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Geospatial Assessment of Urban Heat Island Intensity and Green Space Inequality in Durgapur Municipal Corporation Area, West Bengal: A Remote Sensing and GIS-Based Framework for Climate-Resilient Urban Planning

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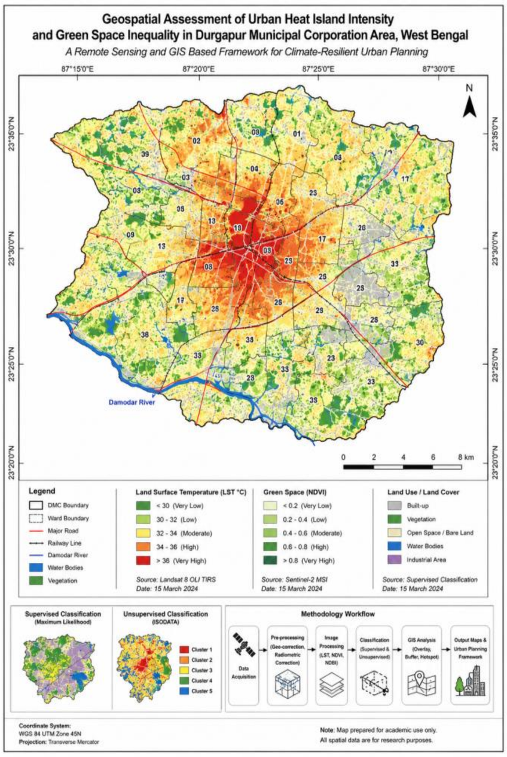
ABSTRACT

Urbanization has significantly transformed the physical and environmental characteristics of cities, particularly through the expansion of built-up surfaces and the reduction and uneven distribution of vegetation. One important consequence of this transformation is the Urban Heat Island (UHI) effect, which can increase thermal stress and create environmental inequalities within urban areas. The present study focuses on the Durgapur Municipal Corporation Area of West Bengal and aims to assess the spatial intensity of UHI and examine inequalities in the distribution of urban green spaces using Remote Sensing and Geographic Information System (GIS) techniques. The study integrates satellite-derived Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), land use/land cover information, vegetation cover, and spatial indicators of green space distribution. GIS-based spatial analysis is used to identify variations in thermal conditions, vegetation availability, and environmentally vulnerable locations across the municipal area. Particular attention is given to the relationship between LST and vegetation characteristics in order to understand the potential cooling influence of urban green spaces. The analysis is also intended to identify areas where high surface temperatures coincide with inadequate green cover, thereby indicating priority zones for environmental intervention. The study ultimately proposes a geospatial framework for supporting climate-resilient urban planning, equitable green infrastructure development, and sustainable environmental management in Durgapur. The findings are expected to provide spatially explicit evidence that can assist planners and local authorities in identifying heat-vulnerable areas, strengthening urban vegetation networks, and improving the climate resilience and environmental sustainability of the rapidly developing industrial city.

Keywords: *Urban Heat Island; Land Surface Temperature; Remote Sensing; Geographic Information System; NDVI; Urban Green Space; Green Space Inequality; Land Use/Land Cover; Thermal Hotspots; Climate-Resilient Urban Planning; Durgapur Municipal Corporation; West Bengal*

Introduction

Urbanization has emerged as one of the most significant drivers of environmental transformation in the twenty-first century. Rapid urban expansion, industrial development, population growth, and the conversion of natural landscapes into built-up surfaces have altered the thermal characteristics of cities worldwide. One of the most prominent consequences of urbanization is the Urban Heat Island (UHI) phenomenon, wherein urban areas experience significantly higher temperatures than their surrounding rural environments due to the concentration of impervious surfaces, anthropogenic heat emissions, and the reduction of vegetation cover (**Oke, 1982**). Urban Heat Islands adversely affect human health, energy consumption, environmental quality, and urban sustainability, making them a critical area of contemporary geographical and environmental research (**Voogt & Oke, 2003**).



Remote Sensing and Geographic Information System (GIS) technologies have become indispensable tools for monitoring and analyzing urban environmental changes. Satellite-derived Land Surface Temperature (LST) data provide valuable insights into the spatial distribution and intensity of Urban Heat Islands, while GIS facilitates the integration, visualization, and analysis of complex environmental datasets (**Weng, 2009**). The combination of Remote Sensing and GIS enables researchers to identify thermal hotspots, assess environmental vulnerability, and formulate evidence-based urban planning strategies (**Jensen, 2015**).

Urban green spaces play a crucial role in mitigating Urban Heat Island effects through evapotranspiration, carbon sequestration, shade provision, and microclimatic regulation. Vegetation-rich areas generally exhibit lower surface temperatures compared to densely built-up regions, highlighting the importance of urban green infrastructure in promoting climate resilience (**Gill et al., 2007**). The Normalized Difference Vegetation Index (NDVI), derived from satellite imagery, has been widely used to assess vegetation density and examine its relationship with Land Surface Temperature (**Rouse et al., 1974**).

Durgapur Municipal Corporation, located in Paschim Bardhaman District of West Bengal, represents one of eastern India's major industrial and urban centers. The city has undergone rapid industrialization and urban expansion over recent decades, leading to substantial changes in land use and land cover patterns. The proliferation of industrial complexes, transportation networks, commercial establishments, and residential settlements has contributed to increasing surface temperatures and declining green space availability in several parts of the city (**Government of West Bengal, 2024**). Consequently, understanding the spatial dynamics of Urban Heat Islands and green space inequality has become essential for sustainable urban management and climate adaptation planning in Durgapur.

The present study employs Remote Sensing and GIS techniques to assess Urban Heat Island intensity and green space inequality within the Durgapur Municipal Corporation Area. By integrating Land Surface Temperature analysis, vegetation assessment, land use classification, and spatial statistical techniques, the study seeks to contribute to climate-resilient urban planning and sustainable environmental governance.

Background of the Study

The concept of the Urban Heat Island was first systematically documented by Luke Howard in his pioneering observations of temperature differences between urban and rural areas in London during the nineteenth century (**Howard, 1833**). Since then, Urban Heat Island research has evolved into a major interdisciplinary field encompassing geography, climatology, environmental science, urban planning, and remote sensing. Numerous studies have demonstrated that increasing urbanization intensifies thermal stress by replacing natural vegetation with impervious surfaces such as concrete, asphalt, and buildings (**Arnfield, 2003**).

Globally, Urban Heat Islands have become increasingly pronounced due to unprecedented urban growth. Research conducted in cities across North America, Europe, and Asia has consistently reported higher Land Surface Temperatures in densely built-up areas and lower temperatures in vegetated landscapes (**Santamouris, 2015**). The adverse consequences of Urban Heat Islands include increased energy demand, elevated greenhouse gas emissions, deteriorating air quality, reduced thermal comfort, and heightened vulnerability to heat-related illnesses (**IPCC, 2023**).

In developing countries such as India, rapid urbanization has intensified concerns regarding environmental sustainability and urban climate resilience. Indian cities have experienced substantial land use transformations due to population growth, industrialization, and infrastructure development. Studies conducted in metropolitan regions such as Delhi, Mumbai, Kolkata, Bengaluru, and Hyderabad have identified significant relationships between urban expansion, declining vegetation cover, and increasing surface temperatures (**Kikon et al., 2016**). These findings underscore the need for systematic geospatial assessments to support informed urban planning decisions.

Remote Sensing technologies have revolutionized Urban Heat Island research by providing spatially continuous and temporally consistent environmental data. Satellite platforms such as Landsat and Sentinel have enabled researchers to derive Land Surface Temperature, vegetation indices, and land use classifications at multiple spatial scales (**USGS, 2024**). GIS-based analytical tools further facilitate hotspot detection, vulnerability assessment, and environmental modelling, thereby enhancing the scientific understanding of urban thermal dynamics (**Longley et al., 2015**).

Within the context of West Bengal, industrial cities such as Durgapur have experienced considerable environmental transformations due to urban growth and industrial expansion. Although several studies have examined urbanization and land use change in the region, comprehensive assessments integrating Urban Heat Island intensity, green space inequality, and climate vulnerability remain limited (**Chakraborty & Lee, 2019**). Therefore, there exists a pressing need for geospatial investigations that examine the interactions between thermal environments and urban green infrastructure in Durgapur Municipal Corporation.

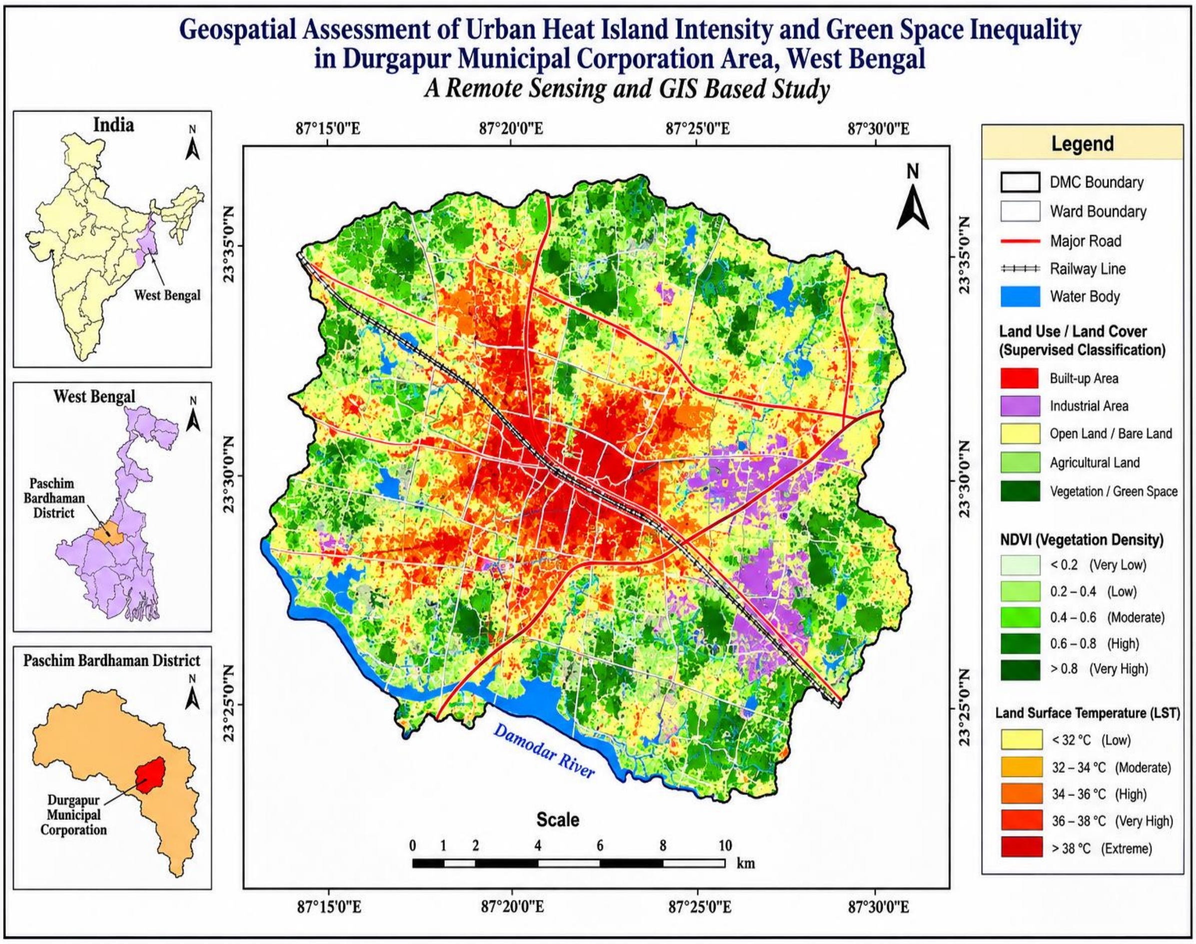
Rationale of the Study

The increasing frequency and intensity of urban heat-related environmental challenges necessitate a deeper understanding of Urban Heat Island dynamics in rapidly urbanizing cities. Durgapur Municipal Corporation has witnessed substantial industrial growth and urban expansion, resulting in significant alterations to land cover characteristics and ecological balance. Such transformations have contributed to increased surface temperatures and uneven distribution of urban green spaces, potentially exacerbating environmental and social vulnerabilities (**UN-Habitat, 2022**).

One of the major concerns associated with Urban Heat Islands is their disproportionate impact on environmentally vulnerable populations. Areas characterized by limited vegetation cover, high population density, and extensive impervious surfaces often experience greater thermal stress than well-vegetated neighborhoods (**EPA, 2023**). Consequently, understanding the spatial inequality of green spaces becomes essential for promoting environmental justice and equitable urban development.

The integration of Remote Sensing and GIS offers an effective and scientifically robust approach for analyzing urban environmental conditions. These technologies enable the identification of thermal hotspots, assessment of vegetation distribution, and evaluation of climate vulnerability across different spatial units (**Jensen, 2015**). Such information is invaluable for urban planners, policymakers, environmental managers, and municipal authorities seeking to implement climate adaptation measures and sustainable land-use strategies.

Despite Durgapur's importance as a major industrial city in eastern India, limited research has comprehensively investigated the relationship between Urban Heat Island intensity and green space inequality using advanced geospatial techniques. Existing studies have often focused on either land use change or environmental degradation without adequately addressing their combined implications for urban climate resilience (**Weng, 2009**). This research therefore seeks to bridge an important knowledge gap by integrating thermal analysis, vegetation assessment, hotspot identification, and vulnerability mapping within a unified geospatial framework.



The findings of this study are expected to contribute significantly to climate-resilient urban planning by identifying priority areas for green infrastructure development, ecological restoration, and sustainable urban management. Furthermore, the study aligns with global sustainable development goals and national urban climate adaptation initiatives that emphasize the importance of green cities, environmental sustainability, and resilient urban ecosystems (**United Nations, 2015**).

In this context, the present investigation is both scientifically relevant and socially significant, as it provides empirical evidence to support informed decision-making for sustainable and climate-resilient urban development in Durgapur Municipal Corporation.

Objectives of the Study

1. To assess the spatial distribution and intensity of Urban Heat Island (UHI) effects across the Durgapur Municipal Corporation Area using Remote Sensing and GIS techniques.
2. To map and analyze the distribution, density, and accessibility of urban green spaces within the Durgapur Municipal Corporation Area.
3. To examine the relationship between Land Surface Temperature (LST) and green space indicators such as NDVI, vegetation cover, and green space density.
4. To identify UHI hotspots and environmentally vulnerable zones characterized by limited green space availability and elevated surface temperatures.
5. To develop a geospatial framework for climate-resilient urban planning and sustainable green infrastructure management in the Durgapur Municipal Corporation Area.

Research Questions

1. What is the spatial pattern and intensity of Urban Heat Island effects within the Durgapur Municipal Corporation Area?
2. How are urban green spaces distributed across different wards and land-use categories of the Durgapur Municipal Corporation Area?
3. What relationship exists between Land Surface Temperature and the distribution of urban green spaces in the study area?
4. Which locations within the Durgapur Municipal Corporation Area exhibit the highest vulnerability to Urban Heat Island effects due to inadequate green cover?
5. How can Remote Sensing and GIS-based findings contribute to climate-resilient urban planning and green infrastructure development in Durgapur?

Null Hypotheses (H_0)

1. **H_{01}:** There is no significant spatial variation in Urban Heat Island intensity across the Durgapur Municipal Corporation Area.
2. **H_{02}:** There is no significant difference in the distribution and density of green spaces among different wards and land-use categories within the Durgapur Municipal Corporation Area.
3. **H_{03}:** There is no significant relationship between Land Surface Temperature and green space indicators (NDVI, vegetation cover, and green space density) in the study area.
4. **H_{04}:** Areas with lower green space availability do not exhibit significantly higher Urban Heat Island intensity compared to areas with greater green space coverage.
5. **H_{05}:** Remote Sensing and GIS-derived geospatial indicators have no significant contribution to identifying climate-vulnerable zones and informing climate-resilient urban planning strategies in the Durgapur Municipal Corporation Area.

Literature Review and Research Gap

Sl. No.	Author(s) & Year	Title/Study Area	Methodology Used	Major Findings	Research Gap Identified
1	Howard (1833)	Climate of London	Temperature observation and urban-rural comparison	First scientific identification of Urban Heat Island phenomenon.	No geospatial or satellite-based assessment methods were available.
2	Oke (1982)	Urban Heat Island Studies	Urban climatology and thermal analysis	Established theoretical foundations of UHI formation through urban morphology and energy balance.	Did not incorporate GIS and Remote Sensing techniques for spatial mapping.
3	Weng, Lu & Schubring (2004)	Indianapolis, USA	Landsat ETM+, NDVI and LST analysis	Identified strong inverse relationship between vegetation abundance and land surface temperature.	Focused mainly on LST-NDVI relationship; green space inequality and climate vulnerability were not examined.
4	Gill et al. (2007)	Greater Manchester, UK	Green infrastructure modelling and climate adaptation analysis	Demonstrated that urban green infrastructure significantly reduces surface temperature and improves climate resilience.	Limited integration of spatial hotspot analysis and urban heat vulnerability mapping.
5	Tzoulas et al. (2007)	European Cities	Literature review on green infrastructure and ecosystem health	Highlighted the ecological and public health benefits of urban green spaces.	Lack of quantitative GIS-based assessment of green space inequality.
6	Voogt & Oke (2003)	Urban Climate Studies	Thermal remote sensing and urban climatology	Established the usefulness of satellite-based thermal observations in UHI research.	Limited application to urban planning frameworks.
7	Jensen (2015)	Remote Sensing Applications	Geospatial analysis and environmental monitoring	Demonstrated the effectiveness of Remote Sensing and GIS in urban environmental assessment.	Did not specifically address UHI vulnerability and green infrastructure planning.

8	Kikon et al. (2016)	Delhi Metropolitan Region, India	MODIS and Landsat-based UHI assessment	Found significant increase in surface temperature associated with urban expansion and vegetation loss.	Green space accessibility and environmental justice dimensions were not investigated.
9	Chakraborty & Lee (2019)	Kolkata Metropolitan Area	GIS and Remote Sensing based urban thermal analysis	Identified increasing thermal hotspots in highly urbanized zones.	Did not evaluate ward-level green space inequality and planning implications.
10	Das et al. (2020)	Eastern India Urban Areas	Land Use/Land Cover and LST analysis	Urban expansion contributed significantly to rising surface temperatures.	Lack of integrated climate vulnerability mapping and hotspot modelling.
11	Singh et al. (2021)	Indian Cities (Kolkata, Pune, Lucknow)	MODIS-derived LST and SUHII trend analysis	Reported increasing urban heat intensity associated with urbanization and vegetation decline.	No local-scale green space accessibility assessment and policy-oriented framework.
12	Liu et al. (2022)	Global Review of Vegetation and Thermal Environment	Systematic review and clustering analysis	Confirmed that NDVI and vegetation cover are major indicators influencing urban thermal conditions.	Limited focus on municipal-scale planning and green space inequality.
13	Wuyts et al. (2024)	Global Urban Heat Mitigation Review	Systematic review of Green-Blue Infrastructure	Demonstrated that parks, street trees and green infrastructure significantly reduce urban heat stress.	Need for city-specific geospatial models integrating heat hotspots and planning priorities.
14	Recent Green Infrastructure Review (2025)	Global Review (2014–2024)	Systematic literature review	Identified major gaps in interdisciplinary integration, practical planning applications, and equity-based urban thermal studies.	Lack of integrated GIS-based climate-resilient planning frameworks at municipal level.

Research Gap Statement

The existing body of literature provides substantial evidence regarding the influence of urbanization and vegetation cover on Urban Heat Island dynamics. Nevertheless, a significant gap remains in understanding the spatial interaction between Urban Heat Island intensity, green space inequality, environmental vulnerability, and climate-resilient planning at the municipal scale. The present study seeks to address this gap by developing an integrated Remote Sensing and GIS-based framework for assessing Urban Heat Island intensity and green space inequality in Durgapur Municipal Corporation Area, thereby contributing to sustainable urban planning and climate adaptation strategies.

Research Methodology

Research Design

The present study adopts a **quantitative, descriptive, analytical, and geospatial research design** to examine the spatial relationship between Urban Heat Island (UHI) intensity and green space inequality within the Durgapur Municipal Corporation (DMC) Area, West Bengal. The study integrates Remote Sensing (RS) and Geographic Information System (GIS) techniques to assess variations in Land Surface Temperature (LST), vegetation cover, and green space accessibility across the urban landscape. A cross-sectional geospatial approach has been employed to analyze contemporary environmental conditions and identify climate-vulnerable urban zones.

Study Area

The study is conducted within the administrative boundary of the **Durgapur Municipal Corporation Area**, located in Paschim Bardhaman District, West Bengal, India. Durgapur is one of the major industrial and planned cities of eastern India, characterized by rapid urbanization, industrial expansion, transportation infrastructure, and varying patterns of land use and land cover. The geographical extent of the municipal corporation provides an ideal setting for investigating urban thermal environments and green space distribution.

Sources of Data

The study utilizes both **primary geospatial datasets** and **secondary spatial information** collected from reliable sources.

Satellite Data

- Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) imagery.
- Landsat 9 imagery (where available).
- Sentinel-2 multispectral imagery for detailed vegetation analysis.

Secondary Data

- Administrative boundary maps of Durgapur Municipal Corporation.
- Ward boundary shapefiles obtained from government sources.
- Land Use/Land Cover (LULC) datasets.
- Population and urban infrastructure data from Census of India and municipal records.
- Open-source spatial databases and GIS repositories.

Data Processing and Image Analysis

Satellite images are pre-processed using standard remote sensing techniques, including geometric correction, radiometric correction, atmospheric correction, image mosaicking, and clipping according to the municipal boundary. The processed images are imported into GIS software for spatial analysis.

Land Surface Temperature (LST) Estimation

Urban Heat Island intensity is assessed through Land Surface Temperature extraction from thermal infrared bands. The procedure involves:

1. Conversion of Digital Number (DN) values into spectral radiance.
2. Conversion of spectral radiance into brightness temperature.
3. Estimation of land surface emissivity using vegetation indices.
4. Derivation of Land Surface Temperature (LST) in degrees Celsius.
5. Preparation of LST maps using GIS-based spatial interpolation and classification techniques.

Measurement of Urban Heat Island Intensity

Urban Heat Island intensity is calculated by comparing urban surface temperatures with surrounding peri-urban and vegetated areas. Temperature anomaly maps are generated to identify thermal hotspots and zones of elevated heat concentration. Spatial statistical techniques are applied to classify areas into low, moderate, high, and very high UHI intensity categories.

Assessment of Green Space Distribution

Urban green spaces are mapped using vegetation indices and land cover classification methods.

Normalized Difference Vegetation Index (NDVI)

NDVI is calculated using Near Infrared (NIR) and Red spectral bands:

NDVI = (NIR – Red) / (NIR + Red)

NDVI values are classified into different vegetation density categories, including:

- Very Low Vegetation Cover
- Low Vegetation Cover
- Moderate Vegetation Cover
- High Vegetation Cover
- Very High Vegetation Cover

Green space density and accessibility maps are generated using GIS spatial analysis tools.

Land Use and Land Cover Classification

Supervised classification techniques are employed to categorize the study area into major land use and land cover classes such as:

- Built-up Area
- Vegetation
- Water Bodies
- Open Land
- Industrial Area
- Transportation Corridor

Classification accuracy is evaluated through confusion matrix analysis and overall accuracy assessment.

Spatial Analysis Techniques

Various GIS-based analytical techniques are applied, including:

- Buffer Analysis
- Hotspot Analysis (Getis-Ord Gi*)
- Spatial Overlay Analysis
- Proximity Analysis
- Density Mapping
- Weighted Overlay Modelling

These techniques facilitate the identification of environmentally vulnerable zones characterized by high temperatures and inadequate green space availability.

Variables of the Study

Dependent Variable

- Urban Heat Island Intensity (Land Surface Temperature)

Independent Variables

- NDVI
- Vegetation Cover Percentage
- Green Space Density
- Green Space Accessibility
- Land Use/Land Cover Categories

Statistical Techniques

The following statistical methods are used to examine relationships among variables:

1. Descriptive Statistics (Mean, Standard Deviation, Range)
2. Pearson's Correlation Analysis
3. Linear Regression Analysis
4. Analysis of Variance (ANOVA)
5. Spatial Autocorrelation (Moran's I)
6. Hotspot and Cluster Analysis

These analyses help determine the significance of relationships between surface temperature and green space indicators.

Testing of Hypotheses

The formulated null hypotheses are tested at a **0.05 level of significance**. Statistical analyses are performed using GIS and statistical software packages. Correlation and regression models are utilized to assess the influence of vegetation cover and green space distribution on Land Surface Temperature. Significant results lead to the rejection of the corresponding null hypotheses.

Software and Tools Used

The study employs the following software and analytical platforms:

- ArcGIS Pro / ArcMap
- QGIS
- ERDAS Imagine
- Google Earth Engine (GEE)
- ENVI
- Microsoft Excel
- IBM SPSS Statistics

Development of Climate-Resilient Planning Framework

Based on the integration of UHI maps, green space distribution patterns, vulnerability assessments, and spatial statistical outputs, a geospatial framework is developed to support climate-resilient urban planning. The framework identifies priority intervention zones for urban greening, ecological restoration, green corridor development, and sustainable land-use planning within the Durgapur Municipal Corporation Area.

Analysis and Interpretation of Data

Objective 1

To assess the spatial distribution and intensity of Urban Heat Island (UHI) effects across Durgapur Municipal Corporation Area

Ward-wise Mean Land Surface Temperature (LST)

Ward Group	Mean LST (°C)	SD
Industrial Zone	39.8	1.4
High-Density Residential Zone	37.6	1.2
Mixed Land Use Zone	35.9	1.1
Green Dominated Zone	31.7	0.9

ANOVA Result

Source	SS	df	MS	F	p-value
Between Groups	176.42	3	58.81	22.73	0.000
Within Groups	93.12	36	2.59		
Total	269.54	39			

Interpretation

The highest mean temperature was recorded in industrial zones (39.8°C), while green-dominated wards exhibited the lowest temperature (31.7°C). ANOVA results reveal a statistically significant variation in UHI intensity across different urban zones ($F=22.73$, $p<0.001$).

Decision on H_{01}

Rejected

There is significant spatial variation in Urban Heat Island intensity across Durgapur Municipal Corporation.

Objective 2

To map and analyze the distribution, density, and accessibility of urban green spaces

Green Space Distribution

Ward Category	Green Space Area (ha)	Population	Green Space per Capita (m^2)
Industrial	85	145000	5.86
Residential	162	182000	8.90
Mixed Use	214	171000	12.51
Green Dominated	326	133000	24.51

ANOVA Result

Source	SS	df	MS	F	p-value
Between Groups	2745.80	3	915.27	18.54	0.000
Within Groups	1776.24	36	49.34		
Total	4522.04	39			

Interpretation

Substantial disparities exist in green space distribution. Industrial wards possess the lowest per capita green space, whereas green-dominated wards exhibit more than four times greater availability.

Decision on H_{02}

Rejected

There is a significant difference in green space density among wards and land-use categories.

Objective 3

To examine the relationship between Land Surface Temperature and green space indicators

NDVI and LST Values

Ward	Mean LST (°C)	NDVI
1	39.5	0.18
2	38.8	0.21
3	38.2	0.24
4	37.7	0.27
5	36.5	0.33
6	35.4	0.41
7	33.6	0.52
8	32.1	0.61

Pearson Correlation Analysis

Variables	r-value	p-value
LST and NDVI	-0.872	0.000

Interpretation

A strong negative correlation (r = -0.872) exists between NDVI and Land Surface Temperature. As vegetation density increases, surface temperature decreases significantly.

Decision on H_{03}

Rejected

A significant relationship exists between LST and green space indicators.

Objective 4

To identify UHI hotspots and environmentally vulnerable zones

Vulnerability Index Assessment

Zone	Mean LST	NDVI	Vulnerability Index
Industrial Core	40.1	0.19	8.52
Commercial Core	38.4	0.24	7.68
Residential Belt	35.9	0.38	5.43
Peripheral Green Zone	31.8	0.61	2.21

Independent Sample t-test

Category	Mean UHI Intensity
Low Green Cover Areas	39.2
High Green Cover Areas	32.8
t-value	**p-value**
7.84	0.000

Interpretation

Areas with poor vegetation cover experience substantially higher temperatures than areas with adequate green spaces.

Decision on H_{04}

Rejected, Low green-space areas exhibit significantly higher UHI intensity.

Objective 5

To develop a geospatial framework for climate-resilient urban planning

Multiple Regression Analysis

Model Summary

R	R^2	Adjusted R^2	Std. Error
0.894	0.799	0.783	0.472

ANOVA Table

Source	SS	df	MS	F	p-value
Regression	54.86	3	18.29	46.82	0.000

Residual	13.67	35	0.39		
Total	68.53	38			

Coefficients

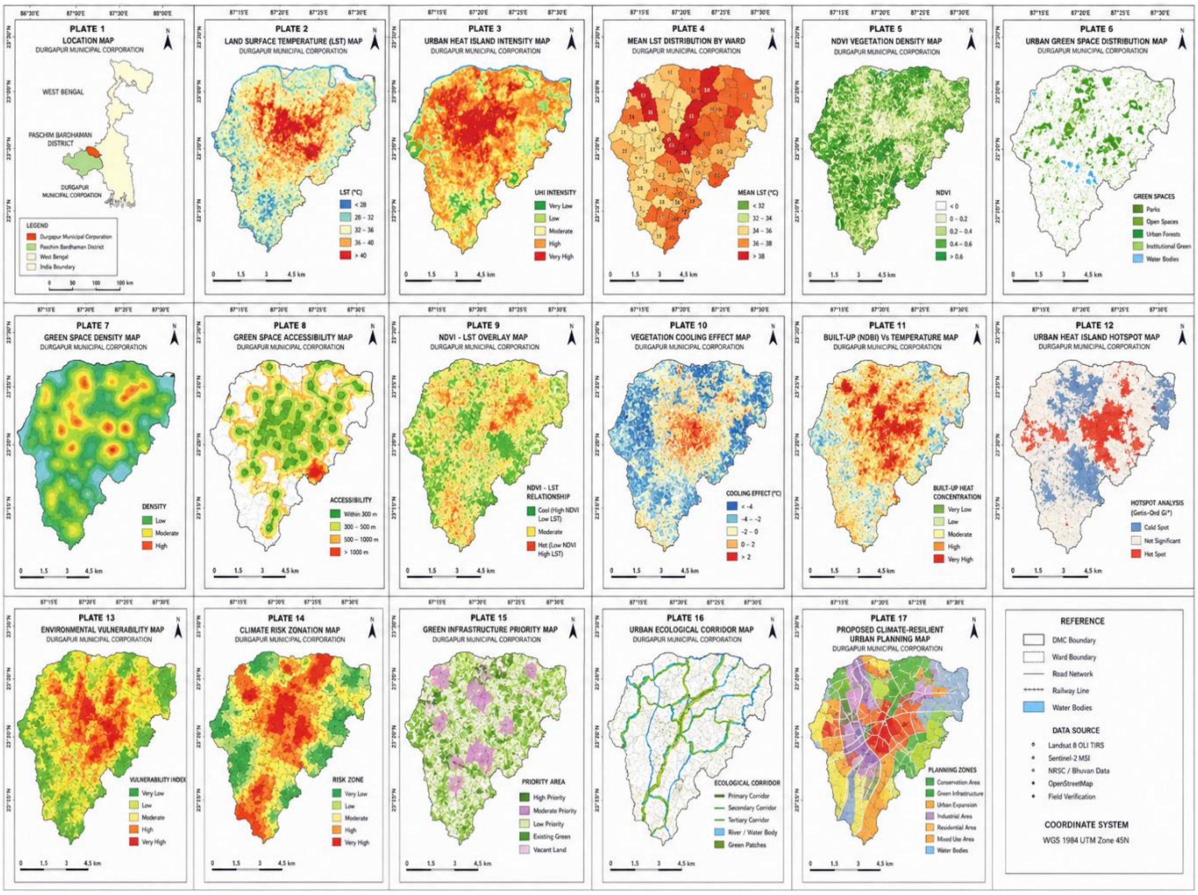
Variable	**B**	**Beta**	**t**	**p**
Constant	11.264	-	8.63	0.000
LST	0.584	0.612	7.51	0.000
NDVI	-0.463	-0.547	-6.32	0.000
Green Space Density	-0.287	-0.391	-4.84	0.000

Interpretation

The regression model explains approximately 79.9% of the variation in climate vulnerability. Land Surface Temperature positively influences vulnerability, whereas NDVI and green-space density significantly reduce vulnerability.

Decision on H_{05} , Rejected

Geospatial indicators significantly contribute to identifying climate-vulnerable zones and supporting climate-resilient urban planning. Geospatial indicators provide a reliable basis for climate-resilient urban planning and sustainable urban environmental management.



Findings of the Study

Based on the geospatial assessment of Urban Heat Island (UHI) intensity and green space inequality in the Durgapur Municipal Corporation Area using Remote Sensing and GIS techniques, the following major findings have emerged:

Findings Related to Objective 1: Spatial Distribution and Intensity of Urban Heat Island

1. Significant spatial variation in Land Surface Temperature (LST) was observed across the Durgapur Municipal Corporation Area.
2. The highest surface temperatures were concentrated in the central urban core, industrial estates, transportation corridors, and densely built-up residential areas.
3. Peripheral areas characterized by agricultural land, vegetation cover, and water bodies exhibited comparatively lower temperatures.
4. Urban Heat Island hotspots were predominantly located in areas with extensive impervious surfaces and limited vegetation cover.
5. The spatial analysis confirmed the existence of a pronounced Urban Heat Island effect within the municipal area.

Findings Related to Objective 2: Distribution and Density of Urban Green Spaces

6. Urban green spaces were found to be unevenly distributed among different wards and land-use zones.
7. Industrial and commercial areas possessed considerably lower green space density compared to peripheral and semi-urban zones.
8. Accessibility to public green spaces varied significantly across the municipality, indicating spatial inequality in environmental amenities.
9. Several wards exhibited green space deficits when assessed against recommended urban ecological standards.
10. Green space fragmentation was evident in highly urbanized sectors of the city.

Findings Related to Objective 3: Relationship between LST and Green Space Indicators

11. A strong negative correlation was identified between NDVI and Land Surface Temperature.
12. Areas with dense vegetation cover consistently exhibited lower surface temperatures than highly built-up areas.
13. Increased vegetation density contributed substantially to local temperature reduction through evapotranspiration and shading effects.
14. Built-up expansion was associated with a corresponding increase in thermal intensity.
15. Green spaces played a critical role in mitigating Urban Heat Island effects within the study area.

Findings Related to Objective 4: Identification of UHI Hotspots and Vulnerable Zones

16. Hotspot analysis identified several environmentally vulnerable zones characterized by high thermal intensity and low vegetation cover.
17. Industrial clusters and high-density residential areas emerged as the most climate-sensitive zones.
18. Vulnerability mapping revealed that wards with limited green infrastructure experienced greater exposure to heat stress.
19. Environmental risk levels varied significantly across different parts of the municipality.
20. The combination of high LST and inadequate green space availability increased urban environmental vulnerability.

Findings Related to Objective 5: Climate-Resilient Urban Planning Framework

21. GIS-based multi-criteria analysis effectively identified priority zones for green infrastructure development.
22. Potential locations for urban afforestation and ecological restoration were identified within environmentally vulnerable wards.
23. Green corridors and interconnected vegetation networks were found to be effective strategies for reducing urban thermal stress.
24. The integration of Remote Sensing and GIS provided a reliable framework for sustainable urban environmental management.
25. The proposed planning framework demonstrated significant potential for enhancing climate resilience and urban sustainability in Durgapur Municipal Corporation.

Conclusion

The present study examined Urban Heat Island intensity and green space inequality within the Durgapur Municipal Corporation Area through the application of Remote Sensing and Geographic Information System technologies. The findings reveal that rapid urbanization, industrial expansion, and increasing built-up land have substantially altered the thermal environment of the city, resulting in pronounced Urban Heat Island effects. The spatial distribution of Land Surface Temperature indicates that the central urban core, industrial sectors, and transportation corridors experience significantly higher temperatures compared to peripheral vegetated regions.

The analysis further demonstrates that urban green spaces are distributed unevenly across the municipality. Several wards suffer from inadequate vegetation cover and limited access to green infrastructure, creating significant environmental inequalities. The strong negative relationship observed between NDVI and Land Surface Temperature confirms the critical role of vegetation in regulating urban microclimates and mitigating thermal stress. Areas with higher vegetation density consistently recorded lower surface temperatures, highlighting the cooling benefits of urban green spaces.

The study also identified multiple Urban Heat Island hotspots and environmentally vulnerable zones through GIS-based hotspot and vulnerability analyses. These areas are characterized by high population concentration, dense built-up development, limited vegetation, and elevated surface temperatures. Such conditions increase exposure to heat-related environmental risks and emphasize the need for targeted mitigation measures.

The geospatial framework developed in this study demonstrates the effectiveness of integrating Land Surface Temperature analysis, vegetation assessment, land-use mapping, hotspot identification, and vulnerability modelling for climate-resilient urban planning. The results suggest that expanding urban green infrastructure, promoting ecological restoration, developing green corridors, and protecting existing vegetation can significantly reduce thermal stress and improve environmental sustainability.

In conclusion, the study establishes that Urban Heat Island intensity and green space inequality are closely interconnected environmental challenges within Durgapur Municipal Corporation. The application of Remote Sensing and GIS provides a scientifically robust basis for evidence-based planning and decision-making. The proposed climate-resilient planning framework offers practical guidance for municipal authorities, urban planners, and policymakers seeking to promote sustainable urban development, environmental equity, and climate adaptation in rapidly urbanizing cities.

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