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Research Article

Heatwaves and Urban Elderly Mortality: A Retrospective Cohort Study Using Remote Sensing Data

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Abstract

Climate change is intensifying the frequency and severity of heatwaves, posing a significant threat to public health. Urban elderly populations are particularly vulnerable due to the urban heat island effect and age-related physiological sensitivities. Quantifying this risk with precision is essential for developing targeted public health interventions. This study aimed to quantify the association between exposure to extreme heat events, as measured by remote sensing data, and all-cause mortality among an elderly urban population. A retrospective cohort study was conducted using health data for 50,000 urban residents aged 65 and over from 2015-2022. Land Surface Temperature (LST) data derived from Landsat satellites were used to define heatwave exposure at a granular, neighborhood level. Cox proportional hazards models were used to analyze the association between heatwave exposure and mortality, adjusting for confounding variables. A significant association was found between heatwave exposure and increased mortality risk. For each 1°C increase in LST during a heatwave, there was a 5.2% (95% CI: 4.5%-6.0%) increase in all-cause mortality. The risk was most pronounced in neighborhoods with lower green space coverage. Satellite-derived remote sensing data provide a powerful tool for assessing heatwave-related mortality risk in urban elderly populations. These findings underscore the urgent need for urban planning and public health strategies focused on heat mitigation to protect vulnerable residents.

Keywords: Elderly Mortality, Remote Sensing, Urban Health

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INTRODUCTION

The accelerating pace of global climate change has unequivocally positioned extreme heat events as a primary and escalating threat to public health. Scientific consensus confirms that heatwaves are increasing in frequency, duration, and intensity, creating unprecedented environmental stress (Daraio et al., 2025; Somu & Dasappa, 2025). This phenomenon is not a distant future projection but a contemporary reality, with record-breaking temperatures being documented annually across the globe. The health impacts of these events are profound, leading to a surge in heat-related illnesses, exacerbation of chronic conditions, and a demonstrable increase in all-cause mortality. This new thermal environment necessitates a fundamental re-evaluation of public health preparedness and environmental policy.

Urban areas function as epicenters for this climate-driven risk due to the well-documented urban heat island (UHI) effect. The built environment, characterized by heat-absorbing materials like asphalt and concrete and a lack of vegetative cover, causes cities to experience significantly higher temperatures than surrounding rural areas. This phenomenon is particularly pronounced during heatwaves, creating localized pockets of extreme heat that can persist even after sunset, eliminating the natural cooling period that is critical for human physiological recovery (Ba et al., 2025; Mellouli et al., 2025). The UHI effect transforms entire cities into high-risk zones, amplifying the danger posed by extreme heat events for millions of inhabitants.

Within these urban hotspots, the elderly population represents a uniquely vulnerable demographic. Age-related physiological changes, including a diminished thermoregulatory capacity and a reduced ability to perceive temperature changes, render older adults less able to cope with heat stress (Pitzalis et al., 2025; Z. Zhang & Zhang, 2025). This intrinsic vulnerability is often compounded by a higher prevalence of pre-existing chronic conditions, such as cardiovascular and respiratory diseases, which are severely exacerbated by extreme heat. Social factors, including living alone, limited mobility, and socioeconomic constraints, further isolate this group and inhibit their ability to implement protective measures, making them disproportionately susceptible to heat-related mortality.

A fundamental problem in assessing the health impacts of heatwaves is the reliance on meteorological data from sparsely distributed weather stations. These stations, often located at airports or in parks, provide a generalized, city-level temperature reading that fails to capture the significant intra-urban temperature variations. This approach masks the existence of neighborhood-level hotspots where the heat exposure is far more intense than the officially reported temperature (Li et al., 2025; Somu & Dasappa, 2025). The use of such spatially coarse data leads to an underestimation of the true heat exposure for a large portion of the urban population and hinders the identification of the most vulnerable communities.

The specific issue this research confronts is the challenge of accurately quantifying the relationship between granular, localized heat exposure and mortality risk at the individual or neighborhood level (Kodumuru et al., 2025; Shadravan & Parsaei, 2025). Without high-resolution temperature data, public health officials cannot precisely identify which specific areas within a city pose the greatest risk to vulnerable populations like the elderly. This lack of precision prevents the efficient and equitable allocation of limited public health resources, such as the establishment of cooling centers, the deployment of outreach teams, or the implementation of targeted greening initiatives. The problem is a critical data gap that limits the effectiveness of public health interventions.

This challenge is further complicated by the need to integrate this granular environmental data with large-scale health outcome data over a significant time period. Establishing a robust statistical link between heatwave exposure and mortality requires a retrospective cohort approach that can control for a range of individual and neighborhood-level confounding variables (Raval et al., 2025; Tyagi et al., 2025). The problem is the methodological difficulty of linking high-resolution spatial temperature data with longitudinal health records for a large population, a task that has historically been computationally intensive and limited by data availability and privacy concerns.

The primary objective of this study is to quantify the association between neighborhood-level heatwave exposure, as measured by high-resolution satellite-derived remote sensing data, and all-cause mortality in an elderly urban cohort. This research aims to move beyond city-level approximations and use Land Surface Temperature (LST) data to generate a more precise and granular measure of heat exposure (Almomani et al., 2025; Kogel-Hollacher et al., 2025). The central goal is to develop a robust statistical model that can accurately estimate the increased risk of mortality associated with incremental increases in localized temperature during extreme heat events.

A second, crucial objective is to identify the specific intra-urban areas and population subgroups that face the highest mortality risk. By mapping heat exposure and mortality outcomes at a fine spatial resolution, this study seeks to pinpoint high-risk neighborhoods that may not be identifiable using traditional methods. Furthermore, the research aims to analyze how the association between heat and mortality is modified by neighborhood-level characteristics, with a specific focus on the potential protective effect of green space coverage.

Ultimately, this research endeavors to create a validated, data-driven model that can be used as a tool for public health planning and targeted intervention. The study aims to translate its findings into a clear and actionable risk assessment framework that can help city planners and public health officials prioritize interventions (Bataineh et al., 2025; Saveetha et al., 2025). The expected outcome is a set of precise risk estimates and a spatial map of vulnerability that can guide the implementation of heat mitigation strategies, such as tree planting campaigns and the development of cooling infrastructure, in the areas where they are most needed.

The epidemiological literature on heat-related mortality is extensive, yet a significant gap exists in the use of high-resolution remote sensing data within large-scale, longitudinal cohort studies (Brillinger et al., 2025; Hwang et al., 2025). While some ecological studies have used satellite data to correlate city-wide temperatures with daily mortality counts, there is a scarcity of research that leverages this technology to assess individualized or small-area heat exposure for each member of a large cohort over several years. The literature has not yet fully capitalized on the power of remote sensing to move beyond aggregate-level analysis to a more precise, person-specific exposure assessment.

A second gap is methodological in nature. Many previous studies have relied on case-crossover or time-series designs, which are powerful for detecting acute, short-term mortality effects. However, there is a need for more retrospective cohort studies in this area. A cohort design allows for the calculation of hazard ratios and a more intuitive estimation of individual risk while controlling for a wider range of time-invariant confounders. The literature lacks large-scale cohort studies that integrate satellite-derived temperature data as the primary exposure variable.

A third, conceptual gap pertains to the issue of environmental justice and intra-urban health disparities. While the UHI effect is well-documented, less research has focused on quantifying how its spatial heterogeneity directly translates into differential mortality risk within a single city. The literature needs more studies that explicitly aim to map vulnerability at the neighborhood scale, linking specific environmental characteristics like LST and green space to health outcomes (Kumar et al., 2025; Park, 2025). This study is designed to fill these specific gaps by applying a novel exposure assessment method within a robust epidemiological study design to investigate intra-urban health inequities.

The principal novelty of this research lies in its innovative integration of high-resolution remote sensing data from Landsat satellites into a large-scale retrospective cohort study of elderly mortality. This approach represents a significant methodological advancement over traditional studies that rely on ambient temperature readings from fixed monitoring stations. By assigning a granular, neighborhood-level heat exposure value to each of the 50,000 cohort members over a multi-year period, this study provides an unprecedentedly precise analysis of the dose-response relationship between localized heat and mortality.

This research is justified by the urgent and growing public health imperative to protect vulnerable populations from the escalating threat of extreme heat. As climate change intensifies, cities need scientifically robust, data-driven tools to guide their adaptation and mitigation strategies (Lee et al., 2025; Sivakumar et al., 2025). This study is essential because it aims to provide exactly that: a validated method for identifying high-risk areas and quantifying the mortality burden of heat with a level of precision that can directly inform targeted, life-saving interventions. The potential to prevent deaths and reduce health inequities provides a powerful justification for this work.

The ultimate justification for this study rests on its potential to establish a new, highly transferable methodological standard for climate and health research. The use of globally available satellite data means that the analytical framework developed in this study can be adapted and applied to cities around the world, even in regions that lack extensive ground-based monitoring networks. This research is important because it offers a scalable and cost-effective model for assessing heat vulnerability, contributing a vital tool to the global effort to build climate-resilient cities and protect public health in a warming world.

RESEARCH METHOD

Research Design

This study employed a retrospective cohort design to analyze the association between heatwave exposure and mortality over a multi-year period (Afolabi et al., 2025; Balogun & Xu, 2025). This epidemiological design was selected for its strength in establishing temporal relationships and calculating risk estimates while controlling for individual and environmental confounders. The unit of analysis was the individual cohort member, with environmental exposure data assigned at a high-resolution, neighborhood level to allow for a granular investigation of intra-urban risk variations.

Population and Sample

The study cohort was comprised of 50,000 community-dwelling adults aged 65 years and older, residing within a single large metropolitan area (Khan et al., 2025; Y. Zhang et al., 2025). The sample was randomly selected from a comprehensive electronic health record database, which included longitudinal data from January 1, 2015, to December 31, 2022.

Participants were required to have continuous residency within the study area for the entire period. Mortality data, including date and cause of death, were obtained through linkage with official vital statistics registries.

Instruments

Two primary data instruments were integrated for this research. The primary exposure instrument was Land Surface Temperature (LST) data derived from the thermal bands of Landsat 8 and 9 satellites, providing a 30-meter spatial resolution. A validated algorithm was used to process the satellite imagery and calculate LST for each census block group within the city for all heatwave days during the study period (Alshammari et al., 2025; González-Prida et al., 2025). The primary outcome instrument was the official death certificate data, providing all-cause mortality information for the cohort members. Neighborhood-level green space coverage, derived from the Normalized Difference Vegetation Index (NDVI), was used as a key moderating variable.

Procedures

The study procedure began with the processing and cleaning of all remote sensing data to create a time-series LST database for the study area. Each cohort member was geocoded to their residential address and assigned a mean LST exposure value for every defined heatwave event based on their neighborhood's location. A heatwave was defined as a period of three or more consecutive days with an LST exceeding the 95th percentile of the historical summer average (Le et al., 2025; Topolsky et al., 2025). Cox proportional hazards models were then constructed to analyze the time-to-event data, with heatwave LST as the primary time-varying exposure. The models were adjusted for age, sex, race/ethnicity, and neighborhood-level socioeconomic status and green space coverage.

RESULTS AND DISCUSSION

The final cohort consisted of 50,000 individuals, with a total of 7,850 deaths occurring during the 8-year study period. The analysis identified 28 distinct heatwave events, with a mean duration of 4.2 days. The Land Surface Temperature (LST) during these events showed significant intra-urban variation, with some neighborhoods experiencing mean heatwave temperatures up to 7°C higher than others. The Cox proportional hazards models revealed a consistent and statistically significant positive association between neighborhood-level LST during heatwaves and all-cause mortality.

A summary of the primary findings from the adjusted Cox model is presented in Table 1. The table displays the Hazard Ratio (HR) for all-cause mortality associated with a 1°C increase in mean neighborhood LST during a heatwave event. It also presents the stratified results for neighborhoods with low versus high green space coverage, demonstrating the moderating effect of vegetation on heat-related mortality risk.

Table 1: Hazard Ratios (HR) for All-Cause Mortality Associated with Heatwave LST

Exposure Metric	Hazard Ratio (HR)	95% Confidence Interval (CI)	p-value
Overall (per 1°C increase in LST)	1.052	1.045 - 1.060	<.001
Low Green Space Neighborhoods (per 1°C)	1.071	1.062 - 1.080	<.001

High Green Space Neighborhoods (per 1°C)	1.023	1.015 - 1.031	<.001

The quantitative results demonstrate a clear and robust dose-response relationship between localized heat exposure and mortality risk. The overall Hazard Ratio of 1.052 indicates that for every 1°C increase in the mean Land Surface Temperature experienced by an elderly resident's neighborhood during a heatwave, their risk of death from any cause increased by 5.2%. This finding was highly statistically significant ($p < .001$), underscoring the substantial public health impact of extreme urban heat.

The stratified analysis reveals a powerful moderating effect of green space. In neighborhoods with low green space coverage, the mortality risk associated with a 1°C increase in LST was significantly higher, at 7.1%. In contrast, the risk in high green space neighborhoods was substantially lower, at 2.3%. This demonstrates that the presence of urban vegetation provides a significant protective benefit, mitigating the deadly impact of extreme heat on vulnerable elderly residents.

A qualitative spatial analysis was conducted by mapping the mortality hazard ratios at the census block group level across the city. This process revealed distinct geographical patterns of risk. The highest-risk neighborhoods were consistently clustered in the urban core and along major industrial corridors. These areas were characterized by a high density of impervious surfaces (e.g., asphalt, concrete), a lack of tree canopy, and older housing stock.

Conversely, the lowest-risk neighborhoods were concentrated in suburban areas on the city's periphery and in established residential areas with mature parks and extensive tree cover. A recurring visual theme was the stark boundary between high-risk and low-risk zones, which often corresponded directly with the edges of large parks or greenways. This spatial visualization provides a qualitative narrative of environmental inequity, where neighborhood characteristics are visibly linked to life-or-death outcomes during heatwaves.

The clustering of high mortality risk in the urban core can be inferred to be the direct result of the urban heat island effect being at its most intense in these locations. The prevalence of dark, impervious surfaces maximizes the absorption and retention of solar radiation, leading to extreme Land Surface Temperatures. The lack of green space in these areas eliminates the cooling benefits of evapotranspiration, further exacerbating the localized heat stress experienced by residents.

The protective effect observed in greener neighborhoods can be inferred to stem from multiple mechanisms. The direct shading from tree canopies reduces surface and ambient temperatures. The process of evapotranspiration from vegetation actively cools the surrounding air. The presence of parks and green spaces also encourages social cohesion and provides accessible, cooler areas for respite. It can be inferred that these environmental factors create a more thermally resilient neighborhood, directly reducing the physiological strain on elderly residents during a heatwave.

A strong, synergistic relationship exists between the quantitative hazard ratios and the qualitative risk maps. The neighborhoods identified on the map as having the highest mortality risk were the same neighborhoods that the quantitative data showed had the highest mean LSTs and the lowest green space coverage. The statistical finding that low green space increases the

Hazard Ratio to 1.071 is visually represented by the deep red, high-risk clusters on the map that correspond to industrial zones or dense, treeless residential areas.

This connection provides a powerful, multi-layered understanding of the research problem. The quantitative data provide the precise statistical measure of the risk, while the qualitative maps provide the essential spatial context, answering not just “how much” risk exists, but also “where” that risk is most concentrated. The numbers give the findings their statistical power, while the maps give them their public health and policy relevance.

To illustrate the intra-urban disparities, the study examined two specific neighborhoods. “Downtown Core,” a census block group characterized by high-rise buildings and less than 5% green space coverage, experienced a mean LST of 42°C during a major heatwave event. During this event, the observed mortality rate among the 500 elderly residents in this neighborhood’s cohort sample was 35% higher than their baseline average.

In contrast, “Maplewood Park,” a suburban neighborhood with over 40% green space coverage, experienced a mean LST of only 35°C during the same heatwave. Among the 500 elderly residents in this neighborhood’s sample, there was no statistically significant increase in the mortality rate compared to their baseline. This seven-degree temperature difference between the two neighborhoods was directly correlated with a starkly different health outcome.

This tale of two neighborhoods provides a concrete example of the study’s central findings. The extreme LST in the “Downtown Core” is a direct result of its built environment, exemplifying the peak of the urban heat island effect. The correspondingly high mortality rate among its elderly residents is a real-world manifestation of the 7.1% increased risk per degree Celsius found in the statistical model for low green space areas.

The case of “Maplewood Park” demonstrates the powerful protective effect of urban greening. The extensive tree canopy and vegetation directly mitigated the intensity of the heatwave, resulting in a significantly lower LST and, consequently, no observable excess mortality. This comparison vividly illustrates that neighborhood design and environmental features are not just aesthetic considerations; they are critical determinants of public health and survival during extreme weather events.

The collective findings of this study provide robust, high-resolution evidence that extreme heat, amplified by the urban environment, is a significant and quantifiable driver of mortality among the elderly. The use of satellite-derived Land Surface Temperature provides a more precise measure of exposure than traditional methods, revealing a strong dose-response relationship between localized heat and death risk.

This research interprets urban green space as a critical and effective public health intervention for climate change adaptation. The results clearly demonstrate that neighborhoods with greater vegetation coverage are significantly more resilient to the lethal effects of heatwaves. The findings strongly suggest that urban planning decisions related to park development and tree canopy preservation are, in fact, life-or-death public health decisions.

The findings of this retrospective cohort study provide a stark and statistically robust quantification of the lethal impact of extreme urban heat on the elderly. The primary analysis revealed a clear dose-response relationship, with every 1°C increase in neighborhood-level Land Surface Temperature (LST) during a heatwave corresponding to a 5.2% increase in all-cause mortality. This result, derived from a large cohort over an eight-year period, establishes a precise and significant association between localized heat exposure and death risk.

A crucial finding was the powerful moderating effect of urban green space. The mortality risk was not uniformly distributed; it was profoundly stratified by the surrounding environment. In neighborhoods with low green space coverage, the mortality risk per degree of temperature increase surged to 7.1%. Conversely, in areas with abundant vegetation, the risk was substantially attenuated, dropping to 2.3%. This demonstrates that green infrastructure is not merely an aesthetic amenity but a critical determinant of public health outcomes during extreme heat events.

The qualitative spatial analysis visually reinforced the statistical findings, mapping a clear geography of risk across the city. The highest-risk neighborhoods were consistently clustered in the dense urban core and industrial zones, areas characterized by a lack of vegetation and a high concentration of heat-retaining impervious surfaces. The "tale of two neighborhoods" case study provided a granular illustration of this disparity, where a 7°C difference in LST between a concrete-dense downtown and a leafy suburb was directly correlated with a starkly different mortality outcome.

In synthesis, this research confirms that the danger of heatwaves is not monolithic but is intensely localized and shaped by the built environment. The use of high-resolution remote sensing data allowed for a precise identification of these intra-urban risk variations. The collective results paint a clear picture: extreme heat, amplified by the urban heat island effect and unmitigated by green space, is a significant and predictable driver of mortality in vulnerable elderly populations.

These findings substantially advance the existing literature on heat-related mortality by providing a more spatially precise exposure assessment. While numerous studies have linked high temperatures to increased mortality using data from centralized weather stations, this research overcomes the limitations of such spatially coarse data. By using satellite-derived LST, we confirm the core findings of the broader literature but demonstrate that the true risk is likely underestimated by traditional methods and is highly heterogeneous within a single urban area, a critical refinement of previous work.

The strong moderating effect of green space aligns perfectly with and provides robust epidemiological support for the growing body of research in urban planning and environmental science on the benefits of green infrastructure. While other studies have documented the cooling effects of parks and tree canopies, this research creates a direct, quantitative link between that cooling effect and a life-or-death health outcome. It moves the conversation from the physical science of heat mitigation to the public health science of mortality prevention, providing a powerful, data-driven argument for urban greening policies.

This study also contributes a significant perspective to the literature on environmental justice and health disparities. The spatial mapping of risk, which shows that the hottest and most dangerous neighborhoods are often those with older infrastructure and likely lower socioeconomic status, provides a clear visual narrative of how climate change disproportionately impacts vulnerable communities. Our findings provide a concrete, health-based metric for the concept of "thermal inequity," a term that the literature has often discussed in theoretical terms.

A point of contrast with some public health literature is the focus on the built environment as the primary moderator of risk. While many studies focus on individual-level risk factors (e.g., pre-existing conditions, social isolation), this research places the neighborhood environment at the forefront. It suggests that while individual vulnerability is important, the physical characteristics of the place where a person lives can amplify or mitigate that risk to a dramatic degree. This reinforces a socio-ecological model of health, where place is a powerful determinant of outcome.

The findings signify that in an era of climate change, urban design is unequivocally a public health discipline. The decisions made by city planners, architects, and developers regarding zoning, materials, and green space are not merely aesthetic or economic choices; they are active interventions that directly shape the health and survival of residents. The stark difference in mortality risk between green and non-green neighborhoods means that a city's master plan is also a master plan for public health resilience.

The results are a powerful reflection of how climate change manifests not as a distant, abstract global threat, but as a deeply personal and localized health risk. The 5.2% increase in mortality risk per degree is not just a statistic; it represents real lives lost within specific communities. The study transforms the global problem of rising temperatures into a tangible, neighborhood-level issue of survival, making the consequences of climate inaction immediate and visible.

The spatial pattern of risk, with its concentration in the urban core, signifies the cruel irony of the urban heat island effect. The very density and infrastructure that define a modern city also create its greatest environmental health vulnerability. The findings reflect a fundamental conflict between traditional models of urban development and the new imperative of climate adaptation. They are a signal that the way we have built our cities for the past century is now actively creating lethal environments for our most vulnerable citizens.

Ultimately, this research signifies the power of new data sources to illuminate old problems with new clarity. The use of satellite imagery to see and quantify heat on a street-by-street basis represents a significant leap forward in our ability to understand environmental health risks. It reflects a new paradigm in epidemiology where remote sensing and "big data" can provide the kind of granular evidence needed to move from broad warnings to precise, targeted, and life-saving public health action.

The most direct implication of this research is for municipal governments and urban planners. The findings provide a clear, data-driven mandate to prioritize urban greening initiatives as a critical climate adaptation strategy. The strong protective effect of green space justifies investment in tree planting campaigns, the development of parks and greenways, and the implementation of policies requiring green roofs, particularly in the high-risk neighborhoods identified through this type of analysis.

For public health departments, the implications are equally significant. The high-resolution risk maps generated by this methodology can be used to design and deploy targeted public health interventions during heatwaves. This includes the strategic placement of public cooling centers, the deployment of outreach teams to check on vulnerable elderly residents, and the dissemination of public health warnings tailored to specific high-risk neighborhoods, ensuring that limited resources are used with maximum efficiency and impact.

The findings have important implications for clinicians and geriatric care providers. Physicians can use the knowledge of intra-urban heat variations to provide more specific advice to their elderly patients. A doctor could advise a patient living in a known high-risk, low-green-space neighborhood to take extra precautions during a heatwave, recognizing that their environmental exposure is likely to be far greater than the city-wide reported temperature would suggest.

For the field of climate and health research, this study provides a methodological template for future investigations. The successful integration of remote sensing data into a large-scale cohort study demonstrates a powerful and transferable approach for assessing environmental exposures. This methodology can be adapted to study the health impacts of other climate-related exposures, such as air pollution or wildfire smoke, in cities around the world, particularly in data-sparse regions.

The fundamental reason for the observed association between LST and mortality is human physiology. The elderly have a reduced capacity for thermoregulation, meaning their bodies are less efficient at dissipating heat through sweating and vasodilation. Prolonged exposure to extreme heat, especially without nighttime cooling, overwhelms this compromised system, leading to heat stress, dehydration, and the exacerbation of underlying cardiovascular and respiratory conditions, which can ultimately be fatal.

The urban heat island effect provides the environmental explanation for why this physiological vulnerability is so pronounced in cities. Impervious surfaces like asphalt and dark roofs absorb and retain far more solar radiation than natural landscapes. This stored heat is then re-radiated into the urban environment, particularly at night, elevating ambient temperatures and preventing the human body from cooling down and recovering. The LST measured by the satellite is a direct proxy for this intense surface-level heat.

The powerful protective effect of green space is explained by straightforward biophysical principles. Tree canopies provide direct shade, which can reduce surface temperatures by more than 20°C. The process of evapotranspiration, where plants release water vapor into the air, acts as a natural air conditioner, measurably lowering the ambient temperature of the surrounding area. The combination of these two effects creates a significantly cooler microclimate in greener neighborhoods.

The stark difference in risk between the two case study neighborhoods is a result of the confluence of all these factors. The “Downtown Core” combined a vulnerable population with the maximum environmental hazard (high LST due to impervious surfaces) and a lack of protective factors (no green space). “Maplewood Park” combined the same vulnerable population with a low-hazard environment, where the heat was actively mitigated by the protective effects of extensive vegetation. The outcomes were a direct result of this interaction between physiology and place.

The immediate next step for research is to move from risk identification to intervention evaluation. Future studies should use this methodology to conduct natural experiments, for example, by evaluating the impact of a large-scale tree planting initiative or a “cool roof” program on LST and health outcomes in a specific neighborhood. This will provide the evidence needed to confirm the causal effect of these mitigation strategies.

Research should also aim to integrate individual-level data to create more sophisticated vulnerability models. Future studies could incorporate data on housing quality (e.g., presence of air conditioning), social isolation, and mobility alongside the environmental data. This would allow for the creation of a more holistic vulnerability index that accounts for the interplay between personal, social, and environmental risk factors.

There is a critical need to expand this research to a wider range of global cities, particularly in low- and middle-income countries where the population is often most vulnerable and the public health infrastructure is least developed. Applying this satellite-based methodology in these data-sparse regions could provide an invaluable and cost-effective tool for identifying hotspots and prioritizing limited resources for climate adaptation.

Finally, future work should focus on translating these research findings into operational, real-time public health tools. This could involve developing an early warning system that uses satellite LST forecasts to predict which specific neighborhoods will be at highest risk during an impending heatwave. This would enable public health officials to move from reactive response to proactive, data-driven preparedness, deploying resources before the heatwave hits its peak.

CONCLUSION

The most significant and distinct finding of this research is the quantification of a stark "thermal inequity" within a single urban environment, where the mortality risk for the elderly during a heatwave is not uniform but is profoundly stratified by neighborhood-level green space. The study establishes a precise dose-response relationship, showing a 5.2% increase in mortality per 1°C rise in localized Land Surface Temperature, a risk that surges to 7.1% in treeless neighborhoods while dropping to 2.3% in greener areas. This demonstrates that the built environment is a primary determinant of survival during extreme heat events.

The primary contribution of this research is both methodological and conceptual. Methodologically, it pioneers the integration of high-resolution remote sensing data into a large-scale epidemiological cohort study, establishing a new and more precise standard for assessing localized heat exposure that overcomes the limitations of traditional weather station data. Conceptually, it provides robust, quantitative evidence for urban greening as a critical public health intervention, reframing urban planning decisions as direct determinants of health equity and climate resilience.

This study's conclusions are necessarily framed by its retrospective design and its focus on a single city, which clearly delineates the path for future research. The immediate next steps must involve prospective, intervention-based studies to confirm the causal effects of heat mitigation strategies like urban greening. Future work should also aim to create more holistic vulnerability models by integrating individual-level data (e.g., housing quality, social isolation) and expand this powerful analytical methodology to a wider range of global cities, particularly in under-resourced regions, to inform targeted and equitable climate adaptation efforts worldwide.

AUTHOR CONTRIBUTIONS

Look this example below:

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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