

Spatial Assessment of Urban Heat Island and Heat Related Risks in Chandni Chowk, Delhi

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Abstract— Urban Heat Island is a growing concern in large cities or urban areas, especially in old and densely built areas. This study aims to assess the impact of Urban Heat Island effect on public health in Chandni Chowk. Chandni Chowk is one of the oldest and busiest parts of Delhi which experiences extreme heat due to narrow streets, excessive construction, dense buildings, heavy commercial activities and very limited green spaces. This dissertation focuses on understanding the nature and intensity of Urban Heat Island in Chandni Chowk and understand how the urban environment contributes to rising surface temperatures. The study analyzes the land use and land cover changes from 2000-2025 using satellite imagery. This study is based on primary survey and indicators such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) are used to examine the relationship between urban development, vegetation loss. Vegetation cover, built up surfaces and population pressure are examined to identify their relationship with temperature variation. Field observation and secondary sources are also used to support the analysis. The result shows that the areas with dense commercial activity and limited green cover show significantly higher surface temperatures, increasing discomfort for local people and workers.

Keywords— Urban Heat Island, Urban Environment, Normalized Difference Vegetation Index, Normalized Difference Built Up Index

1. Introduction

An Urban Heat Island is a phenomenon where temperature in urban areas are significantly more than surrounding rural areas. Urban Heat Island is a growing concern in rapidly urbanizing cities, where human activities are causing urban areas to become significantly warmer than rural areas. “Urban Heat

Island refers to the condition where urban areas record higher temperatures than their surrounding rural areas due to dense built up surfaces, reduced vegetation and anthropogenic activities” (R.B. Singh, 2005). “The Urban Heat Island refers to the higher temperatures observed in urban areas compared to their surrounding areas, mainly due to human activities and urban development” (Gordan Manley, 1958). Urban Heat Island has become a great climatic issue worldwide, many cities in the world face this issue such as Tokyo, New York, Dubai etc. This is because of rapid urbanization, industrialization, decline in green cover, high population density and rising temperature.

In India cities like Delhi, Mumbai, Bengaluru, Ahmedabad and many more experiences extreme summers, the Urban Heat Island effect has intensified due to unplanned urbanization, loss of green cover, high rise constructions, rapid industrialization, etc. The outcome of Urban Heat Island not only degrades our environment but also affects human health as well.

Urbanization has converted natural green spaces into constructed spaces and more heat is trapped, resulting in drastic climatic change. One of the climatic modification is the Urban Heat Island effect in which urban areas temperature reaches higher than surrounding rural or peri urban areas. Due to expansion of urban areas natural surfaces such as water bodies, forest, soil are being replaced by concrete and closely packed buildings. The temperature difference is mainly caused by dense infrastructures, low vegetation, high use of materials like concrete and asphalt, and high vehicular heat emissions. In developing nations like India with high rate of urbanization it is

anticipated that the intensity and frequency of Urban Heat Island occurrences would increase, making it an important problem for city planners, environmental researchers, and health authorities.

In Delhi, climate change is a big problem, the city has been witnessing hotter summers and more uncomfortable nights. People living in highly congested areas of Delhi feels more heat related problems compared to those living in more greener areas.

Land Use and Land Cover analysis is an important method which helps us to understand how land is being used by human beings and what physical features exist on Earth's surface. Human activities like increase of agricultural land, deforestation and urbanization are degrading natural landscapes and resulting in environmental degradation (King et al,2023).

- Land Cover: It refers to the natural or physical material on surfaces of the land such as vegetation, water, soil or built-up structures.
- Land Use: It refers to how people utilize that land for example for housing, markets, transport, industry or open spaces.

In large metropolitan city like Delhi, rapid urban growth has changed the natural landscape significantly. Agricultural fields, open grounds and green areas have gradually been replaced by roads, buildings, complexes, dense residential colonies. These transformation affect temperature patterns, wind circulations, and environmental quality. Therefore, Land Use Land Cover analysis becomes very useful for understanding urban environment problems, including the Urban Heat Island effect and its influence on public health. The changes in land use and land cover, for instance can modify the physical characteristics of the land surface and contribute to greenhouse gas emissions, which may impact local weather patterns and raise the risk of natural catastrophes (Bikis et al.,2025)

In the case of Delhi, the pattern of land use varies greatly from one area to another. Some parts of Delhi have wide roads, green parks and planned residential zones, while older parts of the city are densely packed with narrow streets and continuous construction. The central city area including Chandni Chowk, represents one of the most crowded and commercially active zones. Here, the dominance of residential land, limited vegetation, heavy traffic movement and dense population contribute to higher local temperatures compared to greener areas. Land Use and Land Cover analysis of Chandni Chowk helps us to identify the proportion of built-up surfaces, roads, vegetation cover, etc. Most surfaces in Delhi are paved or made of concrete which increases heat absorption. Lack of green cover reduces shade and limited natural cooling of that area. Additionally, high human emission such as vehicular emission, construction activities, all these factors contribute to urban heat island effect more vulnerable in Chandni Chowk.

To conduct LULC analysis, researchers commonly use satellite images, GIS, remote sensing data. Satellite imagery helps us to identify different land use patterns such as water bodies, vegetation cover, built up, open land. By comparing images from year 2000 and 2025, it is possible to see how land used has changed over time and help in identifying increasing construction density, shrinking greener areas and expansion of infrastructure. In the context of UHI and public health, LULC analysis plays a crucial role. Areas with dense built-up tend to record higher temperatures and exposure to heat can affect human health such as heat stress, dehydration, headache, worsening of respiratory disease and cardio vascular disease. Moreover, dense land use patterns influence air quality and air flow. Narrow lanes and closely packed buildings restrict wind speed, trapping more heat and pollutants within the area. This can intensify discomfort and increase the chances of heat related illnesses.

2. Study Area

Delhi, capital territory of India, is located in the northern part of the country and lies between latitudes 28.4°N and 28.9°N and longitudes 76.7°E and 77.3°E. Geographically, it is situated on the western bank of the Yamuna River, which plays a crucial role in its hydrology and agriculture. Delhi is spread across approximately 1484 square kilometres. The terrain of Delhi is a mix of flat plains and low hills of the Aravalli range, especially in the southern parts. The natural green cover includes deciduous forests, but urban expansion has led to a significant reduction in green cover. Environmental challenges like air pollution, groundwater depletion, and waste management are growing concerns in Delhi's geographical landscape, making sustainable development and planning a critical need for the future.

Narrow lanes, sparse vegetation, very closely built houses, heavy traffic and constant human activities trap heat well into the night. As a result, residents living in congested places experience harsher thermal conditions. High density population areas such as central Delhi, Old Delhi, congested settlements areas create extreme challenges. People living in these areas often lack vegetation, ventilated housing and adequate cooling options. This makes them more vulnerable to heat related stress, dehydration, sleep disturbances and other health risks.

Delhi's land use shows combination of commercial districts, residential hubs, industrial zones, institutional campuses and green belts like the ridge forest but these are unevenly distributed. Residents who rely on outdoor work like street vendors, auto drivers, etc faces the brunt of this heat exposure daily.

The study areas for this research is Chandni Chowk as this area comes in high density zone:

Table 1.1 Parameters of study area.

Parameters	Chandni Chowk
Density	Very High
Vegetation	Sparse
Built up	Very high
Traffic	Congested
Comfort Level	Uncomfortable
UHI	High

Chandni Chowk is one of the oldest and most densely populated area which is known for its narrow lanes, traditional markets, packed buildings and very limited green cover. Chandni Chowk area is marked by continuous built up structures, lack of ventilation and heavy vehicular movement creates condition where heat gets trapped and retained throughout the day. The high concentration of anthropogenic heat from traffic, shops, small industries and human activities further enhances global warming. As a result Chandni Chowk records high surface temperature and air temperature making it one of the Delhi's prominent Urban Heat Island hotspot.

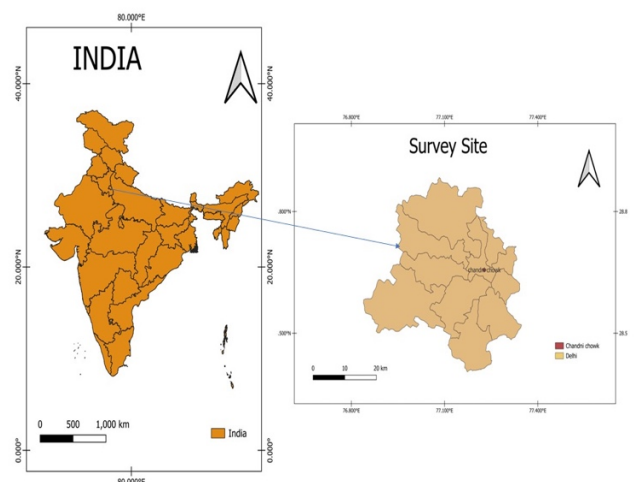


Figure 1. Survey site map.

3. Research Methodology

This study integrates both geospatial analysis and field based primary data to ensure a comprehensive and reliable assessment. The quantitative approach helped in measuring the actual intensity of UHI and its effect on temperature, land use classification, statistical interpretation of survey data.

The study uses geospatial and statistical tools like QGIS for mapping and spatial analysis. Spreadsheet tools like MS Excel was used for data tabulation. Maps of Land use and Land Cover, Land surface temperature, Normalized Difference built up Index, Normalized Difference Vegetation Index were made in QGIS for years 2000 and 2025 of Central Delhi. In addition to the primary source of data we collected secondary data from various websites, articles, government reports, research papers.

4. SECONDARY ANALYSIS OF CENTRAL DELHI 2000-2025

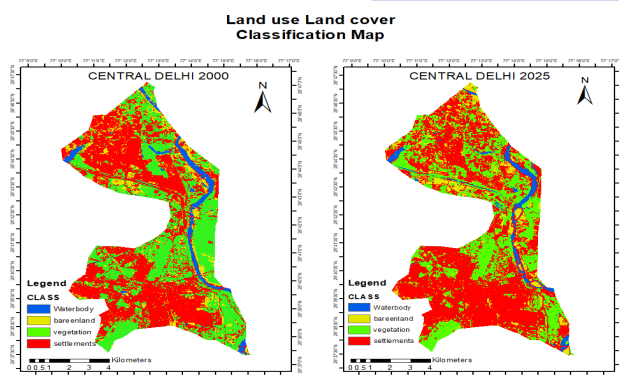


Figure 4.1 LULC (Land Use and Land Cover) map of 2000 and 2025 Central Delhi.

ANALYSIS:

LULC CLASSES	2000 (Area km ²)	2025 (Area km ²)	Change
Waterbody	1.5	1.25	-0.5
Bare land	3.5	2.25	-1.25
Vegetation	8.5	6.5	-2
Settlements	11.5	15	+3.5
Total	25	25	----

LULC CLASSES	2000 (%)	2025 (%)	Change (%)
Waterbody	6%	5%	-1%
Bare land	14%	9%	-5%
Vegetation	34%	26%	-8%
Settlements	46%	60%	+14%

Interpretation:

The Land Use Land Cover classification maps of Central Delhi for the years 2000 and 2025 (Figure 4.1) shows significant spatial changes in different land categories, namely water bodies (blue), barren land (yellow), vegetation (green), settlements (red). Total area of study area is 25 km², the most noticeable change is the increase in settlement area which reflects rapid urbanization and population growth in central Delhi. Vegetation has reduced significantly over time in 2000, green patches were more widespread and in 2025 vegetation appears fragmented and reduced in size due to urban expansion which negatively affect air quality, biodiversity and local climate regulation.

NORMALIZED DIFFERENCE VEGETATION INDEX:

The Normalized Difference Vegetation Index is one of the most widely used indicators in remote sensing to measure the presence of health and density of vegetation using satellite imagery. Healthy plants reflect more near infrared rays (NIR) light.

USES OF NDVI:

NDVI used to check whether plants are healthy or dry, farmers use NDVI to monitor crop growth, low NDVI indicates dry condition, it helps in identifying dense forest and deforestation, used for land degradation. In Landsat 8 it is calculated as:

$$\text{NDVI} = \frac{(\text{Band 5} - \text{Band 4})}{(\text{Band 5} + \text{Band 4})}$$

The result always comes between -1 and 1.

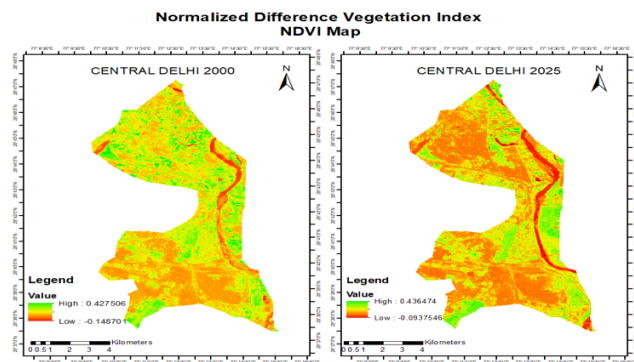


Figure 4.2 NDVI (Normalized Difference Vegetation Index) map of 2000 and 2025 of Central Delhi.

ANALYSIS:

NDVI CLASS	2000 (Area km ²)	2025 (Area km ²)	Change
Built up (<0.0)	2	2.75	+0.75
Sparse vegetation (0.0-0.2)	9	11.25	+2.25
Moderate vegetation (0.2- 0.4)	10.5	8.5	-2
Dense vegetation (>0.4)	3.5	2.5	-1
TOTAL	25	25	=====

NDVI CLASS	2000 (%)	2025 (%)	Change (%)
<0.0	8%	11%	+3%
0.0-0.2	36%	45%	+9%
0.2-0.4	42%	34%	-8%
>0.4	14%	10%	-4%

Interpretation:

The Normalized Difference Vegetation Index maps (figure 4.2) show the spatial distribution of vegetation cover in central Delhi

for the years 2000 and 2025. NDVI values range from low (red/orange) means sparse or no vegetation to high (green) which means dense vegetation. In 2000, the map shows a moderate presence of vegetation, with several green patches distributed across area. By 2025, there is a visible decline in green areas with more shifting towards yellow, orange, red tones which indicates a reduction in vegetation cover over time.

NORMALIZED DIFFERENCE BUILT UP INDEX:

Normalized Difference Built Up Index is a remote sensing used to identify and show built up areas such as buildings, roads, concrete

surfaces, urban settlements. It helps to distinguish urban areas from vegetation and water bodies using satellite imagery.

It helps to identify cities, buildings, roads and settlements, it used to compare urban growth over different years, it used to separate built up areas from vegetation and water, helps planners to understand urban sprawl and land development. In Landsat 8 it is calculated as:

$$\text{NDBI} = (\text{Band 6} - \text{Band 5}) / (\text{Band 6} + \text{Band 5})$$

NDBI values also range between -1 and 1.

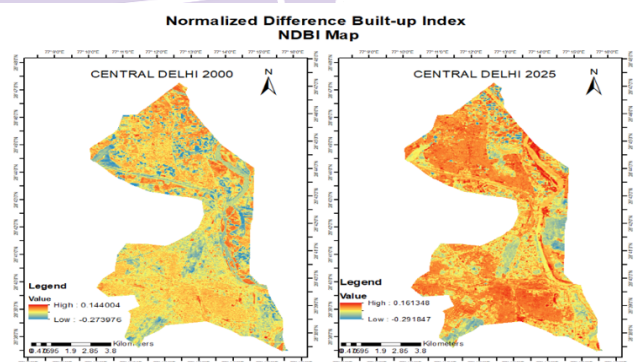


Figure 4.3 NDBI (Normalized Difference Built-Up Index) map of 2000 and 2025 of Central Delhi.

ANALYSIS:

NDBI CLASS	2000 (Area km ²)	2025 (Area km ²)	CHANGE
Waterbody/vegetation (<-0.1)	7.5	5	-2.5
Open land (-0.1-0.0)	9.5	7.5	-2
Moderate built up (0.0-0.1)	5.5	8	+2.5
Dense built up (>0.1)	2.5	4.5	+2
TOTAL	25	25	----

NDBI CLASS	2000 (%)	2025 (%)	CHANGE (%)
<-0.1	30%	20%	-10%
-0.1-0.0	38%	30%	-8%
0.0-0.1	22%	32%	+10%
>0.1	10%	18%	18%

Interpretation:

The NDBI maps (figure 4.3) represent the spatial distribution of built-up areas, where higher values (orange-red) indicate dense built-up area and lower values (blue-green) indicate vegetation, water or open spaces. In 2000, most of the region shows moderate NDBI values (yellow shades) and in 2025, there is a significant increase in high NDBI value (orange and red zones) which reflects vertical and horizontal urban development including commercial expansion, infrastructure growth and increased population pressure and decline in natural land cover in Central Delhi.

URBAN HEAT ISLAND:

Urban Heat Island is a phenomenon in which urban areas become hotter than surrounding rural areas. This happens because cities have more concrete surfaces, roads, vehicles, industries, buildings and less vegetation and water bodies.

These surfaces absorb and store heat during the day and release it slowly at night making cities warmer. It occurs due to loss of vegetation because they provide cooling through shade and evapotranspiration, more use of concrete and asphalt, less water bodies. Effects of UHI are increased temperature, air pollution, reduced air quality, causes heat stress, dehydration, respiratory issues, headache, increased electricity use, more air conditioner use, higher cooling costs.

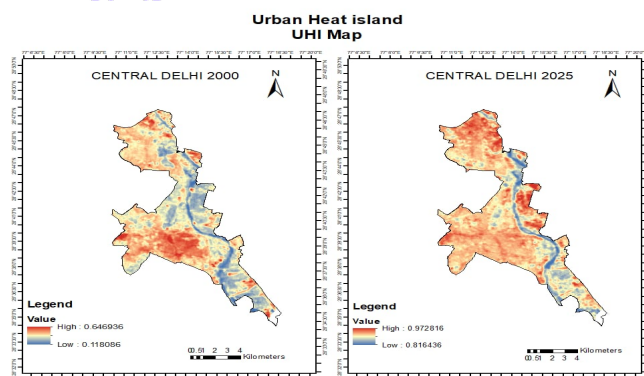


Figure 4.4 Urban Heat Island map of 2000 and 2025 of Central Delhi.

ANALYSIS:

UHI CLASS	2000 (Area km ²)	2025 (Area km ²)	CHANGE
Low UHI	8.75	5	-3.75
Moderate UHI	11.25	10	-1.25
High UHI	5	10	+5
TOTAL	25	25	----

UHI CLASS	2000 (%)	2025 (%)	CHANGE (%)
Low UHI	35%	20%	-15%
Moderate UHI	45%	40%	-5%

High UHI	20%	40%	+20%
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Interpretation:

The Urban Heat Island map of 2000 (figure 4.4) shows relatively moderate UHI intensity, with heat concentrated in scattered pockets particularly in central and southwestern parts. Cooler zones (represented in blue) are more visible and continuous especially along linear features, likely corresponding to vegetation cover water bodies such as the Yamuna river. This indicates that natural elements were still playing a role in regulating surface temperature. By 2025, there is a marked expansion of high temperature zones (red areas), indicating a stronger and more widespread UHI effect. In contrast, cooler areas have become more fragmented and reduced in size.

5. Findings

LAND USE AND LAND COVER ANALYSIS (2000-2025)

The analysis of LULC patterns on Central Delhi over the past 25 years reveals that there has been a substantial decline in vegetation cover due to increasing commercial expansion and infrastructure development and urbanization. Built up area has increased sharply indicating high urban density and congestion. Open spaces have decreased leading to reduced natural cooling mechanisms such as evapotranspiration. The replacement of traditional structures with concrete buildings has intensified heat absorption and retention. These changes have directly contributed to the intensification of the urban heat island effect in the study area.

INCREASE IN SURFACE TEMPERATURE AND UHI INTENSITY

Satellite derived temperature analysis shows a consistent rise in land surface temperature in Central Delhi from 2000 to 2025. Nighttime temperature remain significantly increased indicating heat retention due to dense built up and lack of ventilation. The narrow roads, high building density and

anthropogenic heat sources further increases local temperatures.

6. Conclusion

The study clearly establishes that Chandni Chowk, Central Delhi experiences a high Urban Heat Island effect due to rapid urbanization, dense built up structures and loss of green cover. The land use and land cover analysis (2000-2025) reveals a increase in built up areas accompanied by a decline in vegetation cover. The increase in land surface temperature over time has significantly impacted the health and well being of local residents. The replacement of natural surfaces with concrete structures, high building density, narrow streets and anthropogenic activities have collectively aggravated the thermal environment.

Suggestions and Recommendations:

URBAN PLANNING AND INFRASTRUCTURE MEASURES:

- Increase urban green space- Plantation of trees along roads, rooftops and public spaces. Development of parks in congested areas.
- Promotion of green roofs and vertical gardens- Encouraging buildings owners to adopt rooftops gardening.
- Use of reflective and cool roofing materials- Adoption of high albedo materials to reduce heat absorption.
- Improvement of urban ventilation- Planning building layouts to allow airflow. Reducing excessive construction activity for future developments.

POLICY AND GOVERNANCE MEASURES:

- Implementation of a Heat Action Plan specifically for areas with high UHI effect.
- Integration of UHI mitigation strategies into urban development policies.

- Enforcement of environmental regulations to control unplanned urban expansion.
- Regular monitoring of land surface temperature using remote sensing.

COMMUNITY BASED ADAPTATION STRATEGIES

- Encouraging community participation in tree plantation drives.
- Providing subsidies for cooling appliances to low income household.
- Promoting traditional cooling practices such as use of shaded spaces, water sprinkling in courtyards.

SUSTAINABLE TRANSPORT AND POLLUTION CONTROL

- Reducing vehicular emissions through promotion of public transport, pedestrian friendly infrastructure.
- Limiting congestion in Chandni Chowk to reduce anthropogenic heat.

LITERATURE REVIEW

Islam et al. (2004) explained that the rise in Urban Heat Island (UHI) is due to the rapid growth of cities, industrialization, increasing population. The world is experiencing rapid urbanization, characterized by both horizontal and vertical expansion to accommodate the needs of the rising population. The increase in Urban Heat Island not only raises temperatures but also places stress on urban ecosystems, resulting in soil dehydration and water scarcity which in return impact human health.

Singh et al. (2016) examined that urbanization poses great threat in the urban surrounding. On one hand, urbanization leads to development, but on other side as the population increases, the land use patterns changes, pollution increases. It is found that the urban environment of Delhi has undergone

rapid shift. The health hazard in Delhi and its impact is high and needs urgent attention.

Yadav et al. (2018) analyzed the differences of temperatures in intra city and Urban Heat Island (UHI) effect in Delhi, by analyzing meteorological data that was collected during the monsoon and winter months. This pattern of Urban Heat Island showed higher impact during the nighttime period as compared to morning and noon periods.

Kumari et al. (2021) analyzed the impact of Urban Heat Island on electricity consumption in Delhi. By analyzing Land Surface Temperature and energy use patterns in Delhi, the study finds out how higher temperatures in urban areas are strongly linked with increased electricity demand as compared to rural areas. This research shows that 1.4% of energy consumption is increased in Delhi between 2012 and 2017.

Khare et al. (2021) analyzed that Urban Heat Island is a characteristic of Urban Climate change and is mainly caused by the substitution of natural cover with heat emitting materials like concrete. Such surface retain solar radiation, contributing to higher land surface temperatures, higher energy use and more greenhouse gas emission. Researchers recognized a number of mitigation measures such as green roofs, urban vegetation, reflective pavements, etc .

Dutta et al. (2019) examined that past two decades have witnessed expansions of cities in developing nations like India. In an effort to determine the pattern of urban growth in and around Delhi, the research endeavors to evaluate the land transformation process utilizing multi temporal Landsat datasets. Increased trend seen in the summer temperature data collected from IMD reflects the increase of mean summer temperature in recent decades. Land change coupled with high urbanization growth particularly in Delhi NCTs areas contributed significantly to the rising trend of surface temperature.

Pandey et al. (2019) analyzed the thermal mapping of Delhi with the use of satellite data for the months of November and December. Their research reveals the formation of “cool island” in central part of Delhi which is found to be cooler than the surrounding peri urban areas but during night time it was found that central part of Delhi is much warmer than the surrounding rural areas which shows the formation of urban heat island over Delhi. This study suggests that urban areas have more temperatures than rural areas and Delhi had much higher aerosol level.

Sharma et al (2019) observed that heat waves have become more common and dangerous these days. Now it affects larger area of the planet than before, causing serious health problems like dehydration and heat exhaustion which also reduces people ability to do work. Their study on Delhi highlights how Urban Heat Island can intensify the number of heat wave days. They laid stress on better planning, adaption if heat action plan, improved urban design and early warning system so that government can protect residents more effectively.

Mitchell et al (2021) focused on climate change and urbanization and their risk in global south megacities. Their research on Delhi highlights how increase in temperature and high use of cooling resources create burden for society. They used satellite based data which shows variation of heat in same city because some areas lack green spaces, this uneven distribution linked to socio-economic differences in same city. They calculated NDVI and find out that vulnerable communities are at great risk of heat exposure.

Kapuganti et al (2025) analyzed that how changes in land use shape local temperatures and contribute to Urban Heat Island. Their work also highlights that areas with dense construction, industrial activity, less green cover are much hotter than places with vegetation or water bodies. Their research examines land use has changed over the past two decades and how it affects the land surface temperature in Delhi. They analyze warming

patterns and their links with built up areas. They analyzed that heat levels in north Delhi are going to be rise in future.

Jamal et al (2025) observed that heat has grown rapidly in recent years around the world with increase in temperature and expanding built up index. Their work highlights that indoor heat exposure can be dangerous as outdoor heat especially in densely populated areas. Unlike data collected from satellite this work was done by placing sensors directly at people’s homes, giving a much clearer picture of heat.

Shohan et al (2024) analyzed that rapid urban expansion can dramatically alter local climates and natural land is replaced with concrete, buildings, paved surface and then temperature began to rise. This trend has been linked to variety of urban problems, increased energy use, health problems. As the urbanization increased land surface also increased with same trend, their work shows land use designs such as preserving green areas, reducing fragmentation for future generation. They understand how cities evolve and how microclimates affect local people.

Mohan et al (2023) analyzed that the term Urban Heat Island has grown quickly over the past few decades in big cities around the world because of less vegetation cover, more pollution, rapid construction, rise in energy use, etc. They used methods such as collecting data from satellites, also pointed out that having a nearby rural weather station is useful for comparing urban and rural temperatures. Their studies have recommended steps such as increasing vegetation, using reflective building materials, and improving city planning to reduce the heat island effect.

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