Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/19203
DOI URL: http://dx.doi.org/10.21474/IJAR01/19203

RESEARCH ARTICLE

USING LOCAL CLIMATE ZONE (LCZ) TO STUDY THE URBAN HEAT ISLAND AT CITY LEVEL- A CASE STUDY OF AHMEDABAD

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Manuscript Info

Manuscript History
Received: 31 May 2024
Final Accepted: 30 June 2024
Published: July 2024

Key words:-
Green Space Coverage, Land Surface Temperature (LST), Land-Use Land-Cover Change (LULC), Local Climate Zone (LCZ), Urban Heat Island (UHI)

Abstract

Increased temperature in urban areas brings about various problems and thermal discomfort. Many studies focused on detecting the effects of land cover patterns on Land Surface Temperature (LST) using satellite imagery and subjective study (People's perception) of the thermal environment. A very limited number of studies (Kim et al., 2021) (Stewart & Oke, 2012) have focused on the Local Climate zone (LCZ) classification system and their use in the LULC and LST study. This study focused on investigating the UHI effect at the city level through a detailed step-wise process covering the literature review to the empirical investigation of LST. Using qualitative data from the expert panel discussion and quantitative data from satellite imagery, an experimental study will be conducted to observe the impact of different built-up types on the local temperature. This study presents a methodology to study a city by defining a universal standard that will enhance the understanding of LST at a micro-scale and give insight into mitigating the urban heat intensity through urban design and urban planning.

Introduction:-

By 2050, the urban population is projected to increase from 55% to 68% worldwide, which equates to an additional of 2.5 billion people living in urban areas. Urbanization and city growth change a landscape's demographic, social, and physical attributes, with variable impacts on GHG emissions depending on the degree of development of the participating countries. The natural environment changes into artificial environments (Concrete, brick, and glass) as the green area changes into residential areas, or most of the wetlands are filled up by sand and soil, and new construction is done on it. The artificial environment created by the changes is mostly the impervious surfaces that absorb the heat from the sun. These materials can stop evapotranspiration, which helps to lower the latent heat flow and change the thermal climate of cities. Apart from this, heat generated from anthropogenic activities such as vehicular traffic and AC systems increases heat rise in urban areas.

As a result, Cities become hotter than the nearby rural regions due to urbanization, creating an urban heat island (UHI) (Mills & Stewart, 2021). Due to this phenomenon, climate change is becoming more severe and heat waves are occurring more frequently and intensely, which highlights the need to understand their combined effect in order to mitigate the adverse effect of climate change and decrease its detrimental effects on health. Studies shows the measurement of the UHI effect in two ways- 1) Atmospheric Urban Heat Island (AUHI)- Air temperature measured 2m above ground level by using an Automated Weather Observation System (AWS) or Manual Weather

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Observatory System and 2) Surface Urban Heat Island (SUHI)- By using remote sensing satellite the skin of the earth surface was measured. Researchers mainly used SUHI to investigate the urban heat island effect. Because the instrument which is used for AUHI is very limited to only one present per city, it generally calculates for one area, and that data is used for the whole city. However, satellite data will calculate for each area and has a 30 m resolution, giving accurate information (Gartland, 2008).

Urban areas residents are greatly impacted by UHI, which results in rising energy costs for cooling and an increase in heat-related diseases. Cities' urban environment depends upon the surrounding impervious surfaces and artificial elements like Asphalt, concrete, brick, glass, etc. In this paper, the Urban Heat Island effect is the subject of a thorough literature study. This paper's main goal is to identify the important factors that have an influence on Urban Heat Islands (UHI) and to develop a classification scheme for measuring UHI within the city limits.

Literature Review:-

The literature section was divided into four sections, 1) different methods which are used to calculate the UHI; 2) the satellite features and captured pictures that were utilized to derive the UHI effect; 3) Variables that impact the UHI, 4) classification system which shows the UHI different between areas.

In this paper, 85 papers taken for the literature paper taken with the following criteria- a) in the abstract, the keywords are "Urban Heat Island" and "Satellite Imagery" or "Land use Land cover (LULC) change" and "Urban Heat Island" (UHI), (b) Publication range- from 1965 to 2022 (Urban heat island effect studies first carried out in the year 1965 at Landon), (C) Language of the article in English, (d) peer review paper used. A quick review of the chosen publications reveals that these investigations can be roughly divided into two groups. First, LST was employed as a stand-in for UHI in 44% of the papers (Mokhtari et al., 2022) (Gupta et al., 2019) (Munshi, 2013) (Guo et al., 2016) (Azhdari et al., 2018). This shows that the focus of these research was on whether spatiotemporal variables are connected to LST rather than whether the UHI impact was investigated. Second, the connection between spatio-temporal variables and UHI intensities has been examined in around 56% of the research. The majority of studies used imagery from satellites to illustrate the impact of UHI. It calculates the variation in LST between city and their rural surroundings.

Spatial Instrument to measure Temperature

To assess the changes in land cover, researchers had to build expensive weather station devices and gather photos of the city using photogrammetry. The launching of remote-sensing satellites has alleviated these problems. For two reasons, scientific groups are now easily able to study the UHI effect broadly. First, remote sensing photos offer regular full-wall coverage of a specified setting. These databases are crucial tools for researching vast urban regions. Second, because remote sensing satellites (like “Landsat, MODIS, and ASTER”) provide thermal information as a band and image or as separate products, the extraction of the UHI intensity is simplified (Tan et al., 2010) & Jovanovska, 2016) (Hua & Ping, 2018).

The sample literature found that 56% of paper used Landsat ™, Landsat ETM, and Landsat 8 (OLI) images for the UHI study, as it gives more accurate data compared to the ASTER and MODIS. There are four reasons why Landsat imagery is so popular for UHI studies:

1. Researchers can access them without charge.
2. The reasonable 30*30 meter spatial resolution of their global coverage.
3. Researchers may extract the necessary data over a lengthy period of time to investigate changes in LULC, LST, forest cover change etc. thanks to their long standing spatial- temporal coverage (it is accessible from 1972) (Wulder et al., 2008).

Measurement techniques used for spatial changes

The key factor contributing to the UHI impact is described in the literature as the conversion rural area to impermeable surfaces. The majority of urban construction materials are impermeable, which explains why. Therefore, moisture cannot disperse the radiant energy from the direct sunlight. For example, in a clear sky, dry urban surfaces may achieve temperatures reaching as high as 88 °C. However, low moisture vegetation can only attain temperatures of 18 °C in the same conditions.

Second, darker substances in urban areas with canyon-like layouts capture more solar radiation. In order to assess the effects of urban growth patterns on the UHI effect, a significant body of research was conducted to detect them in cities. In most of the studies, to show the spatio- temporal UHI difference between the three-decade temperature

LULC change analysis was done, it helps in showing how the urban growth happened, and because of it pervious surfaces changes into the impervious surface. As a result, it traps more heat and generates higher land surface temperature than the pervious surfaces. The effective method used to extract LCLU patterns is the land cover indices (group 1 and group 2) (Olesen & Madsen, 1995) (51%), followed by maximum likelihood supervised classification (21%) and linear spectral mixture analysis (10%). Most commonly, NDVI (Normalised Difference Vegetation Index) is used in land cover indices to differentiate the green areas from other land cover classes. Both Land cover indices and unsupervised classification were used in this study to show the changes in the land cover characteristics.

Variables which affect the UHI

Several elements contribute to the development of UHI and its variation. Our study of the literature reveals that earlier research has looked at various variables to pinpoint the root causes of the UHI impact in different literature study (Table 1). In most of the literature, ten variables are mentioned that affect the rise in temperature in urban areas. Based on the literature, UHI variables were assigned a percentage to identify the important ones.

Studies have mainly concentrated on seasons, day and night, and land cover and land use patterns (such as impervious & pervious surfaces, different types of vegetation-dense, low plant, bush and scatter, water body, build structures, and bare soil). Although several of the found characteristics may have a similar meaning, it should be noted that Table 7 displays the factors as they occurred in the examined research. In urban areas, variables that affect the UHI can be categorized into two types- 1) the uncontrollable variables like cloud cover, season, wind speed, and Diurnal conditions, and 2) the control variables, which are the land characteristics, green spaces, Building materials, and Landscape design.

Roads and pavement, for instance, are examples of impermeable surface areas. Within the land cover category, greenery (54%) and built-up areas, hard concrete surface, and impervious areas are the major variables to explain UHI intensity. Impervious surface area is usually believed to be the main cause of LST and, consequently, UHI impact. Dark impervious surfaces, like asphalt, enhance LST because they reduce the Earth's surface's Albedo. From the literature, it was found that Asphalt (1.94), Concrete (2.11), stone (2.25), and brick (1.37) J/ m^3 K* 10^6 have heat capacity, which is higher than the soil (0.58) (Gartland, 2008) and the thermal diffusivity of the Asphalt, brick, concrete is higher than the water. It means the more impervious surface in an area will result in more heat observation from the sun and less diffusion at night, resulting in a warmer environment. From literature it found that, supervised and unsupervised classification methods have been used extensively to show the Impervious surfaces in urban areas contribute to UHI; as a result, urban planning, construction materials, green areas, and open spaces have a significant impact on UHI contribution.

Seasonal fluctuation has an influence on UHI intensity as well. Both differences in the metabolism of plants and changes in the quantity of solar radiation reaching the Earth are to blame for these effects. In comparison to autumn and winter, spring and summer have a greater UHI intensity. Due to the fact that spring and summer are frequently seen as growth seasons. Because of this, rural regions are often covered in live, healthy plants, which widens the LST gap between urban and rural or sub urban areas (Zipper et al., 2016).

In this paper, satellite imagery was used to calculate the LST; due to this, cloud cover plays an important role. More than 10% cloud cover is inaccurate as solar radiation cannot directly reach Earth's surface during this time. Because of this, less than 10% of cloud cover satellite imagery was taken for analysis.

Classification system to show the UHI effect

According to a research, 71% of the literature employed urban-rural categorization methods to display the temperature variation among the two areas, followed by 18% Local climate zone (LCZ) and 11% focuses on the specific geographical area within the city boundary. For example, in 1965, Chandler calculated the temperature difference within the Landon based on geography, Physiography, climate, and built form. In 2011, a new classification system, i.e., Local Climate zone, A more sophisticated land categorization system is needed to understand how various land cover types behave thermally at the local level. One such method that integrates the geometrical and physical characteristics of metropolitan regions and offers a rational approach to researching the urban heat island effect in a city is the "Local Climate Zone" (LCZ) land classification system, created by Stewart and Oke (2012). According to figure 1, LCZs are grouped into 17 classes, with 10 classes of built type and 7 classes of natural types of land cover class. They are "regions of uniform surface cover, structure, material, and human activity that spans from hundreds of meters to several kilometers in the horizontal scale". It shows the different built forms; the correction accuracy rate of the LULC classification system depends on the training sample taken by the research; the more samples, the more accuracy. Apart from this, the benefit of this system are that it is an object-based classification and uses 50 m pixel for sample and classification of the city based on their density, unlike supervised, unsupervised classification system which uses per pixel calculation where 100m pixel sample also used compared to the Urban-Rural classification where it considered two different landscape characteristics, LCZ helps to identify different climatic zone based on their built form. The major drawback of this system is that WUPDT, a tool that is used for LCZ classification, uses large quantities of vector sample data but needs to incorporate the complex auxiliary classification steps. Therefore the accuracy of WUPDT needs to be higher. Due to this, in LCZ mapping, more than 60% accuracy was considered.

Table 1:- UHI Variables.

Variables	Proportion	Source
% of vegetation area	43%	*" (L. Chen., 2016) (A. Chen et al., 2014) (Dai et al., 2010) (Armson et al., 2012) (Zipper., 2016) (Mills & Stewart, 2021) (Gartland, 2008) (W. Chen et al., 2017)(Gusso et al., 2015) (Olesen & Madsen, 1995) "*
% of built up area	27%	*" (Makido et al., 2016) (Hein., 2015) (Imran et al., 2022) (Tan et al., 2010) (Li et al., 2009) (X.-L. Chen et al., 2006) (Wang et al., 2015) (Hua & Ping, 2018) (Olesen & Madsen, 1995) "*
Population	17%	*"(X.-L. Chen et al., 2006) (L. Chen et al., 2016) (W. Chen et al., 2017) (Gusso et al., 2015) (Wang et al., 2015) (Zhou et al., 2014) "*
Water body	6%	*" (Pal & Ziaul, 2017) (Buyantuyev & Wu, 2010) (Feng & Myint, 2016) (Fan et al., 2021) (Cai et al.., 2018) (Azhdari et al., 2018) "*
Seasonal Variation	30%	*" (Kantzioura et al., 2012) (Cardoso & Amorim, 2018) (Cai et al., 2018) (Choi et al., 2014) (Makido et al., 2016) (Mallick et al., 2013) (X. Chen et al., 2020) (Haashemi et al., 2016) (Cheval & Dumitrescu, 2015) (Fan et al., 2021) (Olesen & Madsen, 1995) (Buyantuyev & Wu, 2010) "*
Day night Pattern	28%	*" (Krehbiel & Henebry, 2016) (Mathew et al., 2016) (Buyantuyev & Wu, 2010) (Choi et al., 2014) (Makido et al., 2016) (Mallick et al., 2013) (X. Chen et al., 2020) (Haashemi et al., 2016) (Cheval & Dumitrescu, 2015) (Fan et al., 2021) "*
Area of Road Pavement	5%	*" (Mathew et al., 2016) (Buyantuyev & Wu, 2010) (Feng & Myint, 2016) (Fan et al., 2021) "*
Landscape	3%	*" (Pal & Ziaul, 2017) (Heinl et al., 2015) (Sheng et al., 2015) (Mallick et al., 2013) (Li et al., 2009) (X.-L. Chen., 2006) "*
Soil Moisture	2%	*" (X. Chen., 2020) (Li et al., 2009) (Olesen & Madsen, 1995) (Azhdari et al., 2018)"*
Elevation	1%	*"(Mathew et al., 2016) (Buyantuyev & Wu, 2010) (L. Chen et al., 2016)"*

Figure 1:- LCZ Classification System.

Source: Stewart & Oke, 2012

The study on the "LCZ" classification and its relation to LST is minimal. This paper used the LCZ classification system, compared the LULC, LCZ, and LST within the city boundary.

Study contribution

The systematic literature review found that LST was mostly used as a proxy in many papers to show the UHI effect. Land cover indices and LULC analysis were used to relate the different land cover types and land surface temperature. The LCZ-related paper shows the relationship between the different climatic zones, their built form, and their relationship concerning the LST. However, there is a gap between the LULC analysis and LCZ classification system; apart from this, literature shows that vegetation and water body helps in mitigating the UHI effect; however high, rise building, open rise building, and mid-rise building relation with respect to the UHI is not clearly explained in the most of the paper. So, through this paper, an empirical study was conducted to show the link between the changes in land use land cover and the land surface temperature and how changes in land cover create a different local climate zone within the city boundary.

Aim and Objectives:-

This study aims to empirically investigate the association between Land use Land cover-LULC, and Land surface temperature- LST in an urban area and find out how urban elements contribute to the temperature rise.

The objective of this paper is to-

1. What are the factors which influence temperature rise in urban areas?

a. To determine the major variables through a systematic literature review.
b. To find out the high affecting variables through the Delphi method.

2. Does rapid growth in Urban areas lead to land cover change?
    a. To assess the spatio-temporal changes of land use land cover over the last 20 years.
3. How does Ahmadabad's fast urban expansion contribute to its special pattern of densification?
    a. Identifying the different urban forms based on "Local climate zone (LCZ)" classification by using WUPDT tool.
    b. Calculate the accuracy rate of LCZ map through field verification.
4. To assess a comparative analysis between different built form patterns w.r.t Surface temperature rise.

Case study area

This study focuses on Ahmedabad city in Gujarat, located at a latitude and longitude of 23.03oN, 72.58oE. The population in the Ahmedabad Municipal Corporation (AMC) limits increased to 35.15 lakh in 1991 from 28.77 lakh in 2001 and 55 lakh in 2011 and 84 lakh in 2022. The city climate is classed as hot semi-arid by Köppen and Geiger (Gupta et al., 2019). The annual average rainfall in the study region is around 80 cm. summer (March to July), winter (November to February), and monsoon (July to September) are the three primary seasons of the city). The highest relative humidity (80.09%) is found in August. The driest month relative humidity-wise is April (30.79 %).

Figure 2:- Location Map.

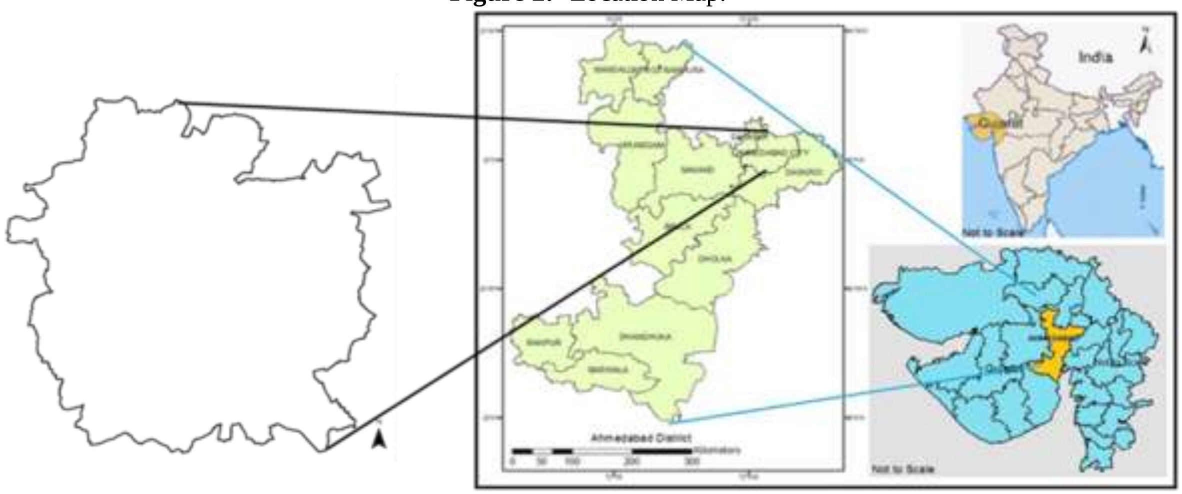
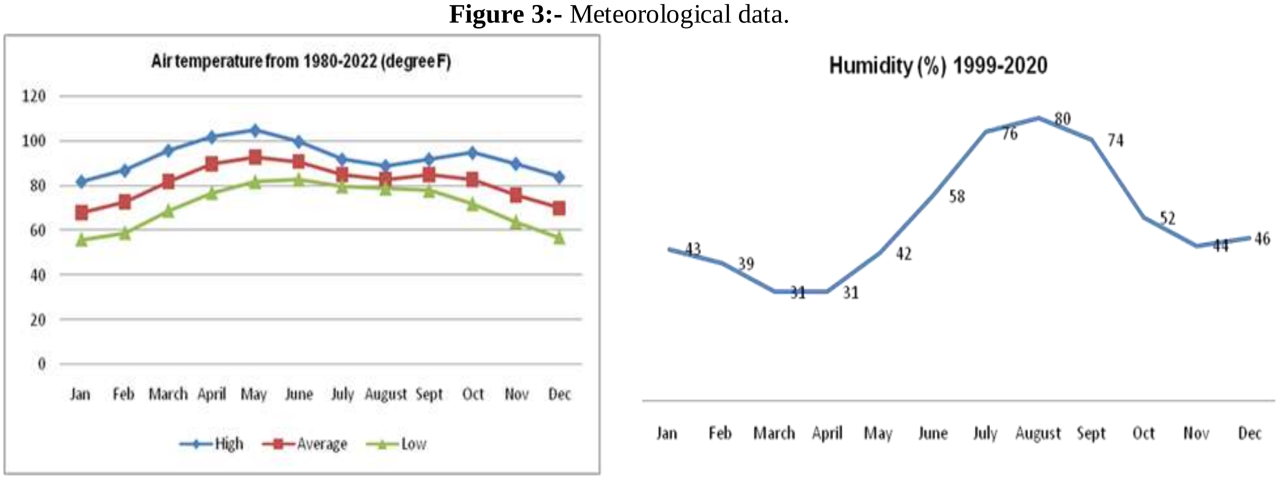


Figure 3:- Meteorological data.



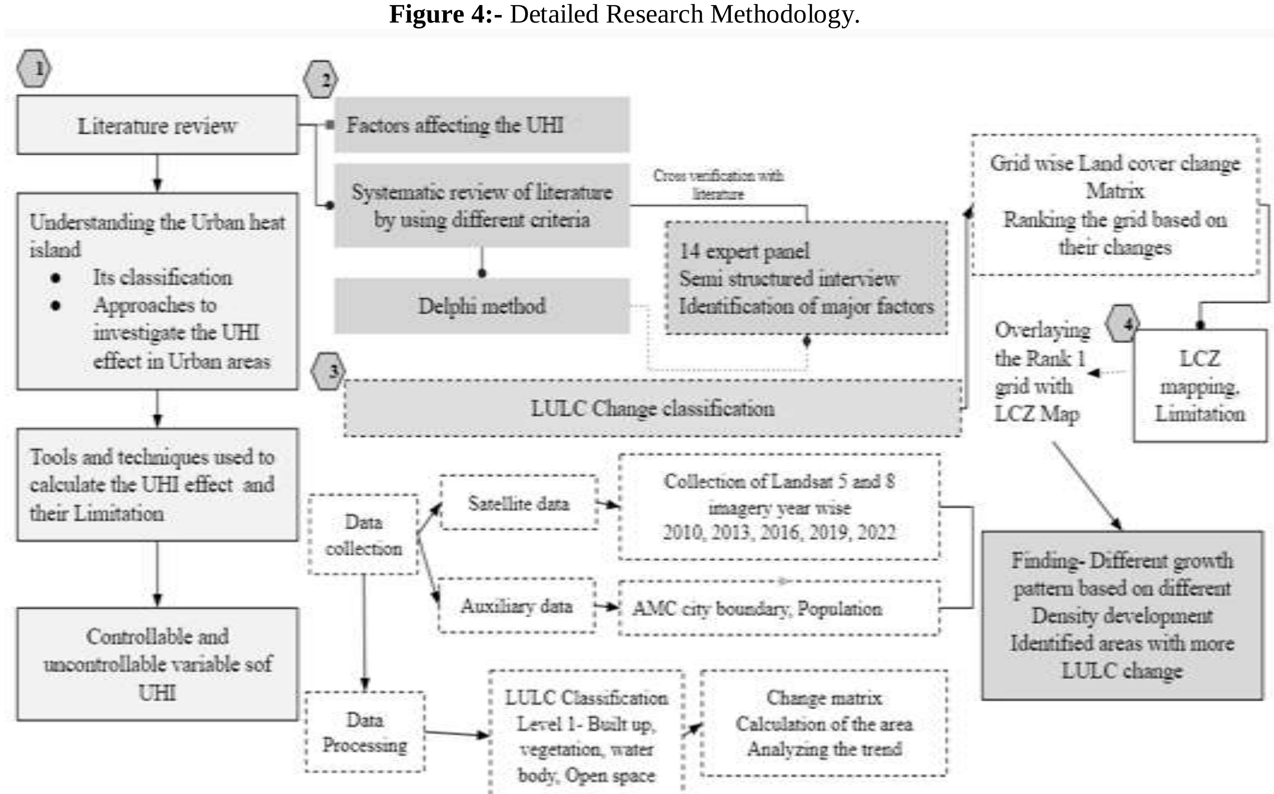
Source- Indian Meteorological department, Pune, 2010

As per the above picture, it shows that May is the month when the air temperature is high. Summer nights are pleasant with a mean low temperature of 26.30 °C, while summer days are quite hot with a mean high temperature of 41.30 °C. Winter time average high and low temperatures are 30 °C and 15.40 °C, respectively.

Research Methodology:-

As shown in the following figure, a step-wise methodological procedure was followed to achieve the goal. To achieve the 1st objective, i.e., identification of parameters that affect the UHI in urban areas, a systematic literature review was done, and then a meeting and discussion with experts in this field were done to identify the variables which are more important during the study of UHI. To achieve the 2nd objective, a spatial analysis approach was taken to study the LULC change. For this purpose, Landsat 7 and 8 satellites imagery was used from 2000 to 2022. A grid-wise LULC change matrix was done to determine which area has changed more in last 20 years. The LULC change analysis found that as the city grows, it forms a specially built pattern like in old Ahmedabad; most of the buildings have G+2 with very few open spaces. However, more high-rise buildings have been constructed near the Sabarmati River with the required green spaces. Also, a designated open space is available near the Sabarmati River, which works as a cool element for that area and helps decrease the Land Surface Temperature. So, to access which type of built form is forming around Ahmedabad city, the LCZ classification system was adopted, which will divide the city into 17 classifications. For the third objective, the "**World Urban Database- World Urban Database and Access Portal Tool (WUPDT)**" tool was used to generate an LCZ map for Ahmedabad city. After that, a comparison study was taken to know which grid which LULC changed more is coming under which LCZ. For fourth objective, from the different grids five different areas were taken, and a detailed study (LCZ, Land cover Indices, Build form, Density) was done with respect to the LST.

Figure 4:- Detailed Research Methodology.



Data Source

Landsat Remote Sensing (RS) and administrative boundaries were the major raster data used in this study for the second objective. The United States Geological Service (USGS) provided the Landsat Remote sensing images for LST, NDBI, and NDVI retrieval.

Table 2:- Details of data source.

Data source and description		
Data source	Spatial resolution	Description
Landsat TM	Band 2,3,4,5 (30 m) Band 6 (120 m)	USGS

Landsat OLI	Band 3, 4, 5, 6 (30m) Band 10 (100 m)	USGS https://earthexplorer.usgs.gov/
Administrative Boundary		Ahmedabad Urban Development Authority

Objective wise Detailed Analysis:-

Variables which affect LST

As discussed previously, some of the major variables was identified which affect the temperature rise in urban areas. To verify the variable shown in the image (5), a Delphi method was used where 14 experts from different fields (Urban Planner, Meteorologist, GIS Analyst, Climatologist, Environment Planner, Geographer, and academia) were selected. The selection criteria for selecting these experts are (a) More than 8 yr. Experience, (b.) Worked on the city development plan or any development plan. A semi-structured interview was conducted among these experts, and based on the literature; the variables which were identified were given to them and to give rank to those variables (5 ranks- for the variable which affected more, rank 1- for the variable which affected less). Apart from the selected variables from literature, other views are also welcomed in this panel.

Table 3:- Statistical representation of Expert view.

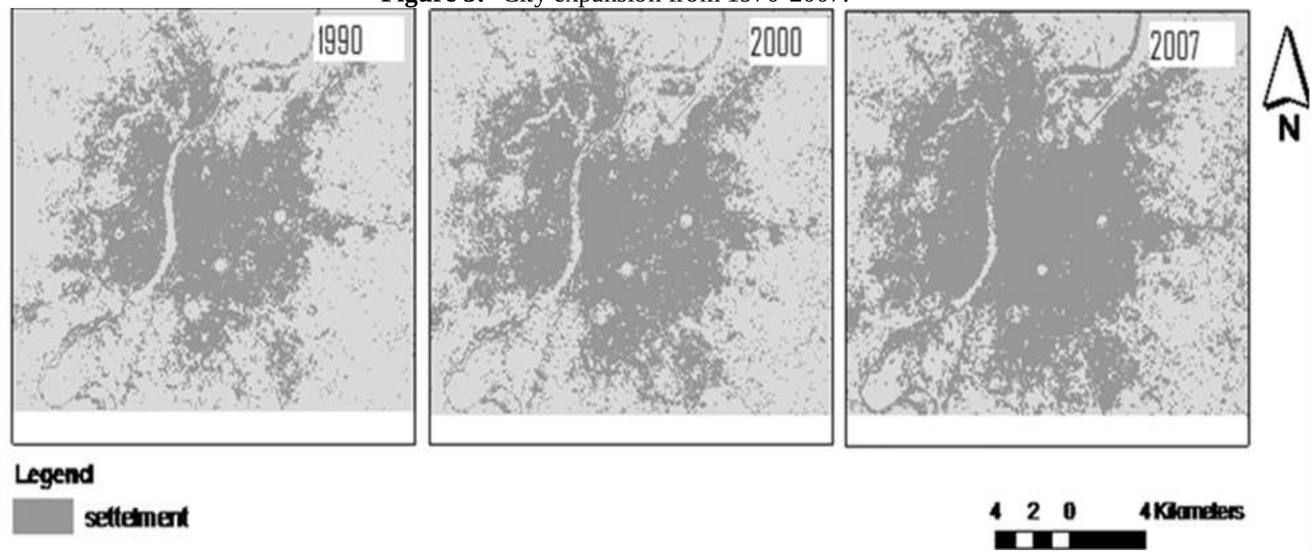
Response	% of vegetation	% of built up	Day night pattern	Seasonal variation	Water body	Population	Density	Landscape	Soil moisture	Elevation
1	5	4	3	5	3	3	3	3	2	2
2	5	4	3	4	3	2	3	3	2	2
3	4	3	5	5	3	3	2	3	2	2
4	4	3	5	5	2	3	2	3	2	1
5	5	4	4	5	2	2	2	2	2	2
6	5	3	4	4	4	2	3	2	2	2
7	5	5	4	4	3	4	2	2	1	2
8	5	5	5	5	3	4	3	2	1	1
9	5	4	5	5	3	3	2	3	1	2
10	5	4	4	4	2	3	2	3	2	2
11	5	4	4	4	3	3	2	3	3	2
12	5	3	4	5	3	3	3	3	3	2
13	5	4	4	5	2	2	3	2	2	1
14	5	4	4	5	4	2	3	3	1	1
Sum	68	54	58	65	40	39	35	37	26	24
Mean	**4.86**	**3.86**	**4.14**	**4.64**	2.86	2.79	2.50	2.64	1.86	1.71

As shown in the figure, most of the respondents give a high ranking to the % of vegetation and built-up area, Seasonal variation and Day night pattern factors as the major variables affecting the UHI in urban areas. For further study, green area, built-up area, water body, density, Seasonal variations, and Day night pattern were studied in a detailed manner.

Ahmedabad city expansion

According to the density pattern shown below, the spatial growth is only occurring in close proximity to the AMC. One of the study area's most densely inhabited locations; the walled city has achieved saturation. Many have preferred to live in the outlying districts where they can take advantage of greater infrastructural amenities, which has led to new outgrowths in the western sections of the city under AUDA control. The city is growing beyond the city boundary, and alteration in natural landscape happened rapidly. Until 2007, the city's urban land was expanding at a rate of around 2.6 sq km per ten years. Yet, the expansion of urban land increased by 132% between 2007 and 2017, reaching 6 sq km per decade (Munshi, 2013).

Figure 5:- City expansion from 1970-2007.



Source: Munshi (2013)

LULC Change Analysis

Image classification

Both unsupervised and supervised classifications were employed to extract specific LULC Classes, such as agriculture land, forest area, water body, built-up land, and unused land. The land cover and land use classification method served as the foundation for the classification scheme, which included the six level 1 classes previously described and twenty-five level 2 classes. Results from many methods are often superior to those from just one. Based on the outcomes of the unsupervised classifications, a maximum likelihood classifier was used for preliminary classifications. Some places that were difficult to discern were examined by us or verified with numerous maps and data to increase the accuracy of interpretation.

Temporal Dynamics of Land use Land cover

To find out the changes in the LULC, both supervised and unsupervised classification were used where the city was divided into four different classes i.e., open spaces, Built Up, vegetation, and water body.

As shown in the figure,

Figure 6:- A detailed process for GIS mapping.

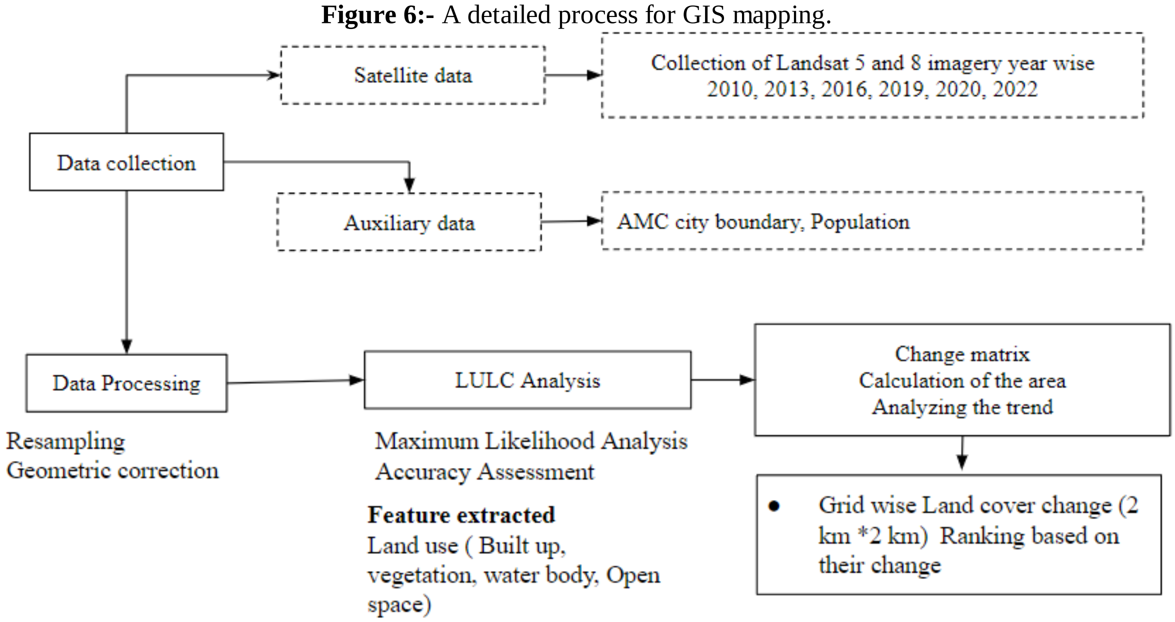
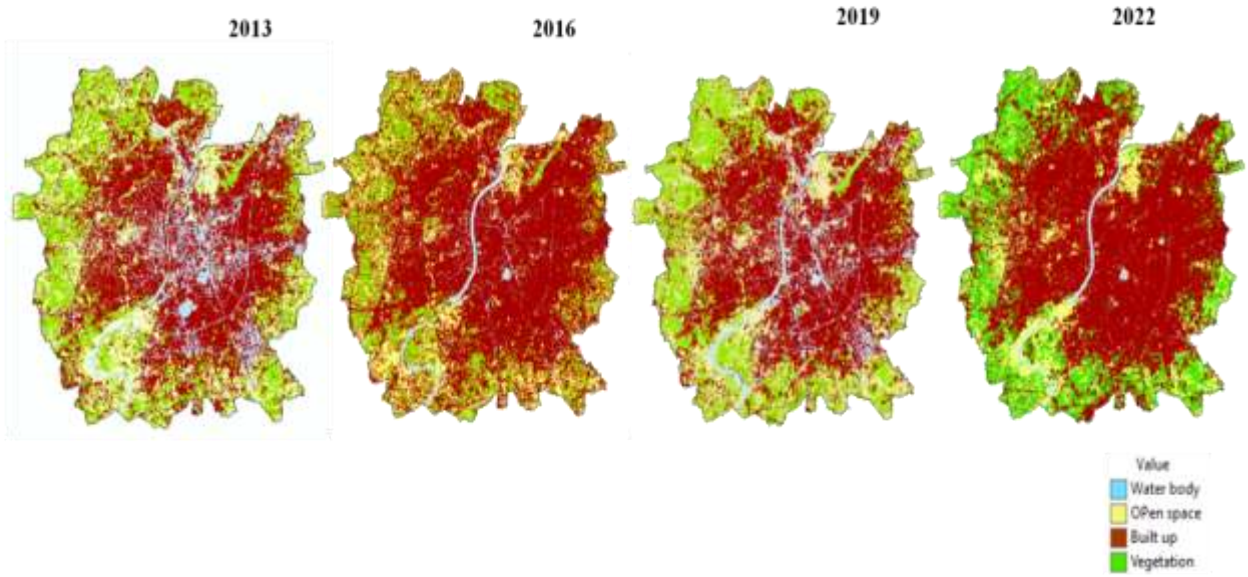


Figure 7:- Temporal changes in LULC from 2013 to 2022.



We employed remote sensing and GIS technology to measure LULC due to the participation of various data sets. We have divided the research area into four categories: vegetation, built-up area, open areas, and water body based on the assessment of remote sensing data, field surveys, and current study area circumstances. LULC changes between 1976 and 2020 were projected for the 192 km2 research area. The key changes in the major categories under LULC are represented in the following table.

Table 4:- Land use changes from 1976-2020.

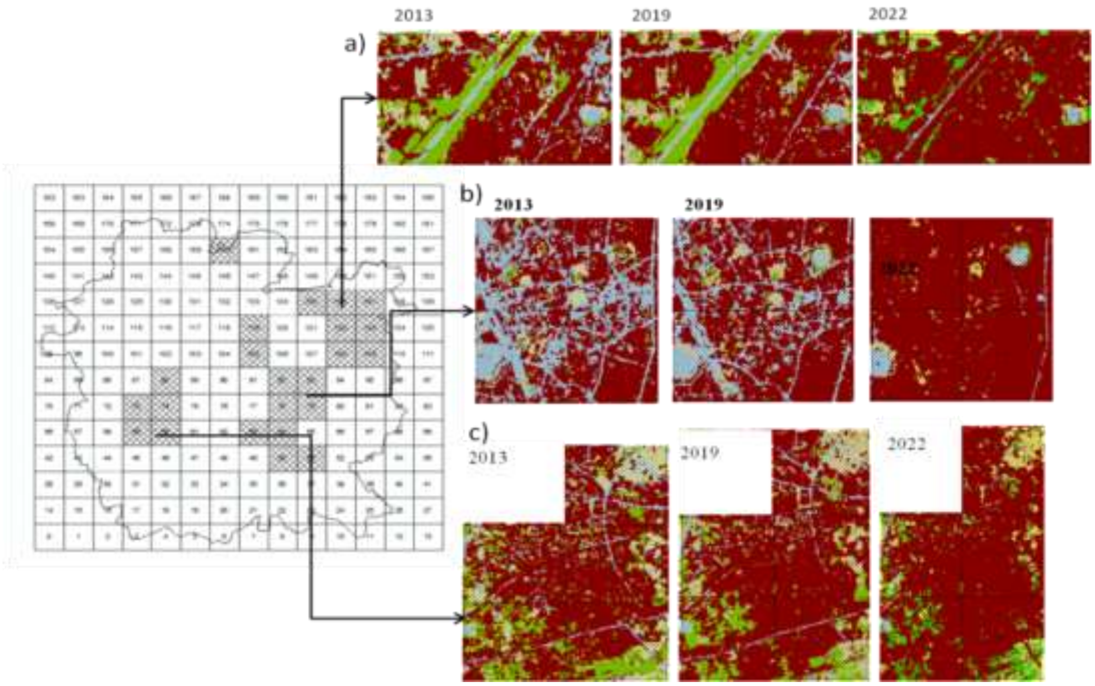
Land Use	1976	1989	1997	2007	2011	2015	2017	2020
Dense Urban	2.8	10.5	39.2	62.5	72.1	82.1	99.6	104.8
Spare Construction	77.3	116.4	112.4	114.7	119.4	127.8	137.5	149
Open spaces	37.9	17.9	18	10.1	9.8	9.1	8.4	7.1
Urban vegetation	3.8	16.2	29.7	45.6	41.8	39.1	35.3	31.8
Agricultural vegetation	269.9	264	225.6	192.7	187.8	168.4	147.2	134.9
Water Bodies	23.7	18.4	18.6	17.7	17.1	16.7	15.6	14.8

The study discovered that although the city's agricultural land, open spaces, and water bodies had severely decreased throughout the study period, densely populated areas had increased to 104.8 sq km.

To know which area has changed more, the AMC city was divided into 2*2km grids; creating 195 grids then a spatial analysis was done to calculate the changes of LULC grid-wise. After that, a weighted ranking method was used to give a ranking to each based on the percentage of changes in LULC class. The grid method followed the following ranking system: More than 80 % = 5, 60-80%= 4, 40-60% = 3, 20-40% = 2 and 0-20% = 1.

As shown in the figure (8), there are three different locations where more than 80% of changes in built-up class happened. The first grid (a) shows the location near the Airport whereas the Ahmedabad Airport developed, the changes of LULC happened, and most of the land was converted into built-up land. The second grid (b) shows the location near the Kalupur station; in the 2013 images, the blue line shows the water body; however it is a road network, but as it shows, most of the land, which shows the blue and yellow color converted into the brown color. The third grid (C) shows the changes in urban vegetation and open areas in the built-up area.

Figure 8:- Grid wise Area study.



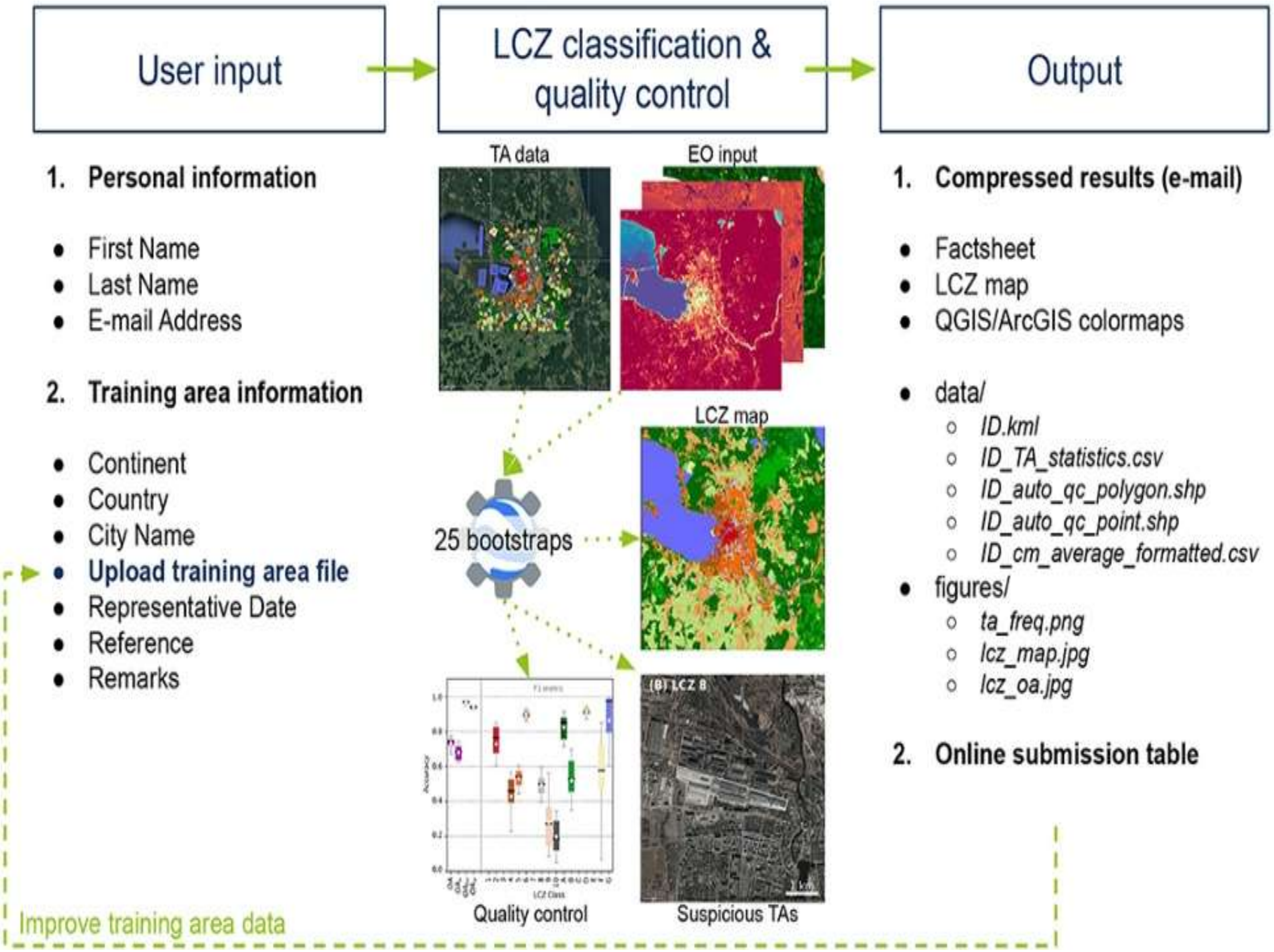
Local Climate Zone (LCZ) Framework

As was previously mentioned, the majority of literature and research project used the difference in temperature between the urban core and the peripheral area to determine the UHI Intensity. With urbanization and growth, the line between "urban" and "rural" is blurrier than ever, and the UHI cannot be correctly described using the suburban comparison approach since it is too straightforward. Using this, Stewart (2011)'s description of the regional variability of the near-surface temperature brought on by the urban underlying land cover needs to be revised. In order to categorize "urban" and "rural" LULC more objectively, Stewart and Oke established the LCZ idea. They also suggested utilizing LCZ 1-LCZ 17 to express the UHI (Stewart & Oke, 2012). Out of the 17 LCZs, "LCZs 1 to 10 are populated regions with a variety of building types, sizes, and densities. Open built-up regions (LCZ 4-5) have fewer dense buildings and greater pervious surface fractions, whereas compact built-up areas (LCZ 1-3) have high impervious and building surface fractions with varied heights of roughness components" (Stewart & Oke, 2012). While LCZs A through G are land cover classifications that represent unique natural landscape. Landscapes and field sites can be efficiently and consistently classified using the LCZ class and all temperature readings can be linked to standardized site metadata.

The Google Pro Earth picture from April 4, 2022, which had a 30 m resolution, no clouds, and was comprehensible visually, was used to determine the training LCZ samples for this investigation. In general, for each of the 17 LCZ categories, 5-28 training samples were used. A minimum of 1 km2 and 200 m in width or length must be provided for each training area. As shown in figure (10), a buffer zone between different LCZ training samples needs to be at least 100 m wide in order to prevent fuzzy border detection. When classifying the LCZ training samples using the random forest approach on the SAGA GIS platform, the Landsat TM image from 4 April 2022 was also used to build the LCZ map. The WUPDT programme was used to build the LCZ map of the research region, which is depicted in the image (10) after multiple iterations and rounds of verification. Table (5) provides further facts regarding the size of the various LCZ types used for the research area, built-up area, and green spaces.

The three main processes of the LCZ Generator web application are depicted in the image below. First, personal and training data must be entered into the online application. Following a successful submission, the back-end LCZ categorization and quality control process is started in order to provide an LCZ map that has been carefully inspected, metadata statistics, and labels for any suspect polygons. The user receives compressed findings by email in the third and final stage, which also adds them to the online submission table. A button that links to the factsheet that offers a visual overview of all findings is included in the output, which is included in an online searchable and sortable submission table along with details about the city, nation, continent, date of submission, and overall correctness.

Figure 9:- The LCZ generator flowchart.



Source: (Demuzere et al., 2021)

Figure 10:- Training Sample for LCZ.

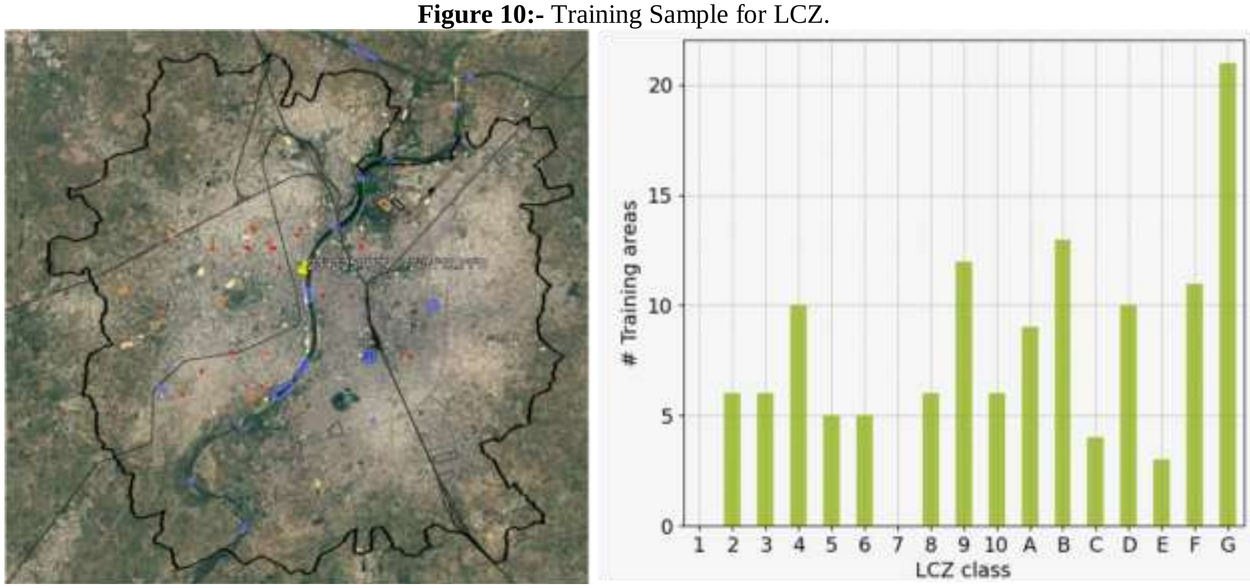


Figure 11:- LCZ map created by WUPDT tool.

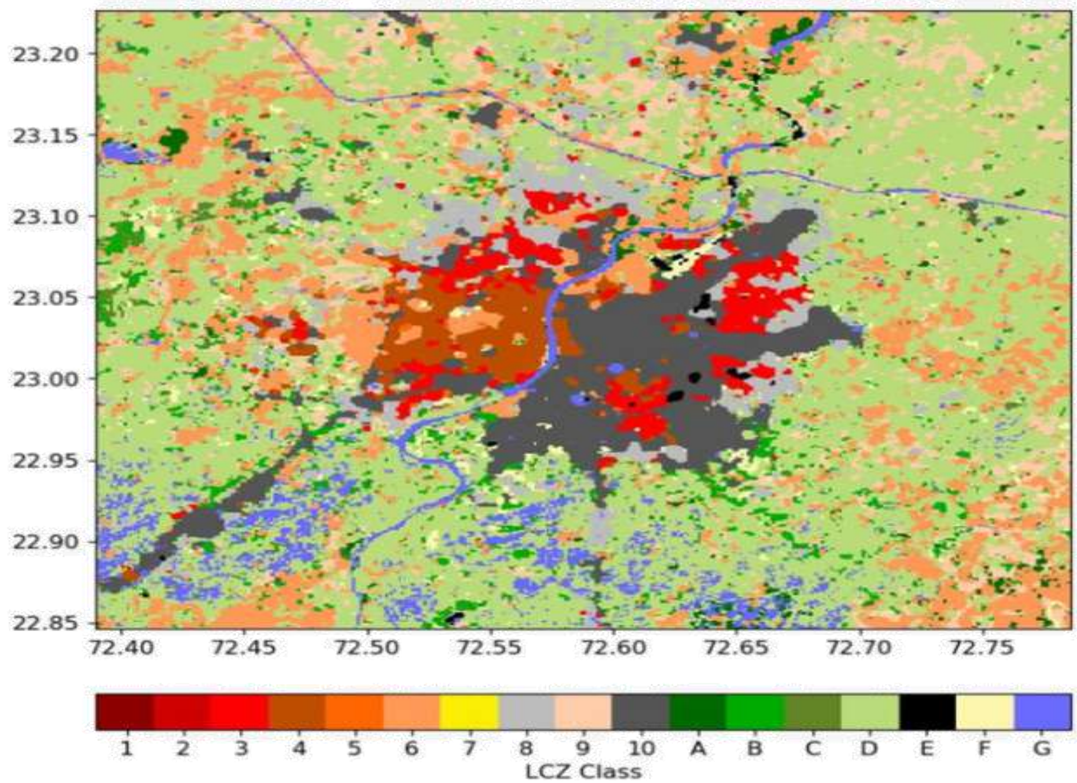


Table 5:- LCZ area.

LCZ class	Name	LCZ	Count	total area (ha)
2	Compact mid rise	LCZ 2	6	7.3
3	Compact low rise	LCZ 3	6	9.5
4	Open high rise	LCZ 4	10	23.7
5	Open mid rise	LCZ 5	5	9
6	Open low rise	LCZ 6	5	35.1
8	Large low rise	LCZ 8	6	21.2
9	Sparsely built	LCZ 9	12	20.7
10	Heavy industry	LCZ 10	6	209.7
11	Dense trees	LCZ 11	9	10.6
12	Scattered trees	LCZ 12	13	7.4
13	Brush, scrub	LCZ 13	4	5.5
14	Low plants	LCZ 14	10	11.9
15	Bare rock	LCZ 15	3	22
16	Bare soil / sand	LCZ 16	11	16.1
17	water	LCZ 17	21	139.6

As shown in the above table, the city was grouped into 17 Local climate zones, out of which open high rise, Low rise, large low rise, and sparsely built LCZ area is more considered than other areas. To verify the LCZ map's accuracy, an accuracy assessment and field verification were done. The accuracy rate of the map was found to be 0.68. As shown in the image below, field verification of different LCZs was done, and based on their different built form accuracy assessment was carried out. In the verification process heavy industry category was considered the fault category, as during the map generation process, the old city of Ahmedabad came under the heavy industry

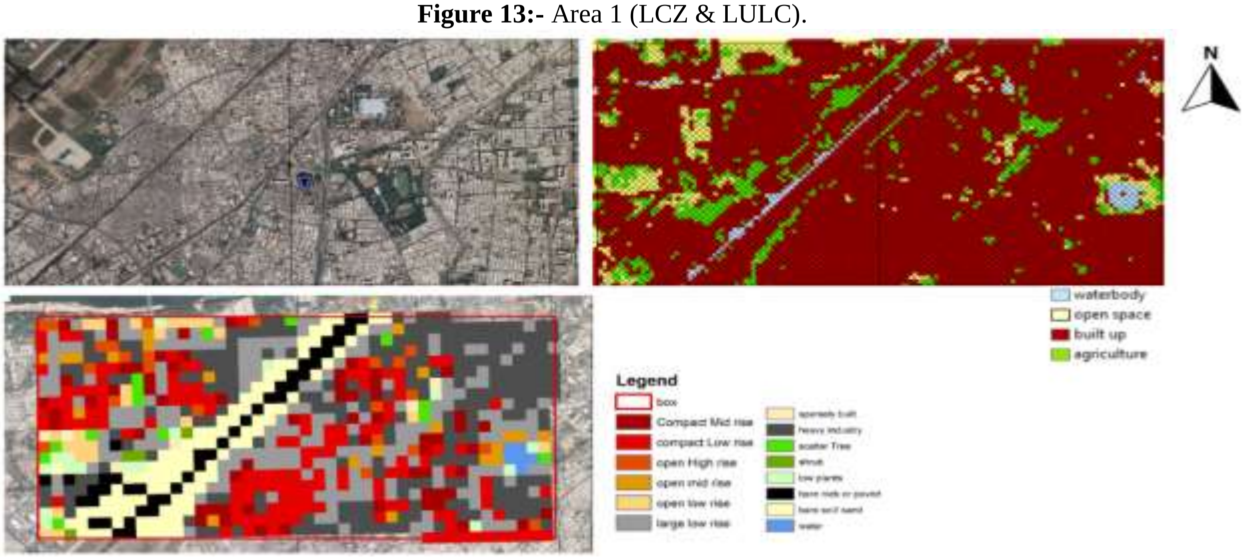
LCZ. So a 2 km area was selected near the old city for a detailed LCZ map, and other industrial areas were not considered for the field investigation.

Figure 12:- Training sample verification.

Area selection for field investigation

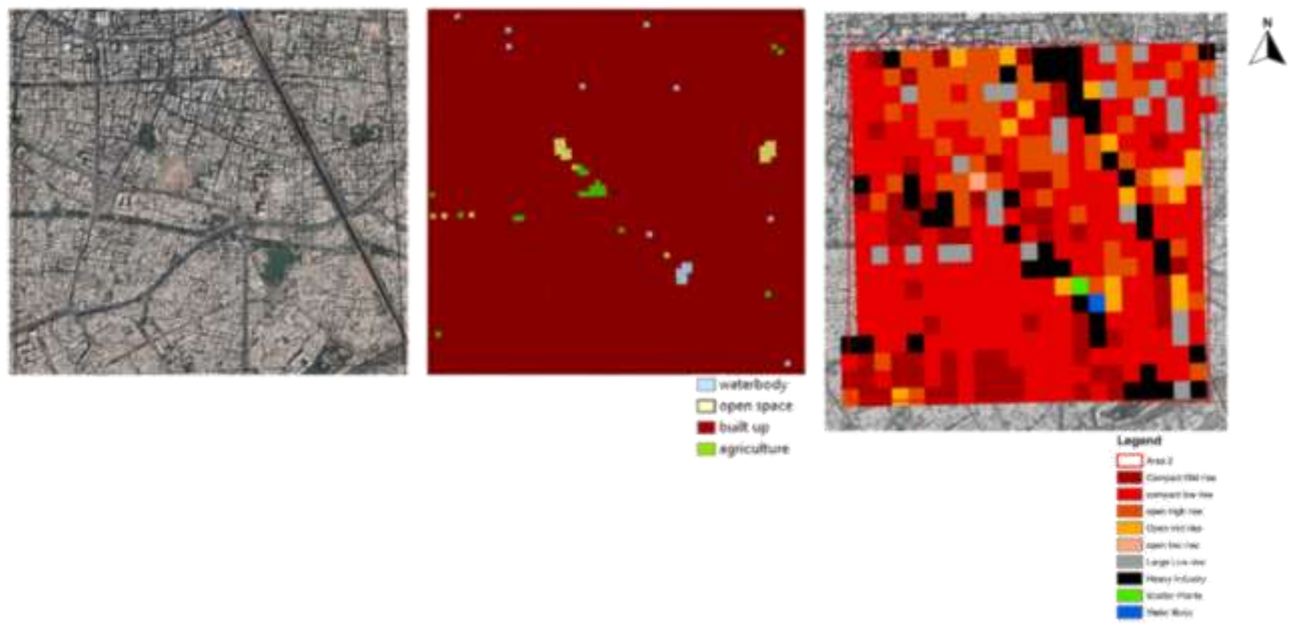
Based on the LCZ map and the grid-wise LULC change matrix, four different locations were found which represent different Local climate zones and more than 80% changes in Land cover. The selected location are followed- 1) 23°03'45.2"N 72°38'25.0"E, Near Airport, (2) 22°59'07.2"N 72°36'25.3"E, Mangleshwar Mahadev Rd, Prakash Nagar, Ghodasar, (3) 23°00'38.4"N 72°30'42.8"E, Prahalad Nagar, (4) 23° 1'34.52"N, 72°36'40.19"E, Saraspur, Ahmedabad, Gujarat and (5) 23° 3'3.01"N, 72°39'37.31" E, Nikol, Ahmedabad.

Figure 13:- Area 1 (LCZ & LULC).



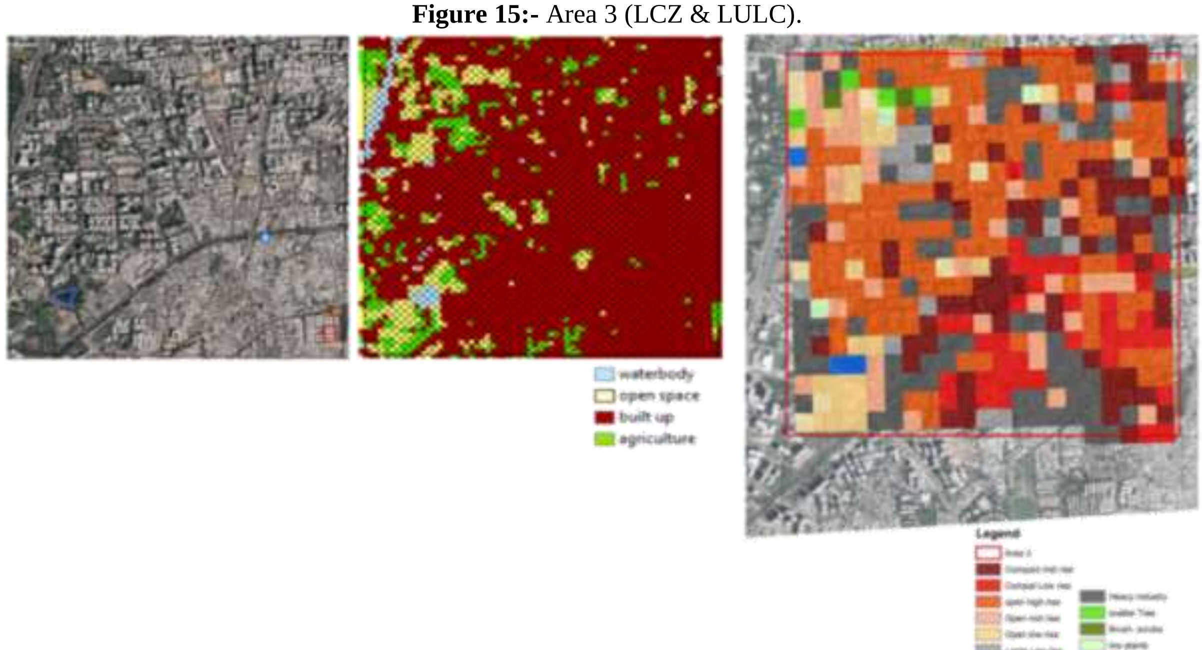
The above image-13 shows the first location where four dominant LCZs available, which are LCZ 3, 12,30,838 sq m, LCZ 8, is total of 17,82,716 sqm, LCZ 10 have a total area 21,55,119 sqm and LCZ F or LCZ 16 have total area 8,50,680 sq m.

Figure 14:- Area 2 (LCZ & LULC).



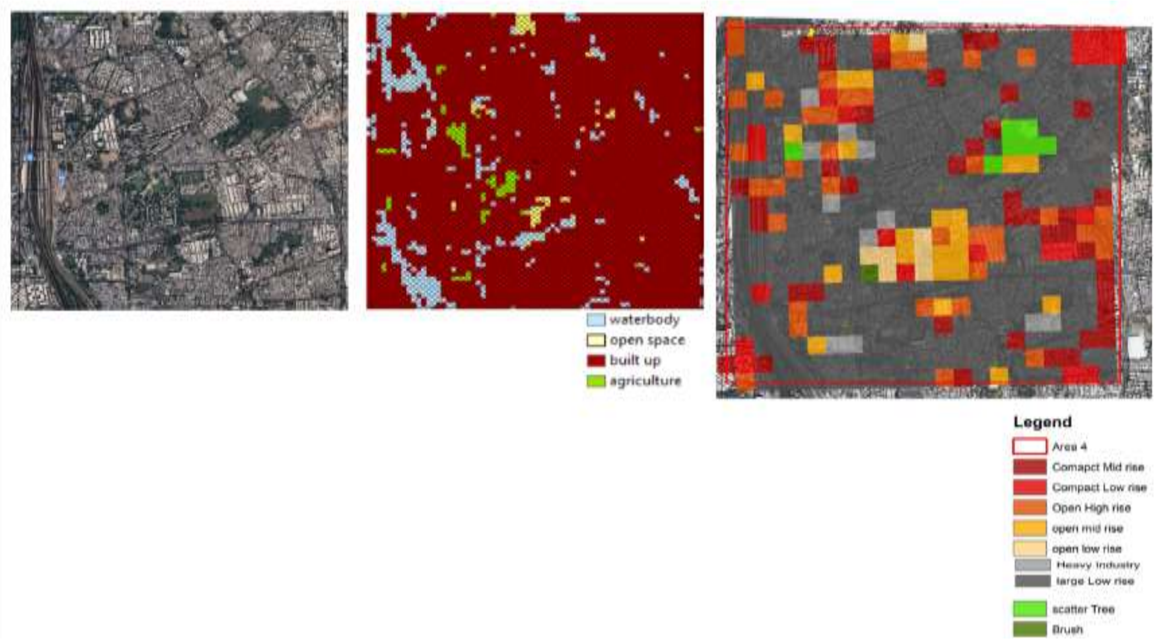
The above image-14 shows the second location; only one grid was selected for field investigation of the built form and LST. This grid was divided into 9 LCZ zones, out of which there are 4 zones that dominate in this grid. Those are LCZ 2, LCZ 3, LCZ 8 and LCZ 10.

Figure 15:- Area 3 (LCZ & LULC).



The above image shows, the 3rd location, which is Prahlad Nagar, where four grids are available, which have changed more than 80% in the last 20 years; however, for the field investigation only, one grid was selected, which is coming under the open high-rise building category. The above grid was divided into 12 LCZ zones, out of which LCZ 2, LCZ 3, and LCZ 4 dominated here.

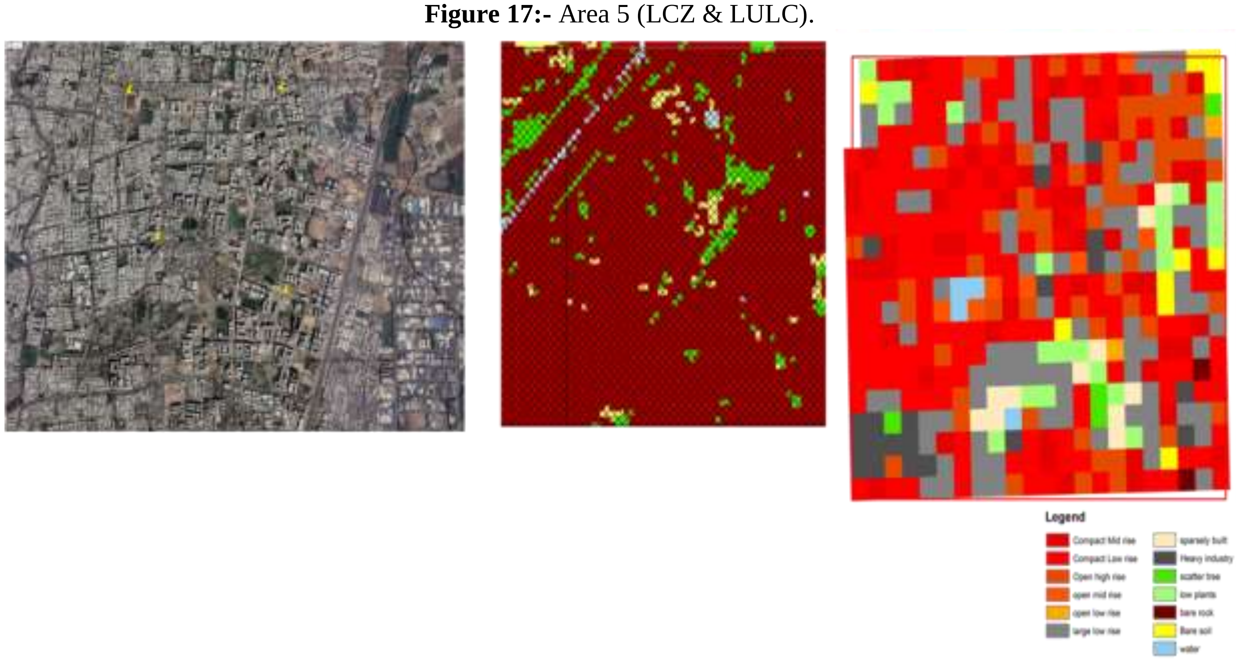
Figure 16:- Area 4 (LCZ & LULC).



The above image-16 shows the fourth location of the study area to investigate the Land cover and LCZ relation with respect to the LST. As shown in the image, most of the area belongs to the LCZ 8 - Large Low rise and LCZ 10 - Heavy Industry.

The below image shows the 5th location of the study area to investigate the LULC and LCZ relation concerning the LST.

Figure 17:- Area 5 (LCZ & LULC).



Data Analysis and Result:-

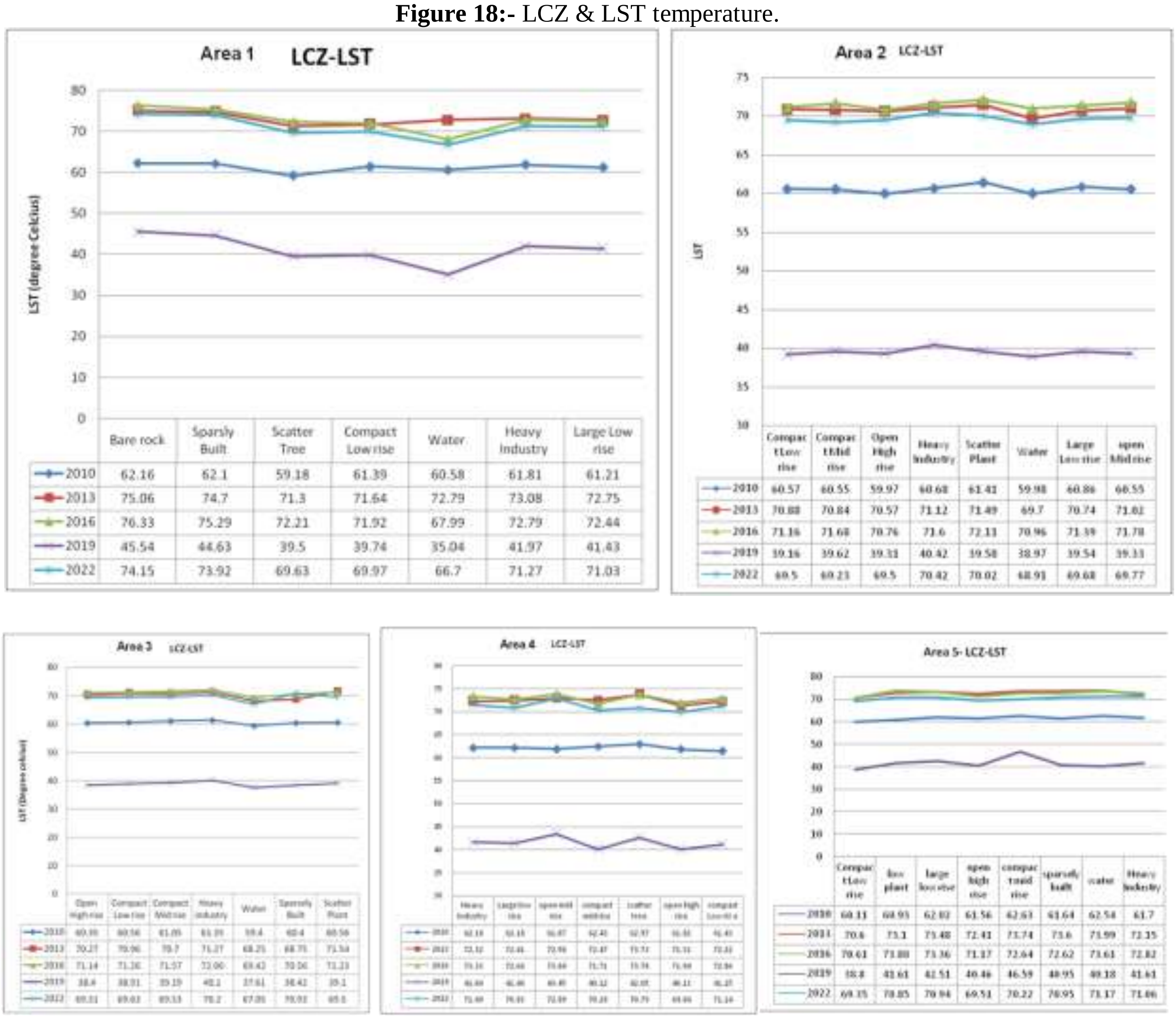
Spatio-Temporal rise of LST

The image below (18) shows the temporal rise of LST from 2010 to 2022 (May month), which shows the continuous rise of LST in the urban area. As shown in the image below, from 2010 to 2022, LST is increasing yearly in different LCZ categories. For first location, in comparison to other LCZs, LCZ 17 has lowest LST 60.58 °C,66.96

°C, 67.99 °C, 35.04 °C and 66.70°C and LCZ 15 (Bare rock) has highest LST, i.e., 62.16 °C, 75.06 °C, 76.33 °C, 45.44 °C, 74.5 °C in the year 2010, 2013, 2016, 2019 and 2022 respectively.

As shown in the 2nd location LCZ classification, the area is divided into nine LCZs, where there is only one water body (LCZ 17) present, which shows the lowest LST from 2010 to 2022, following 59.18°C, 69.70 °C, 70.96°C, 38.97°C and 68.9 °C respectively. Among this LCZ, compact low rise shows the highest LST, which is 60.57 °C, 70.88°C, 71.1 °C, 39.16 °C and 69.50°C respectively, in the years 2010, 2013, 2016, 2019, and 2022. Moreover, an open high-rise built form shows the lowest LST among these built forms, which is 59.97 °C, 70.57 °C, 70.76 °C, 39.31 °C, 69.50°C respectively, in the years 2010, 2013, 2016, 2019, and 2022.

Figure 18:- LCZ & LST temperature.



As shown in the above image, Area 3 is divided into 7 LCZ zones to calculate the LST. Among the three major built forms, LCZ-3 generates more LST compared to LCZ 4. Among the cooling element, Water body, and Vegetation area, which are present in this grid, LCZ 17 shows a lower LST than the scatter plant.

As shown in the image (18), to calculate the LST for Area 4 is divided into seven major categories, among which heavy industry shows the highest LST, and among the different built form, LCZ 5 category generates high LST and LCZ 4 generates less LST. As shown in the Image, for Area 5, LCZs classes are categorized in to 9 categories, where it shows that LCZ 2 generates more LST than other built form.

The common category among the five locations is “LCZ 2, LCZ 3, LCZ 6, LCZ 8, LCZ 10, LCZ 12 and LCZ 17”.

Table 6:- Common LCZ among five locations.

Local Climate zone		Mean LST (°C) From the year 2010-2022				
		Area 1	Area 2	Area 3	Area 4	Area 5
LCZ 12	scatter tree	62.36	62.92	62.39	64.48	64.07
LCZ 17	water	60.2	61.7	60.35	-	64.29
LCZ 3	compact low rise	62.93	62.25	62.26	63.76	61.89
LCZ 2	compact mid rise	-	62.38	62.41	63.4	61.2
LCZ 8	Large low rise	63.77	62.44	-	63.91	64.46
LCZ 4	open high rise	-	62.02	61.89	63.01	63.02
LCZ 10	heavy industry	64.18	62.85	63	64.2	63.86

As discussed above, small, middle, and large industry generates C02, and generally, the temperature of the areas where heavy industry is located is higher compared to the other areas.

Seasonal LST Variation in spatial context

Below figure (19) represents the seasonal LST variation in the study area from the year 2022, as it shows for winter season December, January and February month and for summer season March, April and May month was taken to show the LST variation among the different LCZs. To investigate the effects of spatial context, values of LST to various LCZ types within urban areas are explored. As it is shown in the figure-18, the LST retrieval from different LCZs shows that among different zones LCZ 17 generates less LST compared to the LCZ 12. Within the city boundary of Ahmedabad there is no designated urban forest or eco sensitive region available. However, as the numbers demonstrate, compared to scattered plants across the city, a dedicated green space like an urban forest creates less LST and aids in reducing the heated urban climate. Water body is generating less LST in both winter and summer season. From the five locations, it was found that LCZ 15, LCZ 16 and LCZ 10 generate more LST than other LCZs. In compared to the "LCZ 2 and LCZ 3, LCZ 4 and LCZ 5" generates less LST. Compact built form means using the least amount of land for development and supporting infrastructure that is reasonable under the circumstances. In these circumstances a more impervious surface and less area for greenery was available so in a compact area more solar radiation was trapped in concrete and asphalt so it generated more LST than other built forms. And open built form means the combination of both pervious and impervious surface at the same place, having buildings and around it a certain amount of greenery due to this circumstances solar radiation trapped in the buildings and vegetation however the heat capacity of concrete and vegetation is different so in LCZ 4, LCZ 5 and LCZ 6 generates less LST than LCZ 2.

Discussion and Implication:-

6.1. Variation of LST with response to the LCZ

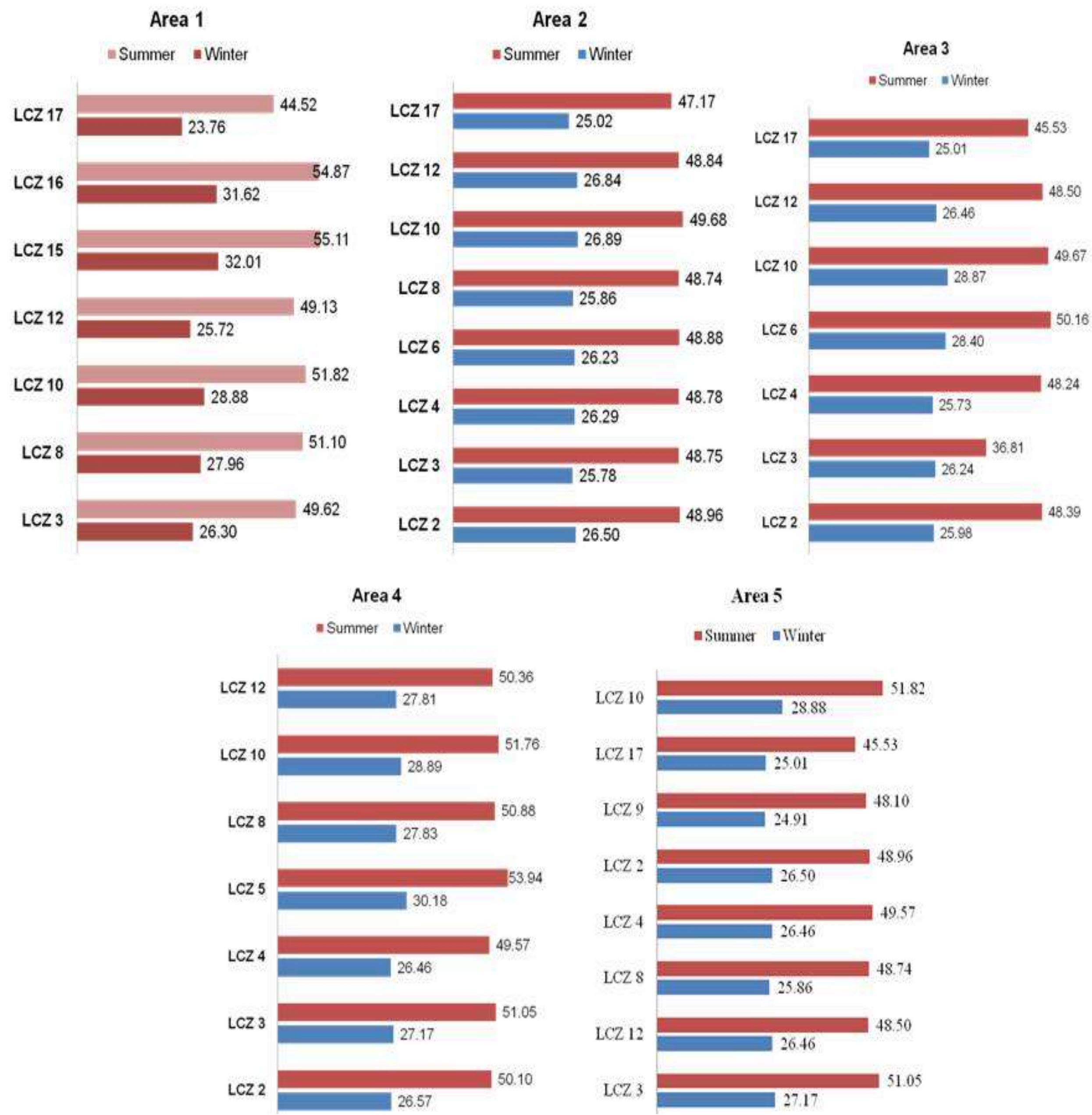
The LCZ technique was created to determine the variation between temperatures across various urban zones, and earlier studies have revealed that the highest LST is frequently found in LCZ-2, LCZ-3, LCZ-8 and LCZ-10 compared to the other LCZs. However, our findings showed that the heat sinks and sources differed greatly by month. LCZ-2, LCZ-10, and LCZ-6 were the LCZs built with the highest LST throughout the summer. These outcomes were consistent across all four of the city's sites. Due to thermal inertia, the link between developed LCZs and urban vegetation and water bodies may exhibit distinct cooling/heating impacts, changing the LCZs' temperature pattern. In three of the four locations, LCZ 17 and LCZ 12 are present, indicating the cooling characteristics of the region that contribute to cooling the environment. The irregular LST patterns of various LCZs demonstrate the variations of various combinations of heat sinks and sources which absorb more heat like unpaved and rocky area, intermittent factory operation area (LCZ 10) which generates more carbon, use of heating and cooling systems in summer and cold seasons, and heat linkages, as well as the cyclical nature of the microclimate in summer and winter seasons.

LST's reactions to LCZs varied as cities expanded. For instance, in an urban setting, the two developed LCZs with the greatest LST throughout the year were LCZ-8 and LCZ-10. In contrast, LCZ 17 and LCZ 12 had the lowest LST throughout the two seasons in comparison to other LCZs. Overall; these findings suggest that the region of interest, particularly the maximum urban temperature, played a role in how LST responded to LCZs.

The potential of the LCZ method to distinguish temperatures difference depends on the urban setting (e.g., different types of built form like compact, open, light weight, large low rise), apart from macroclimate, seasons and months. Overall this study helps in identifying which types of urban design and landscape built form generating how much

LST throughout the year, which will help in determining the potential built form which is better suited for mitigating the heat stress impact on urban areas.

Figure 19:- Seasonal LST Variations.



Implication of the study in Urban Planning

a) In existing development plan

The city's existing zoning regulations either follow a land use- or activity-based approach. Zoning plans are crucial because they control density, manage growth, and organize land uses. However, by layering the LCZ-based technique on top of the Zoning Plan it makes it simple to identify Critically Stressed Areas. Given the concentration of anthropogenic heat in a few select regions of the city, for instance, the areas designated as LCZ10 and LCZ 3 exhibit the maximum intensity of UHI. It can also draw attention to regions that ought to be maintained, preventing a rise in local temperature. The application and interpretation of a zoning technique based on LCZs will be sufficiently flexible. This is made feasible by the 'value ranges' (thermal, radiative, and metabolic attributes for regional climatic zones, such as Surface Albedo and anthropogenic heat output) given in its classification.

b) In Urban Design

The theory of LCZ approach is that it has a set of standards for characterizing urban landscapes according to climate related properties. The set of standards include “Impervious Area, Pervious Area, Anthropogenic Heat Output, Energy Demand, Surface Albedo, Sky view Factor (SVF) , Aspect ratio, Building surface fraction” element. Urban planning and design benefit from the block-by-block standard value that the LCZ method provides. By adhering to a distinct physical process, the LCZ standard assists in deconstructing the urban design aspects into indications. For instance, cool roof design elements may be applied in LCZ 2 to lessen heat stress in urban design elements connected to cooling, such as green walls or corridors.

c) In Building Regulation

Building codes provide rules for the design and construction of buildings in order to improve energy efficiency safeguard the health and safety of everyone who enters or is in close vicinity to them, including those with disabilities. This research will help establish some of the construction requirements. The current building code is used at city level, but by using the LCZ-based approach, an early "value of range" at the level of urban blocks was already known. This will help in monitoring local development at the level of blocks by defining the standard permissible SVF, FAR to control an urban block maximum as per LCZ rather than city-wide regulations. As LCZ wise Building regulation will give more benefit by controlling and monitoring the “Value Ranges”.

Conclusion:-

The basis for reducing and avoiding the many effects of the urban heat issues that many cities suffer is a precise measurement of urban thermal conditions. LCZ method and LULC analysis is a crucial tool for separating surface temperatures from intra-urban temperatures, and LST is one of the essential indications. However, it is still being determined how the landscape affects the seasonal fluctuation of SUHI and the applicability of LCZ method is not used generally. This study examined the variance of SUHI impacts through LST and the applicability of the LCZ method for LST differentiation. The results showed there were spatio-temporal fluctuations in both the LST and the different LCZs. Future research is required to examine the spatiotemporal changes in LST distribution and LST responses to LCZs because this article has significant limitations. First off, just two seasons' worth of data were used here to illustrate how LST varies and second, the study's consideration of varied urban environments within the same city may not adequately reflect heavily and sparsely urbanized cities. Future research is thus required to confirm the findings and draw the necessary inferences for the urban setting with the chosen metropolitan and satellite cities. The results of this study provide support for a method for using the LCZ scheme to analyze the land surface temperature in relation to various built forms and provide an area that is extremely vulnerable to urban heat islands, which will aid in the creation of future development plans and policies for urban planners and architects of climate-sensitive urban designs.

Reference:-

1. Armson, D., Stringer, P., & Ennos, A. R. 2012. The effect of tree shade and grass on surface and globe temperatures in an urban area. Urban Forestry & Urban Greening, 11(3), 245–255.
2. Avdan, U., & Jovanovska, G. 2016. Algorithm for Automated Mapping of Land Surface Temperature Using LANDSAT 8 Satellite Data. Journal of Sensors, 2016, 1–8.
3. Azhdari, A., Soltani, A., & Alidadi, M. 2018. Urban morphology and landscape structure effect on land surface temperature: Evidence from Shiraz, a semi-arid city. Sustainable Cities and Society, 41, 853–864.
4. Buyantuyev, A., & Wu, J. 2010. Urban heat islands and landscape heterogeneity: Linking spatiotemporal variations in surface temperatures to land-cover and socioeconomic patterns. Landscape Ecology, 25(1), 17–33.
5. Cai, Z., Han, G., & Chen, M. 2018. Do water bodies play an important role in the relationship between urban form and land surface temperature? Sustainable Cities and Society, 39, 487–498.
6. Cardoso, R. dos S., & Amorim, M. C. de C. T. 2018. Urban heat island analysis using the ‘local climate zone’ scheme in Presidente Prudente, Brazil. Investigaciones Geográficas, 69, 107.
7. Chen, A., Yao, X. A., Sun, R., & Chen, L. 2014. Effect of urban green patterns on surface urban cool islands and its seasonal variations. Urban Forestry & Urban Greening, 13(4), 646–654.
8. Chen, L., Jiang, R., & Xiang, W.-N. 2016. Surface Heat Island in Shanghai and Its Relationship with Urban Development from 1989 to 2013. Advances in Meteorology, 2016, 1–15.
9. Cheval, S., & Dumitrescu, A. 2015. The summer surface urban heat island of Bucharest (Romania) retrieved from MODIS images. Theoretical and Applied Climatology, 121(3–4), 631–640.
10. Dai, X., Guo, Z., Zhang, L., & Li, D. 2010. Spatio-temporal exploratory analysis of urban surface temperature field in Shanghai, China. Stochastic Environmental Research and Risk Assessment, 24(2), 247–257.
11. Demuzere, M., Kittner, J., & Bechtel, B. (2021). LCZ Generator: A Web Application to Create Local Climate Zone Maps. Frontiers in Environmental Science, 9, 637455. https://doi.org/10.3389/fenvs.2021.637455

12. Fan, Q., Du, F., Li, H., & Zhang, C. 2021. Thermal-comfort evaluation of and plan for public space of Maling Village, Henan, China. PLOS ONE, 16(9), e0256439.
13. Gartland, L. 2008. Heat islands: Understanding and mitigating heat in urban areas. Earthscan.
14. Guo, G., Zhou, X., Wu, Z., Xiao, R., & Chen, Y. 2016. Characterizing the impact of urban morphology heterogeneity on land surface temperature in Guangzhou, China. Environmental Modelling & Software, 84, 427–439.
15. Gupta, N., Mathew, A., & Khandelwal, S. 2019. Analysis of cooling effect of water bodies on land surface temperature in nearby region: A case study of Ahmedabad and Chandigarh cities in India. The Egyptian Journal of Remote Sensing and Space Science, 22(1), 81–93.
16. Haashemi, S., Weng, Q., Darvishi, A., & Alavipanah, S. 2016. Seasonal Variations of the Surface Urban Heat Island in a Semi-Arid City. Remote Sensing, 8(4), 352.
17. Heinl, M., Hammerle, A., Tappeiner, U., & Leitinger, G. 2015. Determinants of urban–rural land surface temperature differences – A landscape scale perspective. Landscape and Urban Planning, 134, 33–42.
18. Imran, H. M., Hossain, A., Shammas, M. I., Das, M. K., Islam, Md. R., Rahman, K., & Almazroui, M. 2022. Land surface temperature and human thermal comfort responses to land use dynamics in Chittagong city of Bangladesh. Geomatics, Natural Hazards and Risk, 13(1), 2283–2312.
19. Kantzioura, A., Kosmopoulos, P., & Zoras, S. 2012. Urban surface temperature and microclimate measurements in Thessaloniki. Energy and Buildings, 44, 63–72.
20. Krehbiel, C., & Henebry, G. 2016. A Comparison of Multiple Datasets for Monitoring Thermal Time in Urban Areas over the U.S. Upper Midwest. Remote Sensing, 8(4), 297.
21. Makido, Y., Shandas, V., Ferwati, S., & Sailor, D. 2016. Daytime Variation of Urban Heat Islands: The Case Study of Doha, Qatar. Climate, 4(2), 32.
22. Mallick, J., Rahman, A., & Singh, C. K. 2013. Modeling urban heat islands in heterogeneous land surface and its correlation with impervious surface area by using night-time ASTER satellite data in highly urbanizing city, Delhi-India. Advances in Space Research, 52(4), 639–655.
23. Mills, G. M., & Stewart, I. D. 2021. The urban heat island: A guidebook. Elsevier.
24. Mokhtari, Z., Barghjelveh, S., Sayahnia, R., Qureshi, S., & Russo, A. 2022. Dynamic and Heterogeneity of Urban Heat Island: A Theoretical Framework in the Context of Urban Ecology. Land, 11(8), 1155.
25. Munshi, T. 2013. Built form, Travel Behaviour, and Low Carbon Development in Ahmedabad, India.
26. Olesen, B. W., & Madsen, T. L. 1995. Measurements of the physical parameters of the thermal environment. Ergonomics, 38(1), 138–153.
27. Sheng, L., Lu, D., & Huang, J. 2015. International Journal of Remote Sensing Impacts of land-cover types on an urban heat island in Hangzhou, China. , 36(6), 1584–1603.
28. Stewart, I. D., & Oke, T. R. 2012. Local Climate Zones for Urban Temperature Studies. Bulletin of the American Meteorological Society, 93(12), 1879–1900.
29. Tan, K. C., Lim, H. S., MatJafri, M. Z., & Abdullah, K. 2010. Landsat data to evaluate urban expansion and determine land use/land cover changes in Penang Island, Malaysia. Environmental Earth Sciences, 60(7), 1509–1521.
30. Wang, J., Huang, B., Fu, D., & Atkinson, P. 2015. Spatiotemporal Variation in Surface Urban Heat Island Intensity and Associated Determinants across Major Chinese Cities. Remote Sensing, 7(4), 3670–3689.
31. Zhou, W., Qian, Y., Li, X., Li, W., & Han, L. 2014. Relationships between land cover and the surface urban heat island: Seasonal variability and effects of spatial and thematic resolution of land cover data on predicting land surface temperatures. Landscape Ecology, 29(1), 153–167.
32. Zipper, S. C., Schatz, J., Singh, A., Kucharik, C. J., Townsend, P. A., & Loheide, S. P. 2016. Urban heat island impacts on plant phenology: Intra-urban variability and response to land cover. Environmental Research Letters, 11(5), 054023.