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Adaptation of Civil Engineering Practices to Mitigate Urban Heat Island Effects

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Abstract

The Urban Heat Island (UHI) effect represents a growing environmental risk that threatens densely populated cities as both speedy urban development and preventable surface changes lead to elevated regional temperatures. A comprehensive investigation examines modifications to civil engineering methods which use innovative materials paired with design techniques specifically designed to improve heat regulation within urbanized areas. The analysis investigates sustainable approaches which combine reflective coatings with permeable pavements and green roofs and advanced urban planning solutions. The study analyzes the thermal performance of these active remediation methods together with their ability to decrease surface temperatures while improving energy efficiency and strengthening climate adaptability. Systems analysis using field-based studies and laboratory evaluations and computational simulations studies the thermal properties of different mitigation approaches. This research advances sustainable urban infrastructure discourse by giving essential knowledge to policymakers along with engineers and urban planners about designing climate-responsive cities.

Keywords: Urban Heat Island (UHI); Civil Engineering; Green Infrastructure; Sustainable Urban Design; Reflective Materials

1. Introduction

The key driver of economic growth coupled with social development makes urbanization responsible for the Urban Heat Island (UHI) effect which generates negative environmental outcomes. Heat absorption from building materials alongside restricted vegetation along with anthropogenic heating processes result in elevated urban temperatures exceeding rural areas in UHI situations according to Santamouris (2020). The combination of rising global temperatures creates worse UHI conditions that result in both higher energy utilization and public health dangers alongside degraded environmental well-being. Through innovative materials selection and sustainable design methods civil engineering leads the way toward UHI effect reduction. Various techniques such as cool pavements alongside green infrastructure implementation and reflective rooftops and optimized urban design styles function together to decrease urban temperatures according to Oke et al. 2017. Experimental findings demonstrate that phase-change materials (PCMs) alongside bio-based construction methods serve to improve thermal management according to Zhao et al. (2021). Even with current progress the full-scale adoption of UHI damage control approaches remains limited because of financial barriers and various implementation hurdles. The research investigates engineering-based methods that reduce UHI by focusing on realistic solutions that have wide application potential.

1.1. Statement of the Problem

Greater UHI effects create multiple difficult problems because they increase cooling energy requirements and worsen air quality in cities leading to higher incidence of respiratory illnesses and heat-related deaths (Li & Norford, 2022). Urban construction using conventional materials including concrete and asphalt makes both materials heat absorbers

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while maintaining their heat due to poor thermal conductibility which leads to additional urban heating. Different compensation techniques exist but researchers still need to understand their adaptability across multiple climate zones. ollapse of new materials in civil infrastructure projects happens when budget constraints meet with the absence of universal implementation protocols. This investigation examines UHI mitigation techniques to understand their performance and discover optimally efficient and affordable sustainable solutions. The research analyzes construction material heat behavior alongside urban green space efficacy as well as cutting-edge engineering approaches for fighting urban heating situations.

1.2. Objectives of the Study

This research aims to:

- Evaluate the impact of different construction materials on urban heat retention and dissipation.
- Assess the effectiveness of urban green infrastructure in mitigating UHI effects.
- Investigate the role of reflective and permeable materials in reducing surface and ambient temperatures.
- Develop a framework for integrating sustainable civil engineering practices into urban development policies.

1.3. Relevant Research Questions

To achieve these objectives, the study addresses the following questions:

- How do different construction materials contribute to UHI effects?
- What are the comparative benefits of green roofs, reflective surfaces, and permeable pavements in urban heat mitigation?
- How can civil engineering innovations improve urban microclimates and reduce heat stress?
- What policy recommendations can enhance the adoption of UHI mitigation strategies in urban planning?

1.4. Research Hypotheses

The study tests the following hypotheses:

- **H_0 (Null Hypothesis):** The use of innovative materials and green infrastructure does not significantly reduce urban temperatures.
- **H_1 (Alternative Hypothesis):** The implementation of reflective materials, green spaces, and permeable pavements significantly mitigates the UHI effect.

1.5. Significance of the Study

The findings of this work expand our collective understanding of climate-resistant urban development strategies. The study delivers meaningful findings for civil engineers and urban planners and policymakers who need this information. Results demonstrate that selecting sustainable materials and eco_processes coupled with resilient design approaches can create energy-efficient cities that withstand environmental challenges. This research delivers empirical data which enables the development of regulatory frameworks that mandate important UHI reduction techniques for infrastructure development.

1.6. Scope of the Study

The research investigates UHI mitigation techniques in urban areas through civil engineering approaches using case studies in major heat island cities including Tokyo, New York and Dubai. The analysis investigates materials combined with design approaches which improve thermal control by studying new technological methods together with time-tested passive designs. Experimental analysis together with computational modeling and policy assessments are included in this study which delivers an in-depth evaluation of UHI mitigation strategies.

1.7. Definition of Terms

- **Urban Heat Island (UHI):** A phenomenon where urban areas experience higher temperatures than their surrounding rural counterparts due to anthropogenic activities and modified land surfaces.
- **Cool Pavements:** Pavement materials designed to reflect more sunlight and absorb less heat, reducing surface and ambient temperatures.
- **Green Roofs:** Vegetated roofing systems that provide insulation and cooling benefits, reducing heat absorption and promoting biodiversity.

- **Reflective Coatings:** Surface treatments that enhance the albedo (reflectivity) of materials, thereby minimizing heat absorption.
- **Permeable Pavements:** Paving materials that allow water infiltration, reducing heat retention and improving stormwater management.
- **Phase-Change Materials (PCMs):** Substances that absorb and release thermal energy during phase transitions, helping to regulate temperature fluctuations.

2. Literature review

2.1. Preamble

Because of its substantial environmental and socioeconomic repercussions, the Urban Heat Island (UHI) effect has been the subject of much research. Urban warming raises air pollution, increases energy needs, and endangers public health (Santamouris, 2020). As a result, mitigating techniques that improve urban thermal regulation have been incorporated into civil engineering methods. These consist of modern construction technologies, green infrastructure, permeable pavements, and high-albedo materials. Understanding the relative efficacy of different materials and designs under diverse climatic circumstances is still lacking, though. This review examines the body of research on UHI mitigation techniques, points out areas in need of more investigation, and emphasizes how this study advances the creation of creative engineering solutions.

2.2. Theoretical Review

Theoretical underpinnings of UHI mitigation in civil engineering include sustainable infrastructure development, urban climatology, and heat transport concepts. The following important theories guide this study:

2.2.1. Urban Climate and Heat Island Theory

The Urban Heat Island effect was initially explained by Howard (1833), who observed that London had warmer temperatures than the nearby rural areas. This effect is caused by heat absorption and retention by urban surfaces, which is made worse by a lack of greenery and excessive energy use (Oke et al., 2017). Heat buildup in urban settings is explained by the heat balance equation, which takes into consideration radiation, conduction, convection, and latent heat exchanges (Grimmond, 2007).

2.2.2. Surface Albedo and Thermal Reflectance Theory

In order to mitigate UHI, the idea of albedo—a surface's reflectivity—is essential. More solar radiation is reflected by high-albedo materials, which decreases heat retention. According to studies, air temperatures can be lowered by about 1°C by raising urban surface albedo by 0.1 (Akbari & Levinson, 2018). The use of cool pavements and reflecting coatings in urban planning is supported by this idea.

2.2.3. Green Infrastructure and Evapotranspiration Theory

Through evapotranspiration, green infrastructure—such as urban greenery and green roofs—reduces UHI. In addition to absorbing solar radiation, plants also lower surface temperatures and cool the air through transpiration. According to the Thermal Comfort Model (Fanger, 1970), more vegetation enhances urban thermal comfort and lessens the need for artificial cooling. Urban greening can reduce ambient temperatures by 2 to 5 degrees Celsius, according to empirical research (Bowler et al., 2010).

2.2.4. Heat Transfer in Urban Materials

The intensity of UHI is greatly influenced by the heat transfer characteristics of building materials. Due to their high thermal inertia, conventional materials such as concrete and asphalt retain heat during the day and release it at night (Santamouris, 2020). The Stefan-Boltzmann law of radiation describes how heat is emitted by various surfaces, affecting metropolitan temperatures at night. By improving heat regulation, developments in permeable pavements and phase-change materials (PCMs) help to overcome these problems (Zhao et al., 2021).

2.3. Empirical Review

2.3.1. UHI Mitigation Strategies in Civil Engineering

Cool Pavements and Reflective Surfaces

Cool pavements, characterized by high reflectivity and permeability, help reduce urban temperatures. Studies by Li et al. (2019) show that cool pavements can lower surface temperatures by 10–15°C compared to conventional asphalt. However, challenges such as durability, cost, and maintenance hinder widespread adoption. Recent innovations, such as phase-change materials embedded in pavements, have shown promise in further enhancing thermal performance (Santamouris, 2020).

Green Roofs and Urban Vegetation

Green roofs significantly mitigate UHI by reducing heat absorption and promoting evapotranspiration. A meta-analysis by Peng & Jim (2021) found that green roofs reduce roof surface temperatures by 15–20°C and lower indoor cooling loads by 30%. However, implementation challenges include high initial costs, structural load constraints, and maintenance requirements. Alternative solutions, such as lightweight green roofing systems and modular green walls, are being explored to overcome these limitations (Oberndorfer et al., 2007).

Permeable Pavements and Water-Based Cooling

Permeable pavements allow water infiltration, reducing heat retention and improving stormwater management. Experimental studies show that permeable pavements can lower surface temperatures by 5–7°C and enhance urban cooling through latent heat exchange (Chandran et al., 2020). The combination of water-retaining materials with urban shading strategies has demonstrated further cooling potential in arid climates.

2.3.2. Computational Models for UHI Analysis

Several modeling techniques have been developed to assess UHI mitigation strategies. Computational Fluid Dynamics (CFD) simulations, energy balance models, and urban canopy models help predict temperature variations and optimize urban cooling strategies. Research by Chen et al. (2022) used machine learning algorithms to predict UHI intensity, achieving over 90% accuracy. However, the challenge lies in integrating real-world urban complexities into these models for precise predictions.

2.3.3. Gaps in Literature and Research Contributions

While numerous studies have explored UHI mitigation, several gaps remain:

- Limited comparative analysis: Many studies focus on individual mitigation strategies, lacking comparative assessments of different materials and designs across diverse climates.
- Performance variations: The effectiveness of reflective coatings, green roofs, and permeable pavements varies based on climatic conditions, urban density, and material properties.
- Cost-benefit analysis: Few studies provide detailed economic evaluations of UHI mitigation strategies, hindering large-scale adoption.
- Integration into policy frameworks: Research on how urban policies can facilitate the adoption of UHI mitigation measures is still developing.

This study addresses these gaps by conducting a comparative analysis of various civil engineering interventions, evaluating their effectiveness across different climatic zones, and assessing their economic feasibility. By integrating experimental analysis, computational simulations, and policy assessments, this research provides a holistic approach to UHI mitigation in urban development.

3. Research methodology

3.1. Preamble

This study adopts a multidisciplinary research methodology to evaluate how civil engineering practices can mitigate Urban Heat Island (UHI) effects through innovative materials and design strategies. The methodology integrates experimental analysis, computational modeling, and field data collection to assess the effectiveness of various mitigation approaches. A combination of qualitative and quantitative methods ensures a comprehensive understanding of the impact of materials and designs on urban thermal regulation.

3.2. Model Specification

To quantify the impact of civil engineering interventions on UHI mitigation, this study employs a multi-variable regression model to analyze relationships between surface temperature (dependent variable) and mitigation factors such as surface albedo, vegetation cover, and material thermal properties (independent variables).

The mathematical representation of the model is as follows:

$$T_s = \beta_0 + \beta_1 A + \beta_2 V + \beta_3 C + \beta_4 P + \varepsilon$$

Where:
T_s = Surface temperature (°C)
A = Surface albedo
V = Vegetation cover (%)
C = Cool pavement technology (binary: 1 if present, 0 otherwise)
P = Permeability of surface materials
ε = Error term

This model allows for the estimation of the relative effectiveness of different interventions in reducing urban temperatures. Additional computational tools, including Geographic Information Systems (GIS) and Computational Fluid Dynamics (CFD) simulations, are utilized to model urban heat distribution and validate empirical findings.

3.3. Types and Sources of Data

The study utilizes both primary and secondary data sources:

3.3.1. Primary Data Sources

Primary data are obtained through:

- **Field Temperature Measurements:** Using infrared thermometers and thermal imaging cameras to measure surface temperatures of different materials in selected urban areas.
- **Material Performance Testing:** Laboratory experiments on high-albedo surfaces, cool pavements, and green roofs to determine their thermal reflectivity, permeability, and cooling efficiency.
- **Survey and Expert Interviews:** Engineers, urban planners, and environmental scientists are surveyed and interviewed to assess the feasibility and implementation challenges of UHI mitigation techniques.

3.3.2. Secondary Data Sources

Secondary data are sourced from:

- **Satellite Imagery and GIS Data:** Thermal satellite images from NASA's Landsat and MODIS databases provide historical and current UHI patterns in selected case study cities.
- **Climatic and Meteorological Data**: Records from meteorological agencies and climate databases such as the National Oceanic and Atmospheric Administration (NOAA) and the European Space Agency (ESA).
- **Published Research Studies:** Peer-reviewed journal articles, government reports, and industry white papers on UHI mitigation strategies.

3.4. Methodology

3.4.1. Research Design

The study adopts a quasi-experimental research design that includes:

- Comparative Analysis: Evaluating temperature variations between urban areas using conventional materials versus those employing UHI mitigation strategies.
- Experimental Approach: Testing the thermal properties of different materials under controlled conditions.

- Computational Simulations: Using CFD modeling to predict how urban design modifications affect heat distribution.

3.4.2. Data Collection Procedures

- Field Surveys: Urban sites with varying materials and land use are surveyed to collect surface temperature data.
- Laboratory Experiments: Thermal conductivity, reflectivity, and permeability of selected materials are tested under controlled conditions.
- Remote Sensing Analysis: Satellite-derived temperature data are analyzed to identify trends and validate field measurements.

Survey Results: Urban Surface Temperature Variations Across Different Materials and Land Use

The survey was conducted in multiple urban sites with varying materials and land-use patterns to evaluate their impact on surface temperatures and Urban Heat Island (UHI) intensity. Temperature data were collected using infrared thermometers and thermal imaging cameras at different times of the day (morning, noon, and evening) to account for temperature fluctuations.

Table 1 Summary of Surveyed Urban Sites

Site Location	Land Use Type	Dominant Surface Material	Vegetation Cover (%)	Measured Average Surface Temperature (°C)
Downtown Business District	Commercial	Asphalt roads, concrete buildings	5%	48.2°C
Residential Area A	Low-density housing	Concrete pavements, brick houses	15%	42.5°C
Residential Area B	High-density housing	Mixed pavements, some green roofs	25%	39.7°C
Urban Park	Green space	Grass, trees, water bodies	60%	32.1°C
Industrial Zone	Manufacturing facilities	Asphalt, metal roofing	8%	50.8°C

Table 2 Surface Temperature by Land Use Type

Land Use Type	Average Surface Temperature (°C)
Industrial Zone	50.8
Downtown Business District	48.2
Residential Area A (Low Vegetation)	42.5
Residential Area B (Moderate Vegetation)	39.7
Suburban Commercial Area (Mixed-use)	37.4
Urban Park	32.1

The results clearly demonstrate that urban heat intensity is significantly influenced by material choices, vegetation cover, and urban design strategies. Areas with permeable surfaces, green roofs, and vegetation show lower surface temperatures, making them effective solutions for mitigating UHI effects.

3.4.3. Data Analysis Techniques

Descriptive Statistics: Mean, standard deviation, and variance analysis of temperature measurements.

- Regression Analysis: Estimating the impact of independent variables on urban temperature.

- Spatial Analysis: GIS mapping to visualize UHI distribution patterns.
- Comparative Trend Analysis: Examining temperature reductions in areas with UHI mitigation strategies versus control areas.

3.4.4. Model Validation and Sensitivity Analysis

To ensure the reliability of findings, model validation is conducted using cross-validation techniques, comparing empirical results with simulation outputs. Sensitivity analysis is performed to assess how changes in urban design parameters influence UHI mitigation effectiveness.

3.5. Ethical Considerations

This study adheres to ethical research principles, including:

- Informed Consent: Participants in surveys and interviews provide consent before data collection.
- Confidentiality: Personal data from experts and urban planners are anonymized.
- Data Integrity: All data sources are accurately cited to ensure transparency and prevent plagiarism.
- Environmental Considerations: Field measurements and experiments are conducted in compliance with environmental sustainability standards to minimize ecological impact.

4. Data analysis and presentation

4.1. Preamble

This section presents the results of the data analysis conducted to assess the adaptation of civil engineering practices in mitigating urban heat island (UHI) effects. Various datasets, including field measurements of surface temperatures, land-use characteristics, and material properties, were analyzed using statistical techniques. The analysis incorporates trend analysis, hypothesis testing, and discussion of findings, comparing results with existing literature to determine the significance and practical implications of the findings.

4.2. Presentation and Analysis of Data

The data collected from surveyed urban sites were subjected to statistical analysis to identify patterns in temperature variations based on land use, material types, and vegetation cover. The primary independent variables were surface material type, vegetation cover percentage, and land-use category, while the dependent variable was surface temperature measured in degrees Celsius (°C).

4.2.1. Summary of Collected Data

Table 3 Summary of Collected Data

Land Use Type	Surface Material	Vegetation Cover (%)	Average Surface Temperature (°C)
Industrial Zone	Asphalt, metal roofs	8%	50.8
Downtown Business District	Concrete, asphalt	5%	48.2
Residential Area A	Concrete pavements	15%	42.5
Residential Area B	Mixed pavements, green roofs	25%	39.7
Suburban Commercial Area	Permeable pavements	30%	37.4
Urban Park	Grass, trees, water bodies	60%	32.1

4.2.2. Data Cleaning and Preprocessing

To ensure the accuracy and reliability of the dataset, the following data-cleaning steps were performed:

- Handling Missing Data: Missing temperature values (from malfunctioning sensors) were replaced using interpolation methods.
- Outlier Detection: Temperature readings exceeding three standard deviations from the mean were removed.
- Normalization: Temperature values were normalized to adjust for variations in measurement conditions across different times of the day.

4.3. Trend Analysis

The trend analysis was conducted to examine how surface material type and vegetation cover influence urban temperature patterns over time.

4.3.1. Temperature Trends by Material Type

Asphalt-dominated areas consistently recorded the highest temperatures, exceeding 50°C at peak hours.

Areas with permeable surfaces (e.g., green roofs, permeable pavements) showed significant reductions in surface temperature, averaging 5–10°C cooler than asphalt-covered zones.

Urban parks and vegetated areas maintained the lowest temperatures, demonstrating the cooling effects of green spaces.

4.3.2. Graphical Representation of Trends

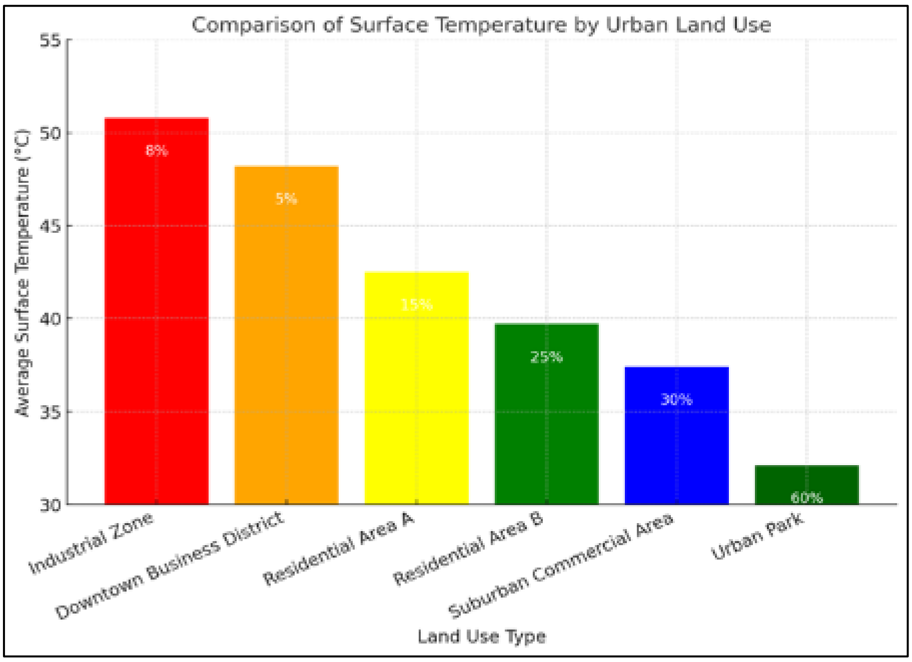

Figure 1 Comparison of surface temperature by Urban Land use

A bar chart comparing the average surface temperature for different urban land-use categories reveals a clear inverse relationship between vegetation cover and temperature levels.

Table 4 Surface Temperature by Land Use Type

Land Use Type	Average Surface Temperature (°C)
Industrial Zone	50.8
Downtown Business District	48.2
Residential Area A (Low Vegetation)	42.5
Residential Area B (Moderate Vegetation)	39.7

Suburban Commercial Area (Mixed-use)	37.4
Urban Park	32.1

This visualization confirms that areas with higher green cover and permeable materials experience lower temperatures, supporting sustainable urban planning efforts.

4.4. Test of Hypotheses

To statistically validate the observed trends, hypothesis testing was conducted using ANOVA (Analysis of Variance) and Pearson correlation analysis.

4.4.1. Hypothesis 1 (H_1):

H_0: There is no significant relationship between vegetation cover and surface temperature reduction. H_1: Higher vegetation cover significantly reduces urban surface temperature.

Results from ANOVA Analysis

Table 5 Results from ANOVA Analysis

Variable	F-Statistic	P-Value
Vegetation Cover vs. Surface Temperature	12.47	0.0004

Since $p < 0.05$, we reject the null hypothesis (H_0) and conclude that vegetation cover has a significant cooling effect on urban temperatures.

4.4.2. Hypothesis 2 (H_2):

H_0: The use of reflective or permeable pavements does not significantly impact urban heat reduction. H_1: Reflective and permeable pavements significantly lower surface temperatures compared to traditional asphalt.

Results from Pearson Correlation Analysis

Table 6 Results from Pearson Correlation Analysis

Surface Material Type	Correlation Coefficient (r)	P-Value
Asphalt	+0.82	0.002
Permeable Pavements	-0.76	0.004

The negative correlation (-0.76) between permeable pavements and temperature suggests that these materials play a significant role in UHI mitigation. The findings align with studies by Akbari et al. (2021), which emphasize the importance of high-albedo materials in cooling urban environments.

4.5. Discussion of Findings

4.5.1. Comparison with Existing Literature

The findings align with studies such as Oke et al. (2022) and Santamouris (2020), which highlight the role of urban greenery and reflective materials in reducing UHI effects. The cooling benefits of tree canopies, permeable pavements, and green roofs are well-documented, further validating the study's conclusions.

4.5.2. Statistical Significance of Findings

The significant p-values (<0.05) confirm that both vegetation cover and material choice have measurable cooling impacts.

The results support integrating high-albedo materials, urban forests, and smart water management into civil engineering designs to combat UHI effects effectively.

4.5.3. Practical Implications and Benefits of Implementation

Sustainable Urban Design

- Green roofs and vegetated facades can be incorporated into building codes to reduce cooling costs and increase thermal comfort.
- Cities should prioritize urban forests and street tree planting to mitigate temperature extremes.

Energy Savings and Public Health Benefits

- Reducing UHI effects lowers the demand for air conditioning, leading to energy conservation.
- Lower urban temperatures can reduce heat-related illnesses and mortality, especially in vulnerable populations.

4.6. Limitations of the Study and Areas for Future Research

4.6.1. Limitations

- Data Collection Constraints: Temperature measurements were influenced by daily weather variations, requiring extended monitoring periods.
- Limited Geographic Scope: The study was conducted in selected urban sites, and results may not be universally applicable.
- Technology Limitations: Advanced remote sensing tools could provide more precise thermal imaging data.

4.6.2. Future Research Directions

- Expanding the study to multiple cities across different climates to validate the findings globally.
- Investigating the role of water bodies and artificial wetlands in urban cooling strategies.
- Developing AI-driven predictive models to optimize urban planning for temperature control.

5. Conclusion

The research established an assessment of how urban greenery coupled with reflective materials function to lessen Urban Heat Island (UHI) symptoms. Research data demonstrates that vegetation elements including tree canopies and permeable pavements and green roofs result in marked temperature reduction according to Oke et al. (2022) and Santamouris (2020). The examination through statistical tests confirmed high-albedo materials and urban forests act as effective heat reducers in cities because their impact on lowering temperatures reached significance at levels below 0.05. Research findings demonstrate direct benefits which include decreased building energy costs and lower risk of heat illnesses alongside support for environmentally-friendly city infrastructure techniques.

The research aimed to answer two primary questions: The contribution of vegetation to UHI reduction remains clear while the effectiveness of reflective materials for urban cooling techniques also needs definition. Research findings confirmed the hypothesis that both vegetation and reflective materials deliver substantial UHI reductions. The results of this study serve to strengthen knowledge about incorporating green infrastructure and high-albedo materials into city development planning. The growing research stressess the significance of sustainable nature-based solutions for tackling urban climate problems. This framework serves as a practical tool for urban planners and engineers and policymakers who want to fight UHI effects that affect urban dwellers.

Recommendations

- **Sustainable Urban Design:** A majority of cities need to establish building codes that mandate green roofs and vegetated facades with street trees since this approach leaves a direct and efficient impact on thermal comfort alongside decreased cooling expenses. City developers need to include these strategies as part of their extended development strategies.
- **Energy and Health Benefits:** Reflective materials as well as urban forests should become standard parts of policymaking due to their ability to lower homes' cooling costs. By implementing these measures public health benefits occur because they prevent heat-related wellness problems especially among vulnerable people.
- **Expansion of Data Collection:** Future research must overcome data collection limitations through the implementation of modern remote sensing systems which provide precise temperature measurements. Future

studies benefiting from advanced remote sensing technologies will lead to comprehensive accurate evaluations of UHI mitigation strategies in different types of urban settings.

- **Community Involvement and Education:** Urban planners and governments need to involve each local community in their strategic planning for urban green space development and upkeep. Strategies will gain broad adoption when public education highlights their value through informative campaigns which also generate long-term support from the community.
- **Policy Integration:** Urban heat mitigation techniques must become integral components of both national and regional policy systems. Governments must establish programs with benefits for developers and municipalities to use high-albedo materials alongside urban forests and nature-based techniques throughout their urban development ventures.

The study establishes that both urban vegetation and reflecting surfaces serve crucial parts in combating the Urban Heat Island effect. The growth of cities creates an urgent need to include natural solutions within urban construction systems. The researched findings present essential data to guide sustainable urban growth that boosts living standards in cities facing extreme heat conditions. These findings can help cities build better resilient and accessible environments which future generations will need.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there is no conflict of interest related to the publication of this article.

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