locations. (Li et al., 2013). The impact of directional effects on satellite LST products has been described by Guillevic (Guillevic et al., 2013). Measuring land surface temperature (LST) accurately can be difficult because of differences in emissivity and atmospheric conditions. Emissivity, which affects how much heat the surface radiates, can vary widely due to the diverse types of land. (Towards a Protocol for Validating Satellite-Based Land Surface Temperature: Application to AATSR Data | Request PDF, n.d.), The homogeneity of a site can be assessed by studying its spatial LST variability (standard deviation) with ground-based (Coll et al., 2009) or by analysing high-resolution TIR imagery. Drones can accurately identify features of the land because they take high-resolution images. Unlike satellites, drones can collect image data anytime and anywhere, without being affected by bad weather. They can also capture precise land surface temperature (LST) data because they fly at low altitudes, around 100 meters, which reduces the impact of weather conditions. (Coll et al., 2009; Webster et al., 2018). In response to these challenges, the aim is to study is as follows :

- To identify the urban heat island effect by capturing the LST by UAV with TIR
- To validate the land surface temperature by using multi-temporal & multi-modal data collection methods
- To propose a comparative framework to analyse granular level UHI effect.

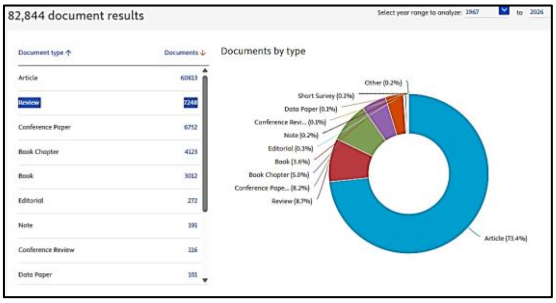
2. Literature Review

2.1 Research Methodology and data statistics

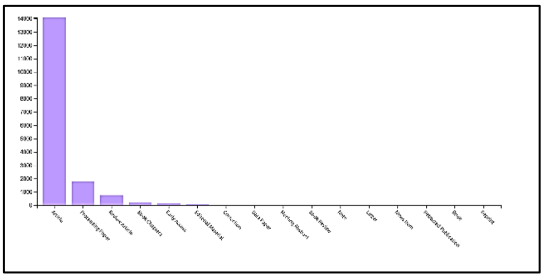
A comprehensive review of selected articles was conducted, following a systematic five-step process to ensure thorough analysis and clarity. This process began with the screening of articles to identify those relevant to the research question, ensuring that only high-quality and pertinent studies were included. The selected articles were then categorized according to their respective fields of study, allowing for a better understanding of the context and discipline each article represented. Next, the articles were organized to facilitate comparison among authors and co-authors, which involved mapping out collaborative relationships and assessing the impact of author contributions on the overall research landscape. After organizing, various themes were identified based on predefined keywords relevant to the research focus, helping to highlight prevailing trends and gaps in the existing literature. Finally, the articles were analyzed concerning their year of publication, providing insights into the evolution of research topics over time and illustrating how shifts in academic focus might relate to broader societal changes. By following these steps, the review aimed to create a detailed and structured synthesis of the literature, thereby enhancing our understanding of the subject matter.

2.2 Primary Keywords and search results

The systematic literature review was conducted by selecting one of the available databases, with Scopus being the most popular choice. The primary reason for selecting Scopus is its extensive collection of published articles, totaling approximately 82,844 journals, which is significantly higher than other online databases, such as Web of Science, which included about 16,574 journals. This search was focused on a common field using the terms “urban,” “heat,” and “island.” Post searching the majority of the data referenced various document types, it included articles (73.4%), reviews (8.7% or 7,248), conference papers (8.2% or 6,752), book chapters (5.0% or 4,123), books (3.6% or 3,012), editorials (0.3% or 272), notes (0.2% or 191), conference reviews (0.1% or 116), data papers (0.1% or 101), and others (0.2%). This breakdown reflects the diverse types of literature available on the subject.



(a)



(b)

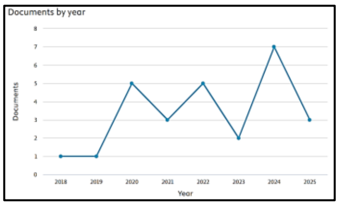
Figure 1. Search result for “urban heat island”
a) database Scopus b) Web of Science

Further, the abstraction of articles from Scopus with a combination of (ALL (urban AND heat AND island) AND ALL ("Land surface temperature")) resulted in 16465 documents, towards each respective combination, i.e. AND ALL ("Landsat")) (10,616 documents), AND ALL (" unmanned aerial vehicles uav") (226)) , AND ALL (" TIR")

(46)) . This extraction covers published articles from 2018 to 2025 (until 08 July 2025).

2.3 Refining results and descriptive statistics

Next, the primary search results were refined by applying specific filters to the document types, which included books, conference papers, and reviews. The languages Korean and Chinese were excluded. The final extraction included published articles from 2018 to 2025 (until 08 July 2025) related to top 15 countries is shown at Figure 2 below



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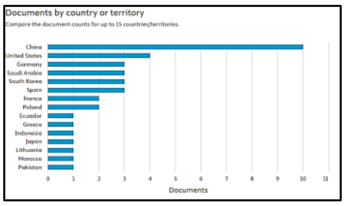

(b) Figure 2. Analysis of Scopus with respect to document (a) Yearwise published (b) Top 15 countries published.

The citation overview of the 27 documents showed citation of 1027 with h - index 11 wherein the filter of excluding self-citation and book citation was applied, refer Figure 3 (below)

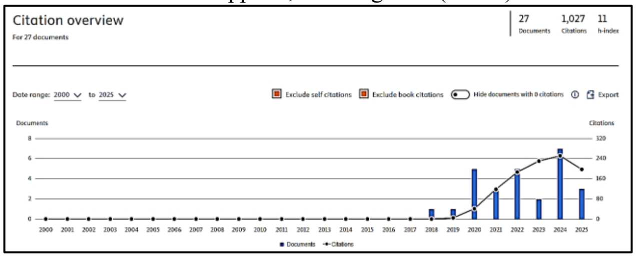

Figure 3. Citation overview

The citation shows multiple scholarly work in the domain of geospatial showcasing the work and their contribution in the domain which has increased manifold due to availability of open source satellite data and advancement in UAV technology. In addition to documenting these contributions, an in-depth keyword analysis was conducted across the articles, revealing emerging trends, frequently studied parameters, and evolving research priorities in the field. The keyword trends, as illustrated in Table 1, provide insights into the thematic focus of current studies, highlighting the growing need on integrating multi-source data, high-resolution thermal mapping, and urban planning applications. These technological developments have enabled more precise spatial and temporal monitoring of urban microclimates, facilitating detailed analyses of heat distribution, land cover interactions, and anthropogenic impacts on local climates.

Table 1 Comprehensive allocation of articles with respect to selected keywords for 27 articles in journals related to the search criteria

Keywords	Occurrence	Total link strength
accuracy assessment	4	37
aerial vehicle	6	45
antennas	10	91
atmospheric temperature	11	101
cameras	3	25
electromagnetic wave emission	4	41
emissivity	3	27
image resolution	4	22
infrared radiation	5	50
land cover	3	19
land surface	7	64
land surface temperature	16	132
landsat	4	24
lst	3	10
mean square error	6	49
meteorology	3	25
radiative transfer	3	30
remote sensing	12	96
root mean square errors	4	31

Source: Scopus database, 2018 – 2025 (08 July 2025) all keywords

From the above keyword analysis, 4 clusters are formed as shown at Figure 6 (a) below, wherein most of the keywords are related to unmanned aerials vehicles, surface temperature, spatial resolutions etc. This peripheral positioning indicates that, although these concepts are fundamental to understanding urban thermal dynamics, they are less frequently integrated with the core technological themes. such a pattern highlights potential research gaps, suggesting the need for studies that bridge methodological innovations with essential geophysical parameters to achieve more comprehensive assessments of Urban Heat Island effects and land surface temperature variability.is shown with Bibliometrics analyses.

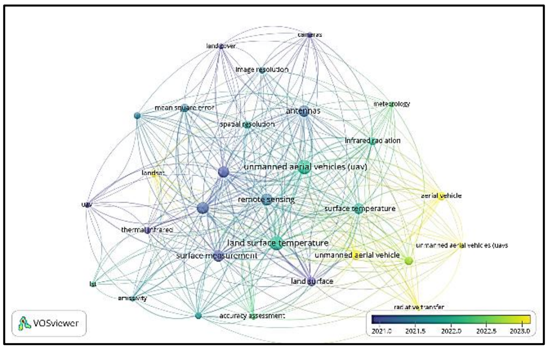

Figure 6 . Bibliometric characteristic of the surveyed literature: Keyword trends reveal Urban Heat Island research shifting toward UAVs, high-resolution imagery, and advanced spatial analyses. (2018–2025).

2.4 Overview of Study

In recent decade, urbanisation in major part of the country has shown notable significant changes in the local atmosphere, thereby raising the surface temperature (Anasuya et al., 2019). Since 2000 the significance of UHI has gained importance due to cities fast growth and urban area expansion due to its role in worsening heat discomfort, energy demand, air pollution which are generally associated with increase in heat wave and heat stress related mortality particularly in densely populated area (Islam et al., 2024). This section showcases comprehensive review of UHI study conducted across various parts of Indian cities in recent years. The extensive study of articles published in various journal as at both country level i.e, regional level and at global level with an aim to identify the data and technology used to identify Urban Heat Island. The table has been divided in to Year, location, objective of the study and data used for the study.

Table 2. Articles on UHI at Regional Level and the outcome is given in Table 1 and Table 2 below along with location, objective of the study and data used

Year	Location	Objective	Data
Feb 2025	Cuttack	To study the unplanned growth of urban area in Cuttack city and its environmental impact .(Patra et al., 2025)	Landsat-7 ETM , Landsat-8 OLI/TIRS, Landsat-5 TM (Patra et al., 2025)
Feb 2025	Pune	To study the influence of UHI on climate in the city during the period from 2012 to 2023. (Tiwari et al., 2025)	Sentinel data for LULC and for UHI from European Centre for Medium-Range Weather Forecasting (ECMWF)(Tiwari et al., 2025)
Apr 2024	Chandigarh	To study the relationship between LST variation based on seasonal and comparing the output with NDVI and NDBI(Taloor et al., 2024a)	Moderate Resolution Imaging Spectroradiometer (MODIS) data of spatial resolution on 1Km and Landsat 8 with 100m resolution (Taloor et al., 2024b)
Jan 2023	Dehradun & Shimla	To analyse the urban growth using in the mentioned cities by using open source satellite data of the period from from 2000 to 2016.(Gupta et al., 2023)	Landsat TM, ETM, OLI satellite data (Gupta et al., 2023)
Dec 2022	Tiruchirappalli city	To identify the cold and hot spots in the city by measuring the urban heat island for the city during the 2 seasons, winter and summer. (Badugu et al., 2023)	Sentinel-1& Sentinel-2 data and LST from MOD11A2 (from Terra) with 1 Km of spatial resolution(Badugu et al., 2023)
Dec 2022	Chandannagar city, West Bengal	To study the UHI pattern for the city for 4 phases pre and post monsoon for the year 1988 and 2000 and compare its relationship with change in LULC (Das & Das, 2022)	Landsat satellite data .(Das & Das, 2022)
Jul 2022	Delhi	To study the LST in relation to NDVI and Built up Area from satellite data of past 20 years from 2000 to 2020. (Singh et al., 2022)	Landsat 5 & 8 thermal data sets with the 30-m spatial resolution(Singh et al., 2022)
May 2022	Bengaluru City	To monitor the different analysis based on Vegetation surface (VS), impervious surface(IS), bare surface (BS), and study the urban cool island for the city the data was studied for last 30 years from 1989 to 2019.(Sarif et al., 2022)	Landsat 5 (TM) , Landsat 8 (OLI/TIRS) and SRTM with 30 m spatial resolution (Sarif et al., 2022)
Apr 2022	Jaipur	To study the changes in LULC pattern in the city and its impact of the pattern on Urban Heat Island.(Islam et al., 2024a) (Role of LULC Change in Inducing UHI in Jaipur District, Rajasthan (2009–2019) | EBSCOhost, n.d.)	Landsat 7 ETM+ and Landsat 8 OLI-TIRS data having 100m resolution(Islam et al., 2024b) *Role of LULC Change in Inducing UHI in Jaipur District, Rajasthan (2009–2019). | EBSCOhost, n.d.)*
Jul 2021	Chennai	To identify the heat island intensity of the city by manual survey traversing and secondly to compare contribution of the environment in changing the microclimate of the city . (Rajan & Amirtham, 2021)	Traverse survey and simulation on ENVI. (Rajan & Amirtham, 2021)
Jun 2021	Delhi & Mumbai	To develop a model based on metro city data collected from 1991 to 2018 and identify relation between the spatio-temporal pattern of UHI and its link with land use indices. (Shahfahad et al., 2022)	Landsat datasets, Used mono window algorithm and land use indices(Shahfahad et al., 2022)
May 2021	Chennai	By using Autoregressive Integrated Moving Average (ARIMA) model, estimate forecasting of LST by remote	Landsat. (Kesavan et al., 2021)

		sensing method and identification of UHI. (Kesavan et al., 2021)	
Apr 2021	Urban Agglomerations east India	To study LULC–LST relationships in three eastern Indian cities. (Saha et al., 2021)	Landsat 8 OLI (TIRS). (Saha et al., 2021)
Mar 2021	Kolkata Metropolitan	To study the surface temperature pattern and categorise UHI for Kolkata city and its satellite towns. (K. Dutta et al., 2021)	Landsat thermal bands, applied mono-window algorithm(K. Dutta et al., 2021)
Jan 2021	Vishakapatnam	To study the transients of land surface temperature (LST) for the city by comparing the field measured temperature with the land use land cover (LULC) (Puppala & Singh, 2021)	Landsat, Google earth for validating LULC. (Puppala & Singh, 2021)
Jul 2020	Mumbai	To study the urban growth and its spatial layout with respect to green space by using data of past 30 year from 1988 to 2018 for the city Mumbai. (Rahaman et al., 2021)	Landsat thematic mapper (TM) and OLI/TIRS (Rahaman et al., 2021)
Nov 2019	Delhi	To study the comparison/links at the sub district level between the LULC with surface urban heat island intensity (SUHII) & LST.(Pramanik & Punia, 2020)	Landsat imageries and MODIS LST. (Pramanik & Punia, 2020)
Nov 2018	Durgapur	To analyses the data of past 25 years of the city and identify LULC on various indices. (D. Dutta et al., 2020)	Landsat data (D. Dutta et al., 2020)
Sep 2016	Ahmedabad	To predict the land surface temperature of area surrounding Ahmedabad and asses its UHI effect. (Mathew et al., 2016)	Moderate Resolution Imaging Spectroradiometer (MODIS) and ASTER sensors. (Mathew et al., 2016)
Apr 2016	Noida	To identify the major land use factor responsible for rise in LST in the city. (Kikon et al., 2016)	Landsat ETM and Landsat 8, used mono window algorithm.(Kikon et al., 2016)
Jan 2015	Delhi	To study/analyse the potential of Landsat and MODIS data to identify biophysical parameters for two seasons summer and winter for the year 2000 and 2010 and estimate LST and heat flux and its effect on anthropogenic het disturbance over city and its surrounding region.(Chakraborty et al., 2015)	Landsat and MODIS data(Chakraborty et al., 2015)
Nov 2014	Jaipur	To analyze spatio-temporal changes in LST and UHI in relation to LULC from 2000 to 2011. (Jalan & Sharma, 2014)	Landsat 7 ETM+ (2000), Landsat 5 TM. (Jalan & Sharma, 2014)

Table 3 Articles on UHI at Global level

Year	City	Objective	Data
May 2021	South Korea	To acquire and study the UAV TIR LST data one one year and compare the various characteristics of the data with the precise satellite TIR LST data. (Kim et al., 2021)	UAV with TIR, Landsat, and GNSS instrument for provision of Ground Control Points (GCPs). (Kim et al., 2021)
Mar 2022	Kyungpook National University Sangju Campus, Korea	To evaluate TIR images taken vertically by land cover.(Lee & Lee, 2022)	UAV TIR camera, GPS equipment Trimble's R8s, two laser thermometers. (Lee & Lee, 2022)
Dec 2021	Tongji University, Shanghai, China	To identify the methodology for calculating land surface temperatures acquired from UAV TIR and meteorological data.(Wu et al., 2022)	Low-altitude UAV TIR and meteorological data (Wu et al., 2022)
May 2017	City of Berlin and Cologne, Germany	To analyse the spatio-temporal relationship between 2D and 3D urban characteristics and LST.(Rahaman et al., 2021)	Very high resolution (VHR) multi-spectral and elevation data, along with multi-temporal Landsat ETM+ imagery. (Rahaman et al., 2021)
May 2016	Tehran Metropolitan City of Iran	To assess the Urban Heat Island and its relationship between LST & LULC. (Bokaie et al., 2016)	Landsat TM satellite image (Bokaie et al., 2016)

From the above articles it is seen that, accurate LST calculation and its analysis and identifying its relationship with existing LULC is very important in mitigating/addressing climate change issues in urban areas which in turn helps to identify the human environment interaction. (Kim et al., 2021). In the above study of the UHI for the Sejong city of South Korea. The LST acquired from UAV TIR were acquired for the study area, generally of the partially distributed area such as the square, entertainment facilities, deck, and foot path were analysed and LST were measured and it was observed that the measurements of these area differed for the period and land cover type. Therefore, in the study area the inaccessible buiding area difficult for insitu measurement were excluded from the analysis. Kim et al., 2021). It is observed that the buildings that were excluded from the study contribute a major heat dissipation in the environment, which also depends on the material used for the construction of the building. Here we can plan in our study for the use of terrestrial Infra Thermography and the data of the equipment can be integrated with data captured from UAV. In the study using UAV with TIR cameras, camera angle to the extent possible to maintain at 80 degree is considered the best. In this study it should be noted that, UAV-based surface temperature acquisition proves highly effective when the data is acquired at 80-90 degree because it ensures accurate temperature measurement and thus resulting into accurate surface temperature as it acts as a baseline data for measuring urban heat environment. (Lee & Lee, 2022). Also in UAV flying, there are various environmental and other factors which affects the data acquisition like wind, temperature, ground state, UAV elevation, its camera performance, shooting height, as well as the angle (Lee & Lee, 2022). During our studies we can explore the possibility of analysing and incorporating the factors such as wind, temperature which can be taken from a IMD data of other sensors. In this study when the low altitude UAV TIR was flown over area wherein metrological observation was carried out and the reading were recorded was compared with LST of UAV TIR the difference in calculated LST and measured LSt was observed (Wu et al., 2022). Based on the availability of the metrological data, we can explore including the method of verification of LST in our studies. From this study a comparison of 2D and 3D urban characteristics as potential indicators of the surface UHI effect and as potential predictors for thermal applications (Rahaman et al., 2021). As the 3D USCs play an important role in assessing the accurate UHI, it becomes important to explore these factors/include them to the maximum extent in our studies. In the study of the city of Tehran analyse was carried out using Landsat TM imagery, and its spatial distribution was generated and compared with LULC, NDVI, population density, energy consumption, and public health for which maximum likelihood classification of Landsat TM data, and population distribution of 2011 census was mapped. (Bokaie et al., 2016). In this study, it is observed that the dense buildings in the cities with dense population can exhibit higher surface temperature, and this data can be collected and correlated based on the census data.

3. Research Gaps

1. No standardized framework for ground truthing of UAV TIR output.
2. Most UAV studies focus on 2D surface temperatures, but exploring vertical profiling methods with terrestrial TIR could provide valuable insights.
3. The data from UAV with TIR is important for understanding urban heat islands and urban geometry. Factors like how dense buildings are, their height, orientation, and the angle at which UAVs capture TIR measurements all affect the accuracy of the data. Additionally, census data provide demographic insights that can improve analyses of urban areas. Together, these elements help us understand how urban structures and environmental factors interact, which is essential for assessing and reducing the effects of urban heat islands.

4. Research Question

1. What methodology is being developed to utilize UAVs and thermal infrared sensors for high-resolution mapping of Urban Heat Islands, and how can this approach help urban planners and environmental scientists in promoting sustainable urban development? .
2. How do the land surface temperature (LST) measurements obtained from UAVs compare to those derived from Landsat 8 TIR, and what spatial anomalies can be identified in this comparative analysis?
3. What calibration and correction strategies are necessary to effectively align UAV thermal infrared (TIR) data with satellite-based land surface temperature (LST) measurements?
4. In what ways do the various physical characteristics of urban area contribute to the micro-urban heat island effect, as captured through thermal infrared imaging from unmanned aerial vehicles (UAVs)?
5. How can a scalable protocol utilizing Unmanned Aerial Vehicles (UAVs) be developed to effectively monitor and validate Urban Heat Islands (UHI) in urban environments, and what specific data collection and analytical methods will optimize its efficacy?

5. Statement of the Problem

Micro-Scale Analysis of Urban Heat Islands Using UAV-Based Thermal Infrared Imaging and Multi-Scale Validation with Satellite and Ground-Based Observations.

6. Objective of the study

1. To create a method using drones with thermal infrared sensors to map urban heat islands (UHIs), which are hotter areas in cities compared to nearby rural areas.
2. To compare UAV-derived land surface temperature (LST) with Landsat data to identify spatial anomalies.
3. To ground-truth UAV-based thermal data using in-situ temperature sensors at representative locations.
4. To evaluate the influence of urban morphology (building density, land use) on micro-UHI patterns.

7. Scope and Limitation

7.1 Scope of the study

1. With High resolution UAV TIR based data will enable detailed, micro-scale (resolution in cm) mapping of Land Surface Temperature (LST) variations across urban heterogeneous characteristics surface.
2. The study will help to combine UAV-based TIR data with medium-resolution satellite data (e.g., Landsat 8) and in-situ ground measurements.
4. A adaptable framework developed under this study can be replicated to other urban areas.

7.2 Limitation

1. Flying of UAV is weather and daylight dependent. Therefore, diurnal monitoring is restricted.
2. Due to UAVs endurance and line of sight limitation coverage of large spatial urban is restricted as compared with satellite coverage
3. To obtain accuracy the TIR sensors integrated with UAV will require proper calibration.
4. Errors from atmospheric interference, emissivity assumptions, or surface reflectance may hamper the desired result.

7.3 Novelty of the research

The novelty of the research is as follows

1. UAV mounted TIR sensors helps to achieve high resolution data (in cms) as compared to satellite data which has resolution of 30 -100m. Thus helps to study te micro heat spots in urban areas.
2. Use of mutlti scale spatial data for verification and comparison like UAV high resolution, Satellite data -low reslotion, insitu ground measurement – very high-resolution data. Therefore, accuracy achieved will be of higher order.
3. Data collected from this study can be used for different urban areas as comparison. Further AI stack as per LULC characteristics can be maintained by expanding the scope of the study.
4. The results obtained from the study will be helpful for Smart city planners, Heat wave early warning systems, Infrastructure vulnerability mapping, Urban cooling strategies, Health sectors, developing future accurate prediction modelling.

8. Methodology and Techniques

8.1 Data sets Description

The dataset consists of a UAV with a high spatial resolution and a Thermal Infra Remote sensor (TIR) payload, software for processing, annotation, and pixel-level classification and segmentation of spatial images. Use of Landsat 8 & OLI data for the extraction of Land surface temperature of the study area. Also, one decade of Sentinel 2 and Landsat 7 data will be downloaded to study the urban growth in the study area.

8.2 Method

8.2.1 Acquisition of the Low-Altitude TIR Sensing Images and High High-Resolution Spatial Images (RGB) A TIR sensing payload mounted on a low-altitude UAV, along with an RGB camera, will be used to collect high-resolution centimeter-scale spatial resolutions data. Flights will be conducted at four to five test sites, covering an area of approximately 50 square kilometers within the study area. The UAV will operate in accordance with the permissions granted on the Digital Sky platform and follow DGCA guidelines. If additional permissions are required, a request will be initiated. UAV data collection offers portability, is unaffected by clouds, and overcomes the challenges of labor-intensive point measurements (Munghemezulu et al., 2023).

8.2.2 Data Processing The RGB geotagged image obtained from the UAV will be processed to create orthoimages with a spatial resolution of better than 30 cm. Additionally, further annotation will be done by creating polygons to delineate the boundaries of the object in the image, which will be done manually. The data will be utilized to train a learning model for the automatic detection and classification of objects. Once the annotation process is complete, the Thermal Infrared (TIR) images will be processed. The RGB and thermal data will be co-registered based on a fixed transformation. Also, TIR sensor data will be collected from the Landsat 8 satellite, which has an image resolution of 100 meters will be resampled to 30m to align to Operation Land Imager (OLI) data with a revisit period of 16 days across two TIR frequency bands. (Awais et al., 2022)

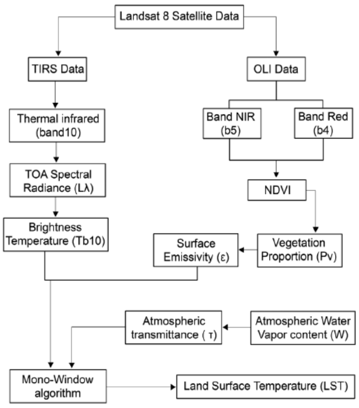

Figure 6: Processing of Landsat satellite data (Bendib et al., 2017)

8.2.3 Comparison of LST derived from UAV & Satellite. The UAV TIR LSTs will be correlated with Landsat 8 LST, and the comparison between the observed values calculated from both the data will be carried out and the accuracy will be measured in terms of RMSE, linear regression analysis and scatter plot. The Pearson correlation will be calculated between the data captured from UAV and data collected from Landsat 8 OLI and the linear relationship between the 2 data will be analysed and the strength received will be compared as per the values.

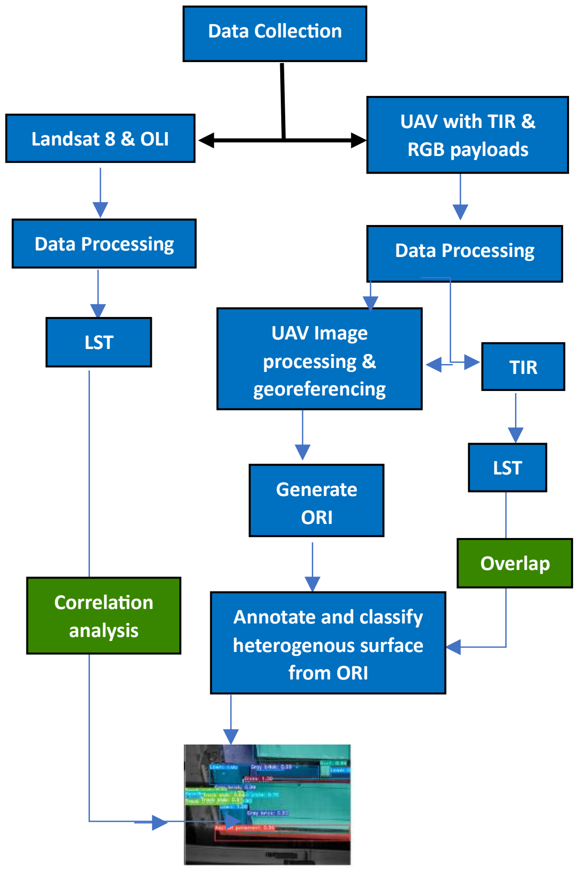

Figure. 7 Methodology of flow for comparison

The data will be generated as per above work flow and comparison of result will be carried out as per Table 4 given below

Table 4 Post correlation, the interval of relationship strength is as follows(Darettamarlan et al., 2021)

The Relationship Strength	The Coefficient Values
Correlation nil	0.0
Correlation weak	0.0 – 0.25
Correlation Good	0.25 – 0.50
Correlation strength	0.50 – 0.75
Correlation very strength	0.75 – 0.99
Correlation perfect	1.00

8.2.4 LULC mapping LULC is determined to study the temporal changes in any land cover type (Kafy et al., 2020). Sentinel 2 will be downloaded from USGS website for the year 2005, 2010, 2015, 2020 and 2025. The land will be classified into 5 classes for the study as per the Annual Land use and Land cover Atlas of India published by NRSC(Atlas_LULC | NRSC Web Site, n.d.). Broadly, 5 classes will be classified as Built-up land, Barren land, water body, vegetative land, and built-up vegetative land. As the forest and agricultural land share similar reflectance patterns, they will be grouped together as "vegetation" for classification. Post classification, change detection software will be used to detect changes that will be used as training samples, and this will ensures an adequate number of pixels from different classes are available for training. of supervised classification using the maximum likelihood algorithm to generate LULC maps for 2005, 2010, 2015, 2020, and 2025, capturing variations across five land cover classes. Accuracy will be assessed using a confusion matrix

9. Conclusion and Future Prospects

As UAVs have the ability to fly low it dimished the effect of weather on the data collected which inturn helps collect more accurate and precise LST as compared to LST calculated from satellite data (Awais et al., 2022). Coarse-resolution imagery cannot capture fine-scale land features, limiting the reliability of satellite-derived products for natural resource management. (Yun et al., 2020) . Also, the detection of UHI from the study data will enable precise mapping of heat stress zones within urban areas, which will help urban planners to initiate mitigation measures for the identified buildings. Urban planners can use the prediction model to identify potential Urban Heat Islands (UHI) during industrial and commercial development. Future studies on Land Surface Temperature (LST) should focus on more frequent data updates instead of long intervals, providing planners with timely information for better policy decisions. Collaboration among various stakeholders like scientist and experts is important for holistic UHI mitigation which will further help to mitigate the health impacts of urban heat stress.

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