Journal of Engineering and Applied Science Vol. 09, No. 02, pp. 48–57, December 2025

Journal of Engineering and Applied Science

Contents are available at www.jeas.ruet.ac.bd

Urban Greening and Public Health: A Study on Heat-Related Illness in Low-Income Neighborhoods of Rajshahi City

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ARTICLE INFORMATION

Received date: 06 May 2025
Revised date: 10 July 2025
Accepted date: 12 July 2025

Keywords

Green Infrastructure
Urban heat stress
Urban Heat Island Effect
Logistic Regression Model

ABSTRACT

Urbanization and global climatic change have intensified urban heat stress and created immense challenges for global public health, especially for cities that are developing rapidly. In this context, cities such as Rajshahi, Bangladesh have recognized that Green Infrastructure will be central to reducing urban heat island effect as well as protecting health This research assessed the role of Green Infrastructure (GI) with respect to urban heat stress across three neighborhoods of Rajshahi City Corporation, Bangladesh. The research utilized a semi-structured questionnaire survey and filed observation checklist mixed methods design to assess household survey to collect necessary data, spatial information, and a logistic regression model to clarify the relationship between vegetation cover, household income and size, proximity to GI, vulnerable members, and perceived heat stress. Results demonstrated a significant, inverse relationship between perceived heat stress at various distances from GI (r = -0.72), indicating that households with higher income had less heat stress due to enhanced access to GI and/or adaptive practices. In Choto Bonogram, only 35% of respondents reported awareness of green infrastructure benefits; this contrasts with 58% in Chalk Kristan Para, which indicates a substantial knowledge discrepancy. Moreover, 72% of low-income respondents identified space to access vegetative shade as a barrier to utilizing GI. Mediation and interaction analyses indicated that access to GI significantly mediated the income–heat stress relationship and generated larger GI benefits for households with vulnerable individuals. These findings have important implications on the geographical distribution of GI and access for communities, the climate and GI education and engagement of communities, and the way planning processes in cities recognize the role of GI and the design and implementation of GI in rapidly growing urban areas.

1. Introduction

Urbanization, while being a driver of economic development and capital infrastructure, also plays an essential role in contributing to environmental stress on cities in the Global South. The factors to consider here to

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maximise beneficial outcomes from cleaning and greening urban areas are numerous [1]. The urban-historic experience factoring in increased heat stress is particularly problematic. Heat stress is intensified in cities due to the urban heat island (UHI) effect, whereby urban areas are significantly warmer than adjacent rural areas, due to dense built environments, reduced vegetation and increased anthropogenic heat generation [2]. The health impacts are significant, with heat stress resulting in a range of health issues beyond discomfort (e.g., dehydration, heat exhaustion, heat stroke) after sufficient exposure to elevated temperatures [3]. The relationship between heat stress and health impacts experienced as cities grow, while real and urgent, has come to fruition with the increasing temperatures already associated with climate change and the steadily rising urban population in a global sense [4]. Amidst this concentration of heat stress, climate change, and city growth, public health concerns relative to heat stress and urban environments are increasingly appearing in climate adaptation discussions.

Due to the effects of high population density, unplanned urbanisation and a limited amount of green areas, the UHI phenomenon is especially severe in the secondary cities of Bangladesh like Rajshahi [3]. Rajshahi is located in northwestern Bangladesh and is notorious for high summer temperatures and is a frequent list-topper among the warmest cities in the country [5]. With a climate that features extended dry seasons and little rainfall when it is most needed in the summer months, the intensity of the UHI effects are also heightened. Additionally, insufficient urban vegetation in various parts of the city particularly in informal settlements and low-income housing, means that available urban vegetation is unable to provide the cooling services it would typically offer [6]. Moreover, inhabitants in informal settlements have limited opportunities for adequate ventilation due to inadequate room congestion and poorly ventilated homes constructed from tin roofs [7]. As a result, residents are at an elevated risk of heat exposure while already strengths of oppression and marginalisation are pronounced.

Heat-related illnesses (HRIs) that range from heat rashes, dehydration, and heat strokes to cardiovascular problems, are being increasingly recorded in urban slums - where rights holders rarely access health services, cooling technologies, and knowledge about heat management behaviours [8]. The elderly, the very young, pregnant women, and people with chronic health conditions are more vulnerable to HRIs [9]. While planning for urban climate resilience has started to receive attention globally, there remain knowledge gaps on how to quantify the health-protective effects of green infrastructure (GI) for the socio-economically disadvantaged pockets within South Asian cities [10]. GI, a concept that describes planned socio-ecological systems at all scales, which include urban trees, parks, gardens, and vegetated rooftops, has been shown to mitigate urban heat island (UHI) which leads to HRIs; and provide a range of essential ecosystem services including air filtration, temperature regulation, and psycho-social benefits [11].

In the realm of climate adaptation and public health, green infrastructure (GI) can be seen as both a preventative approach (by preventing heat stress) and as a remedial approach (by improving health outcomes). GI can significantly reduce ambient air temperatures through shade and evaporative cooling (or evapotranspiration) which mitigate heat risk [12]. In cities like Rajshahi, which experiences both environmental risk and limited adaptive capacity, GI represents low-cost, community-scale adaptation measures that can provide immediate relief from thermal discomfort, thereby delivering better health outcomes [13]. Accessing this type of infrastructure is often inequitable, usually limited to middle - and high-income neighbourhoods. Low-income and informal settlements, often referred to as slums, often lack street trees, parks and vegetation of any type to buffer against climate effects. As a result, people living in low-income communities are significantly exposed to the health and well-being impacts of acute heat waves [14].

Preceding studies from multiple geographic contexts have identified the influence of GI on diminishing urban microclimates and better, human thermal comfort. Studies from China, India, and Brazil, for example, found greater tree canopy cover and distances to parks and greenspace were associated with a reduced frequency of HRIs and self-reporting improvements in health among urban populations [15]. However, this evidence is limited in Bangladesh, particularly for areas outside of the capital, Dhaka. Most of the existing studies either examine urban environmental quality as whole, or even worse, rely heavily on remote sensing and GIS-based officer measurements of heat. While each of these provides useful metrics on heat, they do not capture household experiences, perceptions, and adaptations especially those of the poor and vulnerable [6].

There are several important characteristics that make Rajshahi City a suitable case study. First, Rajshahi is a city that already experiences severe urban heat stress conditions, especially in pre-monsoon and summer seasons, so it is an important case to study around these heat stress related vulnerabilities. Second, it is a secondary city, which has considerable urbanization and informal settlements that have increased this vulnerability, generally speaking from poor housing and limited access to adaptive infrastructure. Third, Rajshahi has implemented some greening programs (e.g., roadsides tree plantation, park rehabilitation, riverside beautification) that will allow for a more in-depth assessment of the success and accessibility of GI interventions after implementation. Lastly, Rajshahi has a manageable governance context that is modestly scaled geographically, which is a useful transition to better understand neighborhood level differences in access to GI and perceptions of heat stress in rapidly urbanizing South Asian cities. Even with its acute exposure to urban heat, there have been numerous greening schemes in the past decade such as tree planting along roadsides, and parks and beautification development along the rivers. There are questions, however, as to how much this has led to positive thermal comfort and associated health benefits for low-income residents living in informal settlements. Therefore, an urgent research need exists to investigate the links between access to GI, usage of GI, and health outcomes due to heat stress in the context of slum populations in Rajshahi.

This study seeks to fill this gap by evaluating whether and how much green infrastructure is a contributor to reducing heat vulnerability to health in specific selected slums in Rajshahi City Corporation. It uses a household survey, physical observation, and statistical modeling to consider how proximity to and use of GI correlates with self-report illness from heat and to consider how socio-economic status of the participant—income, household size, and vulnerable individuals—intervened against their neighbouring environmental exposure to explain health outcome. Several past studies have evaluated social-environmental determinants of heat vulnerability, using GIS-based and spatial methods, such as remote sensing and spatial correlation analysis. For example, Palanisamy et al. [1] and Sadat et al. [5] used geospatial data to examine urban heat island effect and measures for mitigation of urban heat. Likewise, Gao et al. [3] used spatial datasets to assess exposure to heat by population, and cooling potential of green and blue infrastructure. In contrast, this study utilizes statistical methodologies including logistic regression and mediation analysis, to provide similar empirically informed conclusions about socio-environmental constructs and relations.

In this way, the study ultimately seeks to integrate environmental planning and public health research to illustrate green infrastructure as not only the aesthetic and ecological benefits, but as the essential protection of health from worsening climate risk. Overall, if GI could be woven into the central core of urban development policies, along with multiple stakeholders there is potential to deliver better thermal comfort, and healthy, climate-responsive, inclusive cities. The use of GI is especially crucial in secondary cities with rapid growth patterns like Rajshahi where appropriated resources are limited, infrastructure gaps are widely recognized, and the lived experience costs of climate inaction currently exist on the ground.

2. Literature Review

Green Infrastructure and Urban Health Outcomes

In low- and middle-income countries (LMIC), urban heat stress is a major health risk due to rapid urbanization and climate vulnerabilities. Urban areas in the LMIC have seen an increase in surface urban heat island intensity (SUHII), with low-income areas experiencing about a 27% increase in daytime SUHII [16]. Urban heat islands (UHI) represent an increase in urban temperature related to the surrounding suburban or rural temperature section. The public health implications of increased temperatures linked with UHI include everything from mild heat discomfort to serious heat injuries and illnesses. Prolonged exposure to elevated temperatures such as heat exhaustion increased risks for heat-related illnesses along with heat cramps and heat stroke [17].

Green Infrastructure (GI), such as parks, trees, green roofs, and blue-green spaces, is an environmentally and public health acceptable option to reduce the UHI effect. In LMIC contexts, GI has two roles - it changes the micro-climate of the urban area, and GI will also provide opportunities for resilience to heat and flooding events. Vegetation will, in particular trees, by being a natural tool to control urban cooling will reduce air temperatures by as much as 1.6°C [18].

Beyond the thermal effects, GI can provide support towards stormwater management systems and mitigation of urban flooding events - which in most LMIC cities will be faced continually dense urbanization and heavy rain events with insufficient drainage designs [11]. Furthermore, GI will also support urban biodiversity, which will, as we have already learned, provide climate change, ecological, and psychological benefits that will help create healthy cities of the future.

The inclusion of green infrastructure into urban landscapes leads to better public health outcomes. Access to green space offers numerous benefits. Physical and mental health, better stress management, improved physical activity, and better social interaction are all tied to access of green space [19], [20]. As more people in lower middle income and middle income countries deal with infectious diseases and other environmental health challenges, these health advantages are even more important.

Community engagement in the planning and development of GI and later in the management of GI, allows opportunities for social cohesion and improved environmental justice. When GI planning incorporates participatory approaches and includes the residents in the planning process, it adds to the usability and upkeep of green spaces and also serves to equalize access and reflect the community's needs [11].

Strategic Planning and Governance of Green Infrastructure and Scenario in Bangladesh

The effective initiation of GI in urban areas demands the realization of strategic planning and good governance. An integrated approach is thus required to overcome traditional sectoral barriers. Collaborative governance can be employed in planning for enhanced resilient and inclusive urban environments by involving urban planners, public health professionals, and community representatives [21].

In developing policies, certainly positioning GI as invaluable to the urban health strategy will be essential to its sustainability as a climate-resilient and environmentally sustainable entity. In LMICs, where there are growing constraints of finance and institutions, building local capacity and garnering political support are necessary ingredients for the long-term success of GI projects [15].

For max health advantages, GI has to be established with high quality, good accessibility, and ecologically functioning. Healthy green spaces have a positive impact on health outcomes, especially when located close to communities that require the green space in order to diminish health equity [22]. People 80 +, whose older age puts them at risk of heat exposure and mobility constraint, would benefit from public parks and recreational spaces whose design is easily accessible [16].

Vegetation richness creates more value for GI by supplying more diverse ecosystem services. A more diverse plant diversity is associated with better air quality and greater biodiversity, as well as psychological benefits such as reducing stress and increasing mental well-being [22], [23]. Informal greening, including roadside plants and community gardens, adds to the ecosystem value of urban spaces.

Natural green infrastructure (NGI) is a very low-initial-cost option, and low-maintenance alternative to traditional parks (e.g. forests and wilderness). NGI can also liven vacant and distressed urban land by activating these spaces through greening that can decrease crime and foster mental well-being and social interaction [23]. This is particularly relevant to LMICs where resources to build parks and develop new built spaces can be limited. On an important last note, while the health benefits offered through other forms of GI, such as green roofs and rain gardens, are emerging reality, little has been undertaken to explore and assess how these evolving formats can affect public health in more diverse urban contexts [24].

Urbanization across Bangladesh-the-rising emerging-low-and-mid-income countries-and-their-ecosystem-hinterlands-relevant lookouts- thus underscores the importance of GI as an instrument in alleviating urban heat. Urban-afforested areas have helped reduce surface and air temperatures considerably (e.g., Rajshahi and Dhaka). Indeed, green spaces have established air temperature reductions of up to 10 Kelvin, which enhance thermal comfort, thus increasing livability in cities [5].

An evident strong positive association exists between Normalized Difference Vegetation Index (NDVI) and the calculated Heat Mitigation Index (HMI): this implies the ability of vegetation to mitigate urban heat. Increase one unit in HMI; temperatures in air decreased by as much as 2.80°C [25]. Furthermore, green walls and roofs reduced ambient temperatures by as much as 17°C, making these cooling strategies potentially space-saving in extremely high-density built environments [6].

Statistical Approaches in Heat-Health Research

Correctly analyzing statistics is a critical step for understanding the complex interactions between heat exposure(s) and health outcomes. Distributed lag non-linear models, or DLNMs, are popular in time-series studies as they allow for ample flexibility to address both non-linear and delayed effects of temperature on health to allow for time delay (time-lags) between exposure to heat and associated health responses. DLNMs can yield more refined relationships between exposure and risk to health [26].

Conditional logistic regression is used easily and often in case-control, and case-crossover studies to analyze the relationships between heat and selected health outcomes, such as hospital admissions, and mortality [27]. Descriptive logit models are more commonly used in the regions / locations that have robust health surveillance systems such as in Australia [28]. Two-stage time series modeling blends local analyses with meta-analytic design to allow for research on heat-health associations across multiple areas [29]. By pooling data from regions with differing climates and geographic locations, researchers gain an advantage in the generalizability of their findings.

The findings for heat-related mortality across these studies suggest a decline in heat mortality in several (many) countries, reaffirming the role of public health interventions and upgraded infrastructure [29]. The reliability of these results will depend on the data quality, geographic representation, and design quality [19].

Identified Research Gaps and Contribution of This Study

While awareness of green infrastructure (GI) is rising, most research has been focused on rich countries and megacities, resulting in a lack of understanding of GI's function in small, vulnerable South Asian cities like Rajshahi that experience intersections of heat vulnerability, poverty, and planning pitfall. Many studies do not characterize informal settlements separately, and little attention has been paid to include community understandings of GI into quantitative models of GI. Beyond this, few studies have investigated the extent to which GI can reduce heat-related health risks in slums, especially in consideration of the link between GI proximity, use by residents, and health benefits – a significant gap for countries in the Global South. In a future study, we hope to bridge these gaps through GI accessibility and experience within low-income communities in Rajshahi using a household survey to statistical model green access, use, and health outcomes along with community perspectives. This research could provide a model to be replicated in the Global South with an emphasis on providing applicable evidence for urban planners and public health officials in Bangladesh.

3. Methods and Materials

Study Area

This research project took place in three neighborhoods of the Rajshahi City Corporation (RCC), Bangladesh, Choto Bonogram slum (Ward 19), Baze Kazla (Ward 24), and Chalk Kristan Para (Ward 17). These neighborhoods were selected based on high population density, low green space available, and high inequity of urban heat stress vulnerability factors. Furthermore, these neighborhoods displayed indicators typical of marginalized urban settlements in rapidly urbanising cities in the Global South, such as extreme levels of infrastructural deficits (i.e., absence of safe shelter, transportation, and food insecurity) combined with socioeconomic constraints, thus exposing residents to extreme levels of heat events. Choto Bonogram slum (Ward 19) is an informal settlement with an estimated population of 6,300 [30]. It represents a typical high-density neighborhood characterized by congested housing units, low vegetation cover, and limited access to formal cooling infrastructure such as parks or shaded public spaces. Baze Kazla (Ward 24), with a population of about 5,200 [31], is a mixed-income area currently experiencing rapid urban development, leading to a noticeable reduction in open green space over the past five years. Chalk Kristan Para (Ward 17) hosts around 2,000 residents [30] and exemplifies spatial and social marginalization, with poor landscape planning and extensive surfaces exposed to direct solar radiation. Field observations and key informant interviews [32] also confirmed a lack of GI interventions and poor housing orientation, further increasing thermal vulnerability.

These neighborhoods were chosen to highlight different urban heat vulnerability profiles, and to illustrate the environmental injustices that low-income and informal urban communities face. In assessing green infrastructure (GI), this investigation focused on the accessible and current forms of GI in and around the selected neighborhoods. This study considers various types of green infrastructure including roadside trees, community parks, private gardens, vegetative roofing, unpaved green patches, and NGO-initiated tree planting efforts as key elements influencing urban heat mitigation.

Even if green roofs and vertical gardens (green walls) perform positively and are supported in theory, they were not included in the study due their limited availability and adoption in the local urban context. Likewise, formal stormwater green infrastructure (bioswales, permeable pavements, etc.) was excluded due to a lack of meaningful implementation of these interventions and their design in the selected neighborhoods.

This localized approach means the assessment incorporates understanding how existing and often informal or poorly maintained GI can work to mitigate heat where it is needed most and not well planned for or invested in constricting infrastructure.

Data Collection and Analysis

This research used both primary and secondary data to better understand the role of green infrastructure (GI) in reducing urban heat stress and health impacts in selected vulnerable neighbourhoods of Rajshahi City Corporation. Primary data were collected from household surveys, direct field observations conducted in the three purposively selected neighbourhoods: Choto Bonogram (Ward 19), Baze Kazla (Ward 24), and Chalk Kristan Para (Ward 17). The neighbourhoods were selected given their higher population densities, poor quality housing, and minimal green area provided to residents, giving them greater vulnerability to heat stress. Secondary data were obtained from relevant municipality reports, previous research, and satellite imagery to aid spatial analysis of vegetation cover and surface temperature.

A stratified random sampling method was used to ensure adequate representation of all socioeconomic groups within neighbourhoods. Each neighbourhood was further divided into informal blocks. Roughly, a proportional number of respondents were randomly selected from each block. A total sample size 200 household surveys were conducted with 90 in Choto Bonogram (N = 6,300), 70 in Baze Kazla (N = 5,200), and 40 in Chalk Kristan Para (N = 2,000). Sample size was calculated using Cochran's sample estimation formula, at a 95% confidence level and after considering an estimated 85% response rate.

Data collection instruments included a semi-structured household survey questionnaire and a field observation checklist to catalogue green infrastructure components. The household survey included questions on socio-demographic characteristics; awareness about, and experiences with, heat stress; perceived health effects; and access to green spaces or other cooling solutions. The field observations involved coding the presence or absence of GI elements, condition of housing materials, and access to shade or open space.

The main dependent variable in this study was the Perceived Heat Stress Index (HSI), which was developed based on residents' reported experiences of symptoms of heat exhaustion, discomfort and heat stress indoors, and self-assessed health deteriorations during the summer months. Independent variables included proximity and presence of green infrastructure, types of housing materials, access to cooling resources, their economic status, exposure to heat as a job, presence of vulnerable members, perceived tree shading and distance to green space.

Data were analyzed using both quantitative and spatial methods. Descriptive statistics summarized household characteristics, heat exposure, and access to green infrastructure. The study performed correlation and multiple regression analyses to examine the relationships between GI variables and the Heat Stress Index. Moreover, heat stress scores were calculated based on each respondent's own assessment of thermal discomfort on a scale of 0–10, with 0 meaning no stress and 10 meaning extreme heat stress. The mean score for each neighborhood was calculated by taking the mean of all applicable individual responses.

4. Results and Discussion

Among the three neighborhoods surveyed, Choto Bonogram had the most heat stress (7.8/10) given its low green infrastructure (22%), longer average distance to green space (320 meters), and lower average income (BDT 9,500/month) (**Table 1**). The permeable vegetation, narrow streets, close housing, and lack of wind, as well as lack of vegetation made the urban heat island effect worse. In addition, the overwhelming presence of tin roofs and not having access to technology that can enhance physical cooling for residents' exacerbated thermal discomfort among residents. Chalk Kristan Para, on the other hand, had the highest green infrastructure presence (35%) the shortest distance to green areas (250 meters), and the highest average income levels likely contributed to the lowest average heat stress (6.5/10). The extensive coverage of community gardens, with plenty of trees, as well as having alleys that contain vegetation that residents actively use—particularly older residents—provides the relative resilience among slums in Chalk Kristan Para.

Table 1: Descriptive summary of the neighborhoods:

Neighborhood	Population	Avg. Heat Stress Score (0–10)	Avg. Income (BDT/month)	Avg. Distance to GI (meters)	GI Presence (%)
Choto Bonogram	6300	7.8	9500	320	22%
Baze Kazla	5200	7.1	10500	280	28%
Chalk Kristan Para	2000	6.5	11000	250	35%

Baze Kazla was in the middle in terms of outcomes—it had moderate green infrastructures (28%), a slightly better distance to greenery (280 meters), and a mid-range income (BDT 10,500/month) which corresponds with a heat stress index of 7.1. It benefited from some shading by foliage and had some community presence and encouragement to engage with the few green spaces available, but maintenance and the lack of permanent vegetated cover left them ineffective. Overall, the analysis shows neighborhoods in which the presence of green infrastructure and socioeconomic capacity to engage with it will be much better off in terms of heat stress than those that do not have both.

Statistical Modeling of Heat Stress Determinants

The relationship of various environmental and socio-economic factors on the likelihood of residents perceiving high heat stress was examined using a logistic regression model (**Table 2**) and the correlation between the individual factors and heat stress are shown in **Figure 1**. **Figure 2** presents the odds ratios from the logistic regression model, highlighting the impact of GI proximity, shading, and vulnerable household members on heat stress perception.

The model was statistically significant (Model Chi-square = 47.6, df = 6, $p < 0.001$) and explained about 38% of the variance in heat stress perception (Nagelkerke R2 = 0.38). This indicates moderate predictive capability.

Table 2: Logistic Regression Results for Determinants of Heat Stress Perception

Variable	Coefficient (β)	Std. Error	Odds Ratio (Exp(β))	p-value
GI proximity	-0.89	0.28	0.41	0.002
Frequency of GI use	-0.51	0.20	0.60	0.011
Income	-0.00004	0.00002	0.96	0.065
Household size	0.13	0.11	1.14	0.234

Variable	**Coefficient (β)**	**Std. Error**	**Odds Ratio (Exp(β))**	**p-value**
Vulnerable members	1.01	0.36	2.74	0.006
Shading	-0.62	0.25	0.54	0.014

Where, the Model Chi-square = 47.6, df = 6, $p < 0.001$ and Nagelkerke $R^2 = 0.38$.

The proximity of GI had a statistically significant, strong negative association with perceived heat stress ($\beta = -0.89$, $p = 0.002$). Residents that lived nearer to GI were much less likely to report high heat stress, probably due to decreased time to access cooling refuges.

The relationship between proximity and perceived heat stress was also reaffirmed by the Pearson correlation coefficient ($r = -0.68$). Frequency of GI Use also had a statistically significant negative association ($\beta = -0.51$, $p = 0.011$) with an associated odds ratio of 0.60. Increased GI use decreased perceived heat stress, particularly when utilization occurred in peak heat hours. The relationship was also moderate to strong according to the correlation coefficient ($r = -0.61$).

Household income was negatively, and modestly related to heat stress ($\beta = -0.00004$, $p = 0.065$), approaching statistical significance. The odds ratio (0.96) also indicates there was a small effect for every unit increase in income, and the Pearson correlation coefficient was $r = -0.53$, indicative of a moderate negative relationship. Because income likely improves access to adaptive measures, effective cooling in the home (fans, ventilation, reflective roofing materials, etc.) are likely to be much more affordable when household income is increased.

The coefficient for household size was positive ($\beta = 0.13$, $p = 0.234$) but did not achieve statistical significance. The odds ratio (1.14) indicates that, as household size increases, it was slightly more likely that the respondent assessed mental heat stress greater. The Pearson correlation coefficient was $r = 0.22$ indicating a weak positive relationship, likely from overcrowded conditions or limited space for cooling.

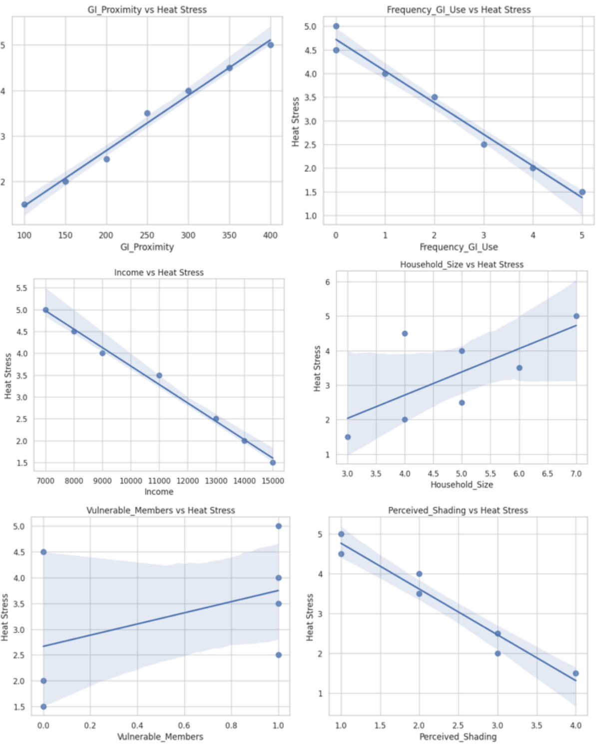

Figure 1: Correlation of the independent variables with heat stress.

Presence of Vulnerable Members had a strong positive and statistically significant relationship on heat stress ($\beta = 1.01$, $p = 0.006$), with an odds ratio of 2.74. Households that contained elderly, children, or chronically ill person, are much more likely to assess themselves as having high heat stresses compared to those without vulnerable members. The Pearson correlation coefficient was $r = 0.59$, indicative of a moderate to strong positive relationship involving those with the presence of vulnerable members.

Perceived availability of shade in the neighborhood significantly protected households from heat stress ($\beta = -0.62$, $p = 0.014$), resulting in an odds ratio of 0.54. The Pearson correlation coefficient was $r = -0.65$ indicating a strong inverse relatedness between perceived shade in the environment and heat stress was clearly indicated in the analysis. By having both natural and human-made shade nearby one clearly emphasized that value of shade.

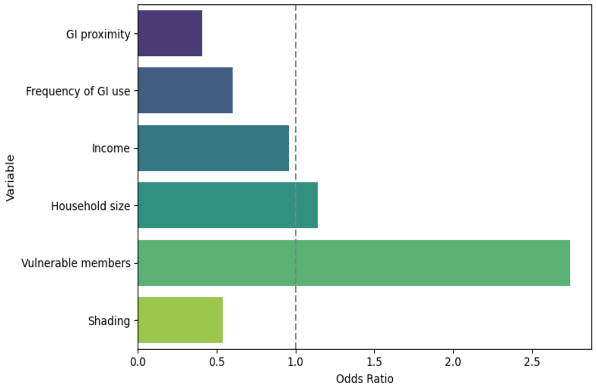

Figure 2: Logistic Regression: Odds Ratio of Heat Stress Determinants

In SPSS, we used the PROCESS macro to conduct a mediation analysis and determine if GI proximity mediates the relationship between household income and heat stress. The mediation analysis produced a significant indirect effect (ab = -0.21, 95% CI [-0.34, -0.09]), which suggested that higher-income households have better access to GI locations, which in turn leads to lower heat stress vulnerability. An interaction term which assessed relationship between the frequency of use across all GI types and presence of groups with vulnerable members was included in the model. The interaction term was statistically significant ($\beta = -0.49$, $p = 0.048$), which indicates the heat mitigation benefits of green spaces are particularly essential for households who have elderly or chronically ill members.

Community People's Understanding and Response

The qualitative data collected through in-depth interviews and open-ended survey responses served to provide greater contexts about residents' experiences of urban heat. In each of the neighborhoods surveyed, residents identified the hours from 1:00 PM to 4:00 PM to be the most thermally uncomfortable and indicated that this discomfort was due to the peak of solar radiation, little shading and lack of wind movement.

In an effort to cope with extreme heat, households implemented a variety of adaptive behaviors while their responses, one of the most common responses was to remain indoors during the peak heat hours of the day, utilize handheld or electric fans, and increase fluid consumption—primarily for cold water. Relying on vegetative shade (a key element of green infrastructure) was noticeably restricted, particularly with a few trees and green patches reported in Choto Bonogram. Only a few of the respondents in this neighborhood identified vegetative shade as an avenue of heat avoidance behavior. This indicates that people in low income areas, that also have dense populations, have little access to green land and outdoors habitats.

There was much variability in community preferences, and knowledge of GI between neighborhoods (**Figure 3**). In Chalk Kristan Para, which is a relatively greener area with more space around homes, 58% of residents supported additional tree planting because they viewed trees as providing (at least) cooling, cleaner air, and visual appeal. In contrast, only 35% of respondents in Choto Bonogram supported similar approaches. Much of the lower support stemmed from issues of space, limited communal open areas, and limited awareness of urban vegetation's ecological and temperature regulation benefits. In addition, residents from Chalk Kristan Para showed greater environmental literacy reflected in their articulating the role of green areas in lowering ambient temperatures, supporting biodiversity, and providing recreational benefits. A number of participants from this neighbourhood expressed their willingness to help maintain the shared green areas suggesting a greater sense of community ownership, in addition to a willingness to co-manage GI.

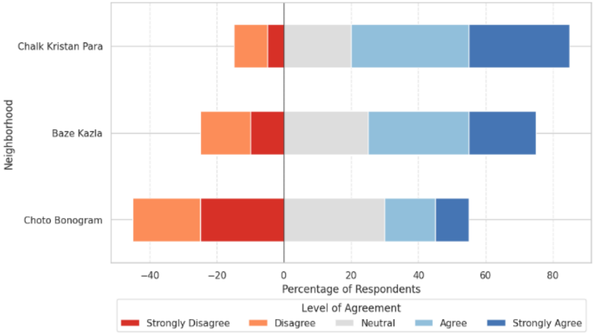

Figure 3: Local Attributes towards GI Maintenance

These results highlight the ongoing need for focused community education and participatory planning processes, especially in the more vulnerable neighbourhoods like Choto Bonogram. Highlighting the awareness gap, and engaging residents in planning, or maintenance, of GI, could support the social acceptability and long-term sustainability of urban climate adaptation strategies.

Policy Gaps in Equitable GI Provision

Urban greening and the installation of green infrastructure are intrinsically framed within urban planning systems. In Rajshahi City Corporation, there have been multiple beautification and roadside tree planting efforts undertaken, however there is limited integrated, equitable-planning policy related to informal settlements. A review of existing planning guidance suggests a need for more equitable avenues that normalizes GI in slum redevelopment; focus on access for those in vulnerable populations, and space-saving solutions, such as vertical greening, and green-roof and rooftop gardening.

5. Conclusion

The research explored the association between green infrastructure (GI) and perceived heat stress in three neighborhoods in Rajshahi City Corporation: Chalk Kristan Para, Choto Bonogram, and Baze Kazla. Utilizing statistical modelling and qualitative elements, the study yielded a diverse and comprehensive understanding of how urban vegetation, socioeconomic status, and behavior, in the context of neighborhoods, influenced heat vulnerability.

Every neighborhood indicated a consistent association between perceived heat stress and GI. Chalk Kristan Para had lower levels of heat stress with greater access to GI and a higher average income. The neighborhood Choto Bonogram with the highest perceived thermal discomfort had the highest density and lower income, as well as with little vegetation. Baze Kazla, in the middle of these two neighborhoods, with moderate GI access and perceived heat stress. Statistical modelling revealed an important negative correlation of heat stress with GI proximity ($r = -0.72$) and household income ($r = -0.53$). The current study therefore highlighted the protective nature of green cover and ability to economically buffer urban heat at the neighborhood level.

Behavioral and perceptual insights distinguished differences in behavior functions. The residents in all three neighborhoods indicated that 1 PM to 4 PM comprised the most uncomfortable period. It was evident that residents in Chalk Kristan Para were the most likely (frequently) to use vegetative shade. The level of awareness regarding GI benefits and support for tree planting was notably higher in Chalk Kristan Para (58%) compared to Choto Bonogram (35%), where residents were similarly constrained spatially and not sufficiently aware of green solutions to launch community engagement.

Logistic regression assured that distance to the nearest GI, the frequency of GI usage, and perceived shading, decreased the odds of reporting high heat stress levels, whereas the vulnerability of household members significantly increased the likelihood of reporting high heat stress. Mediation analysis confirmed that income decreases heat stress by increasing access to GI and showed an interaction effect in terms of frequent GI usage was beneficial especially for households with elder and chronically ill members.

These findings have substantial implications for policy. First and foremost, to support equitable distribution and consideration of distributed green infrastructure (GI) in urban adaptation policy, particular attention needs to be placed on how we equip the most populous and lowest income neighborhoods with GI interventions. Secondly, and directly related to the first point, we need to emphasize public education related to GI with a community capacity building approach at the outset of GI interventions. Thirdly, it should be an important element for public policy - beyond just municipal guidelines - to incentivize vertical greening, rooftop gardening, and small-scale urban forestry, especially where open space is limited [10], [16].. Lastly, since low-income residents in urban centers are disproportionately affected by heat stress, urban planning efforts must prioritize these vulnerable populations through targeted green infrastructure expansion, equitable access to cooling, and inclusive design of adaptation strategies. In summary, this study supports our conclusion that GI is beneficial as a spatial management tool to reduce urban heat stress. However, GI effectiveness is reliant on considerations related to social inequities, spatial distribution, and community engagement/support. Therefore, GI is a potential foundation for creating inclusive and sustainable urban development when taken to a whole-system, contextually sensitive, inclusive and participatory approach to urban planning.

References

[1] P. A. Palanisamy, K. Jain, A. Tiwari, J. Zawadzka, and S. Bonafoni, "Evaluating The Persistence Urban Heat Island and Its Impact on Vulnerable Populations," pp. 4032–4035, Sep. 2024, doi: 10.1109/IGARSS53475.2024.10640655.

[2] J. Pontius and A. McIntosh, "Urban Heat Islands," pp. 119–133, 2024, doi: 10.1007/978-3-031-48762-0_10.

[3] S. Gao et al., "Urbanization-induced warming amplifies population exposure to compound heatwaves but narrows exposure inequality between global North and South cities," NPJ Clim Atmos Sci, vol. 7, no. 1, Dec. 2024, doi: 10.1038/S41612-024-00708-Z.

[4] N. Osborne Jelks and J. C. Gonzalez, "Urban heat islands and associated health effects for vulnerable populations: Exploring data, technology, and community-engaged research to advance health equity," Global Climate Crisis: Seeking Environmental Justice and Climate Equality, pp. 42–63, Jan. 2025, doi: 10.4337/9781035308880.00007.

[5] N. Sadat, H. Sheikh, and M. Asaduzzaman, "Evaluating Urban Heat Island Mitigation Strategies in Rajshahi, Using ENVI-Met: A Remote Sensing Approach," Journal of Contemporary Urban Affairs, vol. 8, no. 2, Sep. 2024, doi: 10.25034/IJCUA.2024.V8N2-15.

[6] M. M. Patwary et al., "Heat stress perception, knowledge levels and health consequences of urban heat in major cities in Bangladesh," Nov. 2023, doi: 10.32942/X2060P.

[7] A. T. Ekra et al., "Changes in human heat discomfort and its drivers in Bangladesh," Urban Clim, vol. 55, May 2024, doi: 10.1016/J.UCLIM.2024.101884.

[8] J. Utzinger and J. Keiser, "Urbanization and tropical health - Then and now," Ann Trop Med Parasitol, vol. 100, no. 5–6, pp. 517–533, 2006, doi: 10.1179/136485906X97372.

[9] S. Singh, P. Priyadarshni, and P. Pandey, "Impact of Urban Heat Island: A Local-Level Urban Climate Phenomenon on Urban Ecology and Human Health," pp. 113–128, 2023, doi: 10.1007/978-981-99-3006-7_5.

[10] P. Herath and X. Bai, “Benefits and co-benefits of urban green infrastructure for sustainable cities: six current and emerging themes,” Sustain Sci, vol. 19, no. 3, pp. 1039–1063, May 2024, doi: 10.1007/S11625-024-01475-9.

[11] S. Pauleit, R. Hansen, E. L. Rall, and W. Rolf, “URBAN GREEN INFRASTRUCTURE: Strategic planning of urban green and blue for multiple benefi ts,” The Routledge Handbook of Urban Ecology: Second Edition, pp. 931–942, Jan. 2020, doi: 10.4324/9780429506758-79.

[12] E. Lemoine, “Evaluation of Green Infrastructure Benefits in Urban Areas in Paris,” Int J Environ Sci, vol. 7, no. 2, pp. 38–47, Jul. 2024, doi: 10.47604/IJES.2737.

[13] A. Almusaed, “The Green Areas Benefits Upon Urban Sustainability Role,” Biophilic and Bioclimatic Architecture, pp. 151–157, 2011, doi: 10.1007/978-1-84996-534-7_11.

[14] S. Khalili, P. Kumar, and L. Jones, “Evaluating the benefits of urban green infrastructure: Methods, indicators, and gaps,” Heliyon, vol. 10, no. 19, Oct. 2024, doi: 10.1016/J.HELIYON.2024.E38446.

[15] M. J. Nieuwenhuijsen, “Green Infrastructure and Health,” Annu Rev Public Health, vol. 42, pp. 317–328, Apr. 2020, doi: 10.1146/ANNUREV-PUBLHEALTH-090419-102511.

[16] N. H. Wong, C. L. Tan, D. D. Kolokotsa, and H. Takebayashi, “Greenery as a mitigation and adaptation strategy to urban heat,” Nat Rev Earth Environ, vol. 2, no. 3, pp. 166–181, Mar. 2021, doi: 10.1038/S43017-020-00129-5.

[17] T. Kjellstrom, “Climate change, direct heat exposure, health and well-being in low and middle-income countries,” Glob Health Action, vol. 2, no. 1, 2009, doi: 10.3402/GHA.V2I0.1958.

[18] V. Huber, S. Breitner-Busch, C. He, F. Matthies-Wiesler, A. Peters, and A. Schneider, “Heat-Related Mortality in the Extreme Summer of 2022,” Dtsch Arztebl Int, vol. 121, no. 3, pp. 79–85, Feb. 2024, doi: 10.3238/ARZTEBL.M2023.0254.

[19] C. Stephens and D. Brown, “Global Issues: Urban Health in Low- and Middle-income Countries,” International Encyclopedia of Public Health, pp. 581–590, 2025, doi: 10.1016/B978-0-323-99967-0.00025-9.

[20] J. C. Johnson and S. Galea, “Urban Health in Low- and Middle-Income Countries,” Making Healthy Places, pp. 350–365, 2011, doi: 10.5822/978-1-61091-036-1_23.

[21] S. Pauleit, A. Vasquéz, S. Maruthaveeran, L. Liu, and S. S. Cilliers, “Urban Green Infrastructure in the Global South,” Cities and Nature, vol. Part F337, pp. 107–143, 2021, doi: 10.1007/978-3-030-67650-6_5.

[22] M. Dennis, P. A. Cook, P. James, C. P. Wheater, and S. J. Lindley, “Relationships between health outcomes in older populations and urban green infrastructure size, quality and proximity,” BMC Public Health, vol. 20, no. 1, May 2020, doi: 10.1186/S12889-020-08762-X.

[23] M. L. McKinney and A. VerBerkmoes, “Beneficial Health Outcomes of Natural Green Infrastructure in Cities,” Current Landscape Ecology Reports, vol. 5, no. 2, pp. 35–44, Jun. 2020, doi: 10.1007/S40823-020-00051-Y.

[24] P. Suppakittpaisarn, X. Jiang, and W. C. Sullivan, “Green Infrastructure, Green Stormwater Infrastructure, and Human Health: A Review,” Current Landscape Ecology Reports, vol. 2, no. 4, pp. 96–110, Dec. 2017, doi: 10.1007/S40823-017-0028-Y.

[25] M. M. Rahman and J. Hasan, “Evaluating the Impact of Green Spaces on Urban Heat Reduction in Rajshahi, Bangladesh Using the InVEST Model,” Land (Basel), vol. 13, no. 8, Aug. 2024, doi: 10.3390/LAND13081284.

[26] X. Yang, X. Xu, Y. Wang, J. Yang, and X. Wu, “Heat exposure impacts on urban health: A meta-analysis,” Science of the Total Environment, vol. 947, Oct. 2024, doi: 10.1016/J.SCITOTENV.2024.174650.

[27] S. C. Sheridan and S. Lin, “Assessing Variability in the Impacts of Heat on Health Outcomes in New York City Over Time, Season, and Heat-Wave Duration,” Ecohealth, vol. 11, no. 4, pp. 512–525, Dec. 2014, doi: 10.1007/S10393-014-0970-7.

[28] P. M. Graffy et al., “Methodological Approaches for Measuring the Association Between Heat Exposure and Health Outcomes: A Comprehensive Global Scoping Review,” Geohealth, vol. 8, no. 9, Sep. 2024, doi: 10.1029/2024GH001071.

[29] W. Nicole, “Time and temperature: Changes in heat-related mortality over 27 years,” Environ Health Perspect, vol. 123, no. 11, p. A287, Nov. 2015, doi: 10.1289/EHP.123-A287.

[30] APN, "Factsheet Rajshahi City in Bangladesh," 2023. [Online]. Available: https://www.apn-gcr.org/wp-content/uploads/2023/06/Factsheet-Rajshahi-City-in-Bangladesh.pdf

[31] M. M. Rahman et al., "Developing Evidence on Water, Sanitation and Hygiene Facilities in the Climate Vulnerable Slums through WASH Poverty Index: A Case Study on Selected Slums in Rajshahi City Corporation, Bangladesh," 2021

[32] M. M. Rahman, M. R. Hasan, and M. A. Razzak, "Towards Green and Climate-Resilient Urbanization in Rajshahi City: Urban Growth Meets Climate Action in Northern Bangladesh," 2024