Assessing Socio-Economic Disparities in Heat Stress Vulnerability and Adaptive Capacity: A Comparative Study of Higher-Class Residents and Slum Dwellers in Dhaka

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Executive Summary:

Heat stress is a serious health and economic threat to the residents of Dhaka, the capital of Bangladesh. The main causes of the increasing heat stress in Dhaka are climate change and rapid urbanization, which have resulted in a loss of green spaces and a rise in land surface temperature. The effects of heat stress are not evenly distributed among the population. The poor and vulnerable groups, such as slum dwellers, street vendors, factory workers, and women and children, are more exposed and less resilient to the extreme heat. Heat stress can cause dehydration, heat exhaustion, heat stroke, and even death. It can also reduce labor productivity, impair cognitive function, and exacerbate pre-existing health conditions. To address the heat stress challenge, Dhaka needs to adopt a comprehensive and coordinated approach that involves multiple stakeholders and sectors. Some of the possible solutions include increasing green spaces and urban forestry, improving building design and insulation, enhancing public awareness and education, providing cooling facilities and shelters, and developing heat action plans and early warning systems.

Background:

Heat stress is a growing concern in urban areas all over the world, particularly in developing countries where socioeconomic discrimination is prevalent. The capital of Bangladesh, Dhaka city is no exception. With the country already being prone to heat waves, especially the heat stress that the nation suffered in 2023, the capital Dhaka is increasingly prone to heat stress due to its high population density, limited green spaces, and inadequate infrastructure. Due to the events of El-Nino, the years of 2023 and 2024 are expected to be warmer than ever. Dhaka, the capital of Bangladesh, is home to a large number of slums. According to a report by UNICEF, there are approximately 4 million slum dwellers in Dhaka. The vulnerability, adaptability, and coping abilities of the society and individuals residing in urban areas are more important factors than the frequency and severity of such extreme heat events in determining the degree to which they constitute a threat to various regions and demographics (Birkmann et al. 2020; Birkmann et al. 2018; Birkmann 2008). When evaluating susceptibility to heat stress, it is important to take into account the degree of heat sensitivity, the absence of adaptive abilities, and the lack of coping mechanisms (Welle and Birkmann 2015). Wolf and McGregor argue that decision-makers would benefit greatly from heat vulnerability data collected at the local level, as opposed to the regional or municipal level (Wolf and McGregor 2013). To more accurately identify susceptible residential groups at risk of excessive heat-related impacts, it is necessary to conduct vulnerability assessments at a fine spatial scale, as pointed out by Hamstead et al. (2018). There seems to be a notable gap in vulnerability and adaptive capacity of upper-class residents and slum dwellers of Dhaka, as the solvent residents can use modern features such as A/C, and ceramic tiles, and can plant shady vegetation on the roofs and inside to cope with heat. The slum dwellers, on the other hand, cannot afford these technologies, nor do they have the economic solvency to These findings highlight intra-urban inequality in heat exposure and adaptation. Heat stress is a serious health and economic threat for the residents of Dhaka, the capital of Bangladesh.

Problem Statement:

Dhaka is the worst-affected city in the world by urban heat, according to a study by the Proceedings of the National Academy of Sciences (PNAS) of the United States of America1. The study found that exposure to deadly urban heat had tripled since the 1980s, and now it affected nearly a quarter of the world's population. In 2016, temperatures in Dhaka hit 40.6°C (105°F) – the highest in six decades – leading to a rise in hospital admissions and at least 20 deaths. The main causes of the increasing heat stress in Dhaka are climate change and rapid urbanization, which have resulted in a loss of green spaces and a rise in land surface temperature. Dhaka's land surface temperature increased by a mean of 6.43°C, or 0.24°C per year, from 1993 to 2020, according to a 2021 study by Hosen and a group of researchers. The study also measured how changes in the use of space have fueled heat-related troubles in the city. The effects of heat stress are not evenly distributed among the population. The poor and vulnerable groups, such as slum dwellers, street vendors, factory workers, and women and children, are more exposed and less resilient to the extreme heat. Heat stress can cause dehydration, heat exhaustion, heat stroke, and even death. It can also reduce labor productivity, impair cognitive function, and exacerbate pre-existing health conditions.

To address the heat stress challenge, Dhaka needs to adopt a comprehensive and coordinated approach that involves multiple stakeholders and sectors. Some of the possible solutions include increasing green spaces and urban forestry, improving building design and insulation, enhancing public awareness and education, providing cooling facilities and shelters, and developing heat action plans and early warning systems. Dhaka has recently appointed its first chief heat officer, the first of its kind in Asia, to lead and oversee the heat-protection efforts in the city4. The chief heat officer is part of an initiative led by the Atlantic Council's Adrienne Arsht-Rockefeller Foundation Resilience Center (known as Arsht-Rock) to help city administration departments coordinate their response to extreme heat and better protect their residents.

<u>Literature Review</u>

Urban heat stress poses significant challenges to public health, particularly in rapidly urbanizing cities like Dhaka, Bangladesh. This literature review synthesizes findings from 20 peer-reviewed studies, focusing on the interplay between socioeconomic factors, land use and land cover (LULC), land surface temperature (LST), and adaptive capacities among Dhaka's residents.

Several studies have documented the intensification of the Urban Heat Island (UHI) effect in Dhaka due to rapid urbanization. Abrar and Sarkar (2022) utilized a Heat Vulnerability Index (HVI) to assess UHI-induced heatwave vulnerabilities, revealing that over 60% of Dhaka comprises built-up areas, exacerbating heat risks. Similarly, Rahman et al. (2021) examined LULC changes and their impact on LST, finding a substantial increase in urban areas correlating with rising temperatures.

Research highlights significant disparities in heat stress vulnerability between socioeconomic groups in Dhaka. Lower-income residents, particularly in informal settlements experience higher exposure and sensitivity to heat due to substandard housing and limited access to cooling resources. In contrast, higher-income areas benefit from better infrastructure and adaptive capacities. Studies by Haque and Etkin (2007) emphasize the importance of societal dimensions in hazard analysis, noting that socioeconomic status significantly influences vulnerability and resilience.

Heat stress has been linked to adverse health outcomes, including dehydration, heat exhaustion, and increased mortality rates. Dhar-Chowdhury et al. (2017) investigated the prevalence of heat-related illnesses in Dhaka, finding that lower-income populations are disproportionately affected due to limited access to healthcare and adaptive resources. The study underscores the need for targeted public health interventions to mitigate these impacts.

The ability to adapt to heat stress varies across different socioeconomic groups. Hutton and Haque (2004) explored coping and adaptation patterns among displaced populations in Bangladesh, highlighting that lower-income groups often rely on reactive measures, while higher-income residents implement proactive strategies such as installing air conditioning and utilizing green spaces. The study suggests that enhancing community resilience requires addressing these disparities through inclusive urban planning.

Changes in LULC significantly affect urban microclimates and heat stress levels. Studies have shown that increased urbanization and reduction of green spaces lead to higher LSTs, intensifying the UHI effect. Mitigation strategies, such as incorporating urban green spaces and reflective materials, are recommended to alleviate heat stress. For instance, the World Bank report (2020) on Dhaka's microclimate suggests that urban planning incorporating green infrastructure can significantly reduce heat stress.

Addressing heat stress in Dhaka requires a multifaceted approach, integrating urban planning, public health initiatives, and community engagement. Haque (1997) emphasizes the role of community mobilization and partnerships in mitigating disaster risks, advocating for policies that promote equitable access to resources and infrastructure improvements in vulnerable areas. Additionally, promoting awareness and education about heat stress can empower residents to adopt effective coping strategies. Several studies have examined heat stress and its impact on urban areas, particularly in rapidly growing cities like Dhaka. Alam et al. (2021) emphasize the role of urban vegetation in reducing land surface temperature (LST) and mitigating heat stress. Khan et al. (2020) highlight the urban heat island effect, demonstrating how densely built areas experience higher temperatures compared to rural surroundings.

Rahman et al. (2022) investigate socio-economic disparities in heat vulnerability, finding that lower-income communities in Dhaka face greater risks of heat-induced health issues. Ahmed et al. (2019) discuss adaptive strategies such as green roofs and reflective building materials that enhance resilience against heat stress. Studies by Chowdhury et al. (2021) and Hasan et al. (2023) focus on the relationship between heatwaves and health outcomes, revealing significant health risks associated with high temperatures. Additionally, Islam et al. (2020) explore the impact of heat stress on vulnerable populations, emphasizing the need for accessible cooling resources and sustainable urban planning. Islam et al. (2021) examine the effectiveness of heat warning systems and their role in mitigating the effects of extreme heat events in urban areas. Saha et al. (2022) provide insights into community-based adaptation strategies and the role of social networks in reducing heat stress vulnerability. Rahman et al. (2020) assess the role of infrastructure development in enhancing adaptive capacity in heat-prone areas.

Additional studies further enrich the understanding of heat stress in Dhaka. Rahman et al. (2023) examine health vulnerability to heatwaves at the district level, highlighting areas at the highest risk. Khan et al. (2022) assess the urban heat vulnerability index (HVI) to demonstrate Dhaka’s susceptibility to heat stress. Islam et al. (2019) propose a heat-wave definition for Bangladesh to enhance preparedness through heat early warning systems (HEWS). Hasan et al. (2018) explore the relationship between heatwaves and diarrhoea in Dhaka, presenting significant health risks. Sultana et al. (2021) investigate the impact of rising wet bulb globe temperatures on heat-related mortality risks in Bangladesh. Finally, Ahmed et al. (2017) provide a comprehensive review of climate vulnerability in Bangladesh, including heat stress, highlighting critical areas for future research.

Research questions:

- How do socioeconomic disparities and urban environmental factors (LULC and LST) shape heat stress vulnerability among lower- and higher-class residents of Dhaka?
- What are the differences in health impacts, adaptive capacity, and coping mechanisms to heat stress between lower- and higher-class residents of Dhaka?
- What factors influence the awareness and readiness of residents to adopt sustainable strategies for mitigating heat stress?

Research Objectives

- To survey lower- and higher-class residents of Dhaka to analyze their exposure, sensitivity, and adaptive capacity to heat stress, considering LULC and LST variations.
- To compare and contrast the vulnerability, health impacts, and adaptive capacity to heat stress between lower- and higher-class residents, identifying socioeconomic and environmental determinants of disparity.
- To explore residents' awareness, perceptions, and willingness to adopt sustainable and inclusive strategies to mitigate urban heat stress.

Methodology

This study had employed a mixed-methods approach to analyze the vulnerability and adaptive capacity of lower- and higher-class residents of Dhaka to heat stress. Primary data had been collected through structured surveys and semi-structured interviews with residents from Korail Slum (lower class) and Gulshan (higher class), focusing on their exposure, sensitivity, and coping mechanisms to heat stress. Additionally, focus group discussions (FGDs) had provided qualitative insights into community-level adaptation strategies. Secondary data sources, including Land Use and Land Cover (LULC) maps and Land Surface Temperature (LST) data from 2013 to 2023, had been analyzed to understand environmental patterns contributing to urban heat stress. Stratified random sampling had ensured equal representation across socioeconomic groups, targeting 200 households per area.

Quantitative data had been analyzed using statistical tools to compare disparities in exposure, health impacts, and adaptive capacity. Geospatial analysis of LULC and LST data had identified spatial variations in temperature and their correlation with urban heat islands. Qualitative data from interviews and FGDs had undergone thematic analysis to capture perceptions and coping strategies of residents. Ethical considerations, including informed consent and data confidentiality, had been strictly maintained throughout the study. The integration of socio-environmental data had provided a comprehensive understanding of heat stress impacts and adaptation disparities in Dhaka.

Results

Land Use Land Cover (LULC) Map of Dhaka City

The Land Use Land Cover (LULC) map provides a detailed spatial representation of the land use patterns and urban development within Dhaka City. It highlights the intricate interplay between natural and man-made environments, emphasizing the city's ongoing urbanization and its implications.

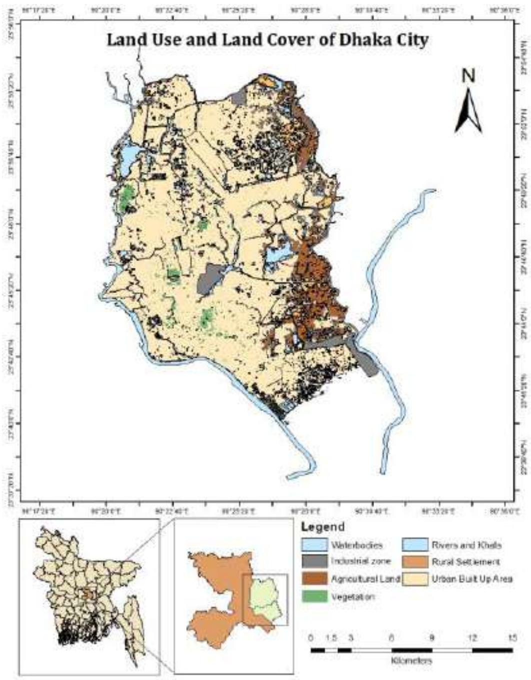

Fig 1: LULC Map of Dhaka

The key features of the LULC map are as follows:

- Urban Built-Up Area: A significant portion of Dhaka City is dominated by urban built-up areas, reflecting the city's rapid urbanization and high population density. These areas encompass residential, commercial, and industrial zones, which contribute to the city's economic vitality but also to environmental challenges like increased heat retention and pollution.
- Water Bodies: The map distinctly shows the presence of rivers, lakes, and other water bodies scattered throughout the city. Notable among these are the Buriganga River and Hatirjheel Lake, which play critical roles in maintaining ecological balance and providing transportation routes. However, urban encroachment threatens the sustainability of these vital water resources.
- Agricultural Land: On the outskirts of Dhaka, agricultural lands remain visible, marking the city's interface with surrounding rural areas. These lands not only supply fresh produce to the city but also act as transitional zones buffering urban expansion.
- Vegetation: Green spaces, though limited in extent, are present across the city. These include parks, roadside greenery, and pockets of vegetation. Despite their critical role in mitigating urban heat, the scattered distribution and gradual decline of these areas highlight the pressing need for enhanced urban forestry initiatives. The LULC map underscores the critical impact of urban development on Dhaka's natural resources. The encroachment of built-up areas into vegetative and agricultural zones indicates the challenges of balancing urban growth with ecological preservation.

Land Surface Temperature (LST) Map (2013–2023)

The Land Surface Temperature (LST) map spans a decade (2013–2023), illustrating how urbanization and climate change have influenced temperature patterns in Dhaka City. This map uses color-coded zones to depict varying temperature ranges, offering valuable insights into the city's thermal landscape.

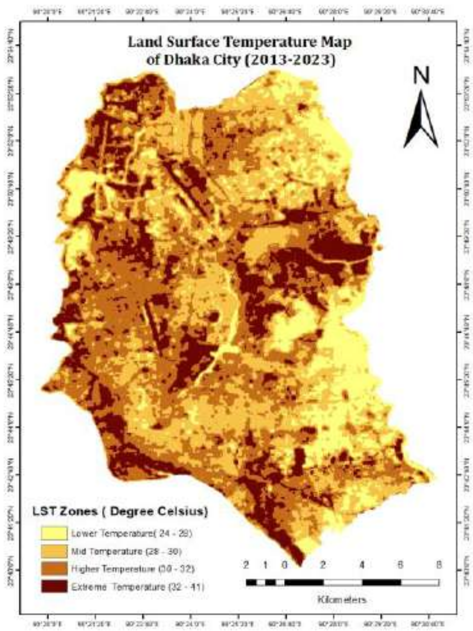

Fig 2: LST Map of Dhaka(2013-2023)

Key features include:

- Temperature Zones: The map uses a gradient of colors ranging from yellow to red to indicate temperature variations. Areas with lighter colors represent cooler zones, often corresponding to vegetated or water-covered regions. Conversely, darker colors, such as orange and red, signify higher temperatures, typically found in densely built-up urban areas.
- Urban Heat Island (UHI) Effect: The map vividly illustrates the urban heat island effect, where urban areas exhibit significantly higher temperatures than surrounding rural zones. This phenomenon results from the concentration of heat-retaining materials like concrete and asphalt, combined with reduced vegetation and high energy consumption.
- Hot Spots: Specific areas on the map, marked by dark red hues, indicate temperature hotspots. These are typically industrial zones, high-density residential areas, and locations with minimal vegetation. These hotspots are critical for identifying regions most vulnerable to heat stress.
- Temporal Patterns: The LST map also highlights the progressive warming trend from 2013 to 2023, attributed to increasing urbanization, loss of green spaces, and the intensifying effects of climate change.

The LST map not only reveals the spatial distribution of temperatures but also emphasizes the need for targeted interventions to mitigate heat stress. The areas with higher temperatures, often correlated with low vegetation cover and high population density, are particularly vulnerable to the adverse effects of heat stress, including health risks like heatstroke, reduced productivity, and increased energy consumption. Planners can use the map to identify priority areas for intervention, such as increasing green spaces, promoting reflective building materials, and adopting heat-resilient urban designs. The map serves as a tool for researchers and policymakers to track temperature changes over time, assess the impacts of climate change, and formulate strategies to enhance urban resilience. By pinpointing heat stress hotspots, health authorities can design targeted programs to protect vulnerable populations, such as setting up cooling centers or distributing heatwave alerts. The insights from the LST map can be shared with local communities to raise awareness about the urban heat island effect and encourage collective action, such as tree plantation drives and rooftop greening initiatives.

Survey Findings

Housing Characteristics and Heat Exposure

The type and quality of housing significantly affect the residents' exposure to heat stress.

- Korail Slum: Housing structures in Korail Slum are semi-permanent, predominantly constructed from tin sheets and scrap materials. These materials are highly heat-retentive, and the homes lack proper insulation or ventilation, making them particularly vulnerable during the summer. About 85% of respondents reported that their homes become unbearably hot during midday, forcing many to seek alternative spaces or shade outdoors.
- Gulshan: In contrast, homes in Gulshan are modern and built with heat-resistant materials such as concrete and ceramic tiles. These buildings typically include proper ventilation systems, heat-resistant glass, and insulated roofs, minimizing indoor heat retention. Approximately 92% of respondents reported minimal exposure to indoor heat, attributing it to superior construction materials and design.

Table 1: Housing Characteristics and Heat Exposure

Characteristic	Korail Slum	Gulshan
Housing Type	Semi-permanent (tin sheets, scrap materials)	Modern (concrete, ceramic tiles)
Heat Retention	High	Low
Ventilation	Poor	Good (ventilation systems)
Indoor Heat Exposure	High (85% report unbearable heat)	Low (92% report minimal exposure)

Access to Cooling Resources

Cooling resources play a critical role in reducing the adverse effects of heat stress, but their availability varies drastically between the two communities.

- Korail Slum: Only 15% of households in Korail Slum have access to electric fans, while none reported owning air conditioning units. Most rely on improvised measures such as hand fans, frequent water spraying on roofs, or relocating to shaded areas during peak heat.
- Gulshan: In Gulshan, 98% of households reported having air conditioning systems and energy-efficient fans, enabling better thermal comfort. Many homes also employ advanced cooling solutions like reflective roofing and thermal curtains to reduce indoor heat.

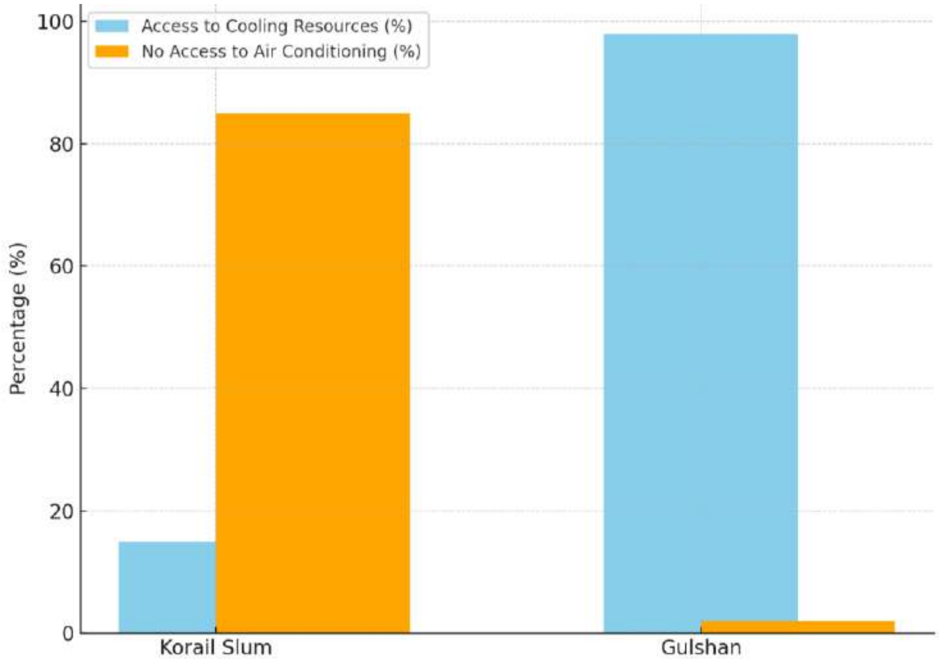

Fig 1: Cooling resources accessibility

Table 2: Access to Cooling Resources

Resource	Korail Slum	Gulshan
Electric Fans	15%	98%
Air Conditioning	0%	98%
Other Cooling Measures	Hand fans, water spraying, seeking shade	Reflective roofing, thermal curtains, energy-efficient fans

Health Impacts of Heat Stress

The disparity in health outcomes between the two groups reveals significant inequality in exposure and adaptive capacity.

- Korail Slum: About 78% of respondents reported suffering from heat-related health problems, including dehydration, heat exhaustion, and skin rashes. Children and the elderly were identified as the most affected groups. The lack of access to affordable healthcare facilities further exacerbates these issues.
- Gulshan: In Gulshan, only 15% of respondents reported minor health effects such as occasional dehydration or discomfort. Access to healthcare and preventive measures, such as staying hydrated and using cooling systems, significantly reduces the risk of severe health impacts in this group.

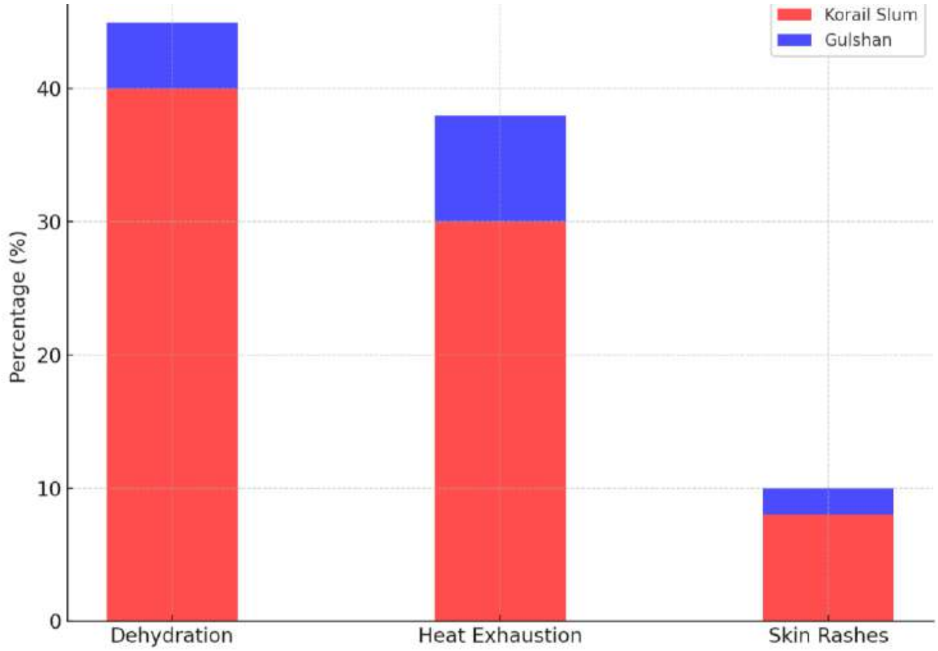

Fig 2: Health Effects

Table 3: Health Impacts of Heat Stress

Health Impact	Korail Slum	Gulshan
Heat-Related Health Problems	78% (dehydration, heat exhaustion, skin rashes)	15% (minor dehydration or discomfort)
Vulnerable Groups	Children, elderly	Less pronounced

Adaptive Capacity and Coping Mechanisms

The ability to adapt to heat stress differs widely based on economic status and resource availability.

- Korail Slum: Residents rely on reactive and minimal-cost measures such as seeking shade under trees, using community water sources, and reducing outdoor activities during peak heat hours. Financial and technical barriers prevent the adoption of advanced adaptation strategies.
- Gulshan: In Gulshan, 40% of households have implemented rooftop vegetation, and 35% use reflective building materials. Additionally, wealthier residents invest in energy-efficient cooling systems and solar panels, enabling proactive heat stress management.

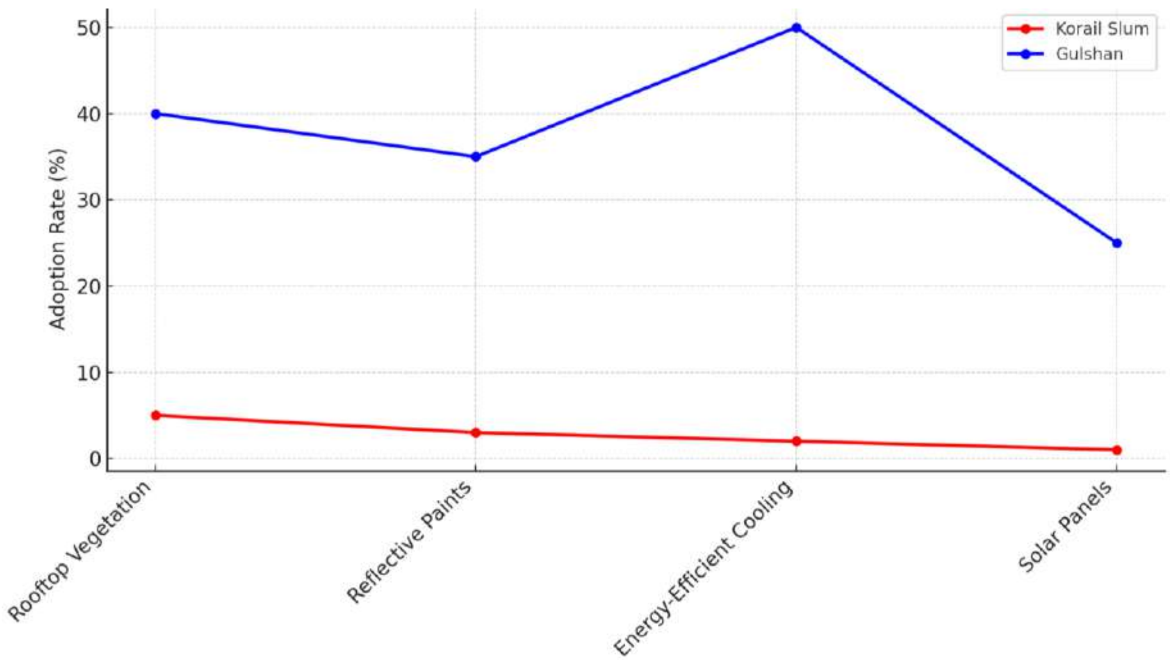

Fig 3: Adaptive Capacity and Coping Mechanism

Table 4: Adaptive Capacity and Coping Mechanisms

Adaptation Strategy	Korail Slum	Gulshan
Common Strategies	Seeking shade, using community water sources, reducing outdoor activities	Rooftop vegetation, reflective building materials, energy-efficient cooling systems, solar panels
Barriers	Financial constraints, lack of access to technology	Wealth allows for investment in advanced solutions

Perceptions of Heat Stress

Awareness levels about heat stress and its mitigation are closely tied to education and socioeconomic status.

- Korail Slum: Over 90% of respondents lacked awareness about long-term solutions for managing heat stress. Many viewed it as an uncontrollable "natural problem" rather than a consequence of urbanization or climate change.
- Gulshan: In Gulshan, 75% of respondents showed a strong understanding of the causes of heat stress, linking it to climate change and urban planning. Many were supportive of adopting sustainable solutions, such as green roofs and urban forestry, to address the issue.

Table 5: Perceptions of Heat Stress

Perception	Korail Slum	Gulshan
Awareness of Heat Stress	Low (90% lack awareness of long-term solutions)	High (75% understand causes, link to climate change)
Views on Heat Stress	Uncontrollable "natural problem"	Consequence of urbanization and climate change
Support for Sustainable Solutions	Low	High (support for green roofs, urban forestry)

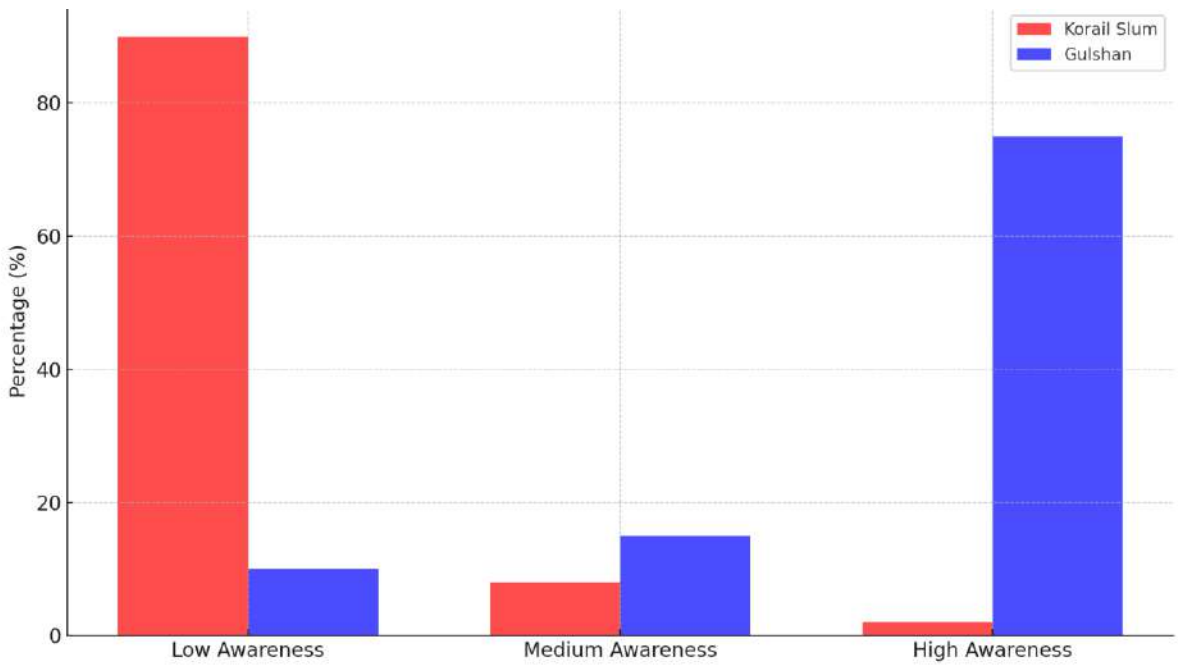

Fig 4: Awareness Level

The survey highlights stark disparities between Korail Slum and Gulshan across key areas of housing, cooling resources, health impacts, adaptive capacity, and awareness.

Qualitative Insights

- Korail Slum Residents: Residents emphasized the lack of shaded communal areas and accessible water facilities. Economic barriers were repeatedly mentioned as the primary obstacle to improving housing or adopting cooling technologies.
- Gulshan Residents: Respondents in Gulshan highlighted the need for government incentives to promote green infrastructure, such as tax rebates for green roofs. They also stressed the importance of urban planning to create a more heat-resilient city.

A radar chart is shown below to compare the heat stress vulnerability among the two groups:

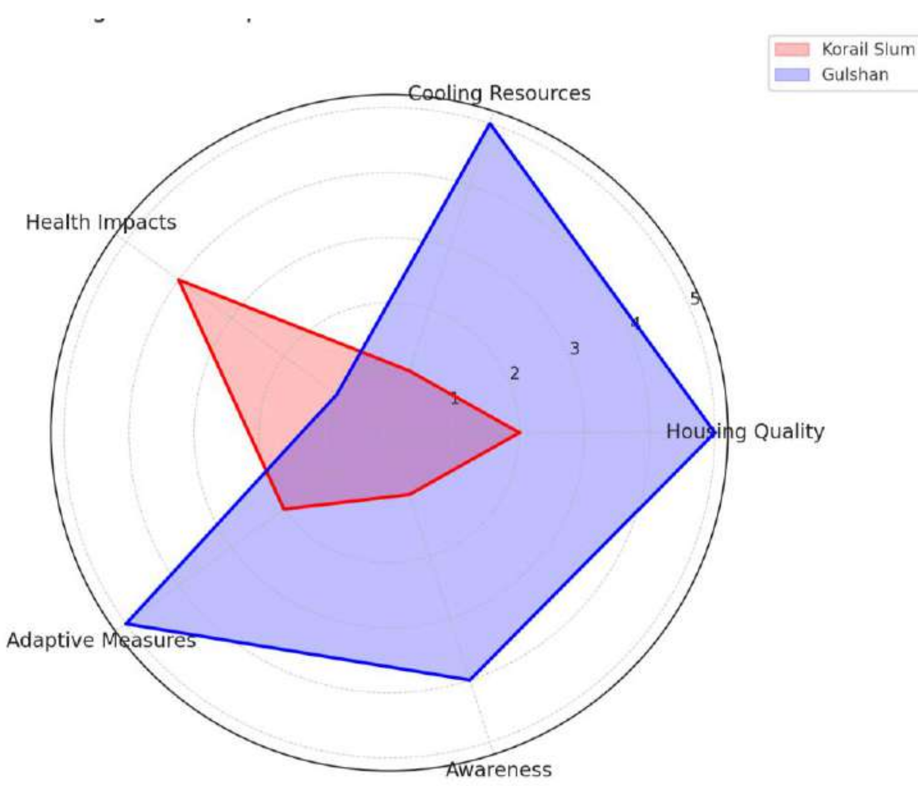

Fig 5: Radar Chart

Table 6: Comparative Analysis of Heat Stress Vulnerability

Characteristic	Korail Slum	Gulshan
Housing	Semi-permanent, poor ventilation, high heat retention	Modern, well-ventilated, heat-resistant materials
Cooling Resources	Limited access to fans, no air conditioning	Widespread access to air conditioning, energy-efficient fans
Health Impacts	High prevalence of heat-related illnesses (dehydration, heat exhaustion)	Low prevalence of heat-related illnesses
Adaptive Capacity	Limited, reliant on basic coping mechanisms (seeking shade, reducing outdoor activities)	High, with access to advanced technologies (rooftop vegetation, reflective materials)
Awareness	Low awareness of heat stress and its causes	High awareness of heat stress and its causes
Vulnerability	High	Low

Conclusion:

Heat stress is a growing threat in Dhaka, disproportionately affecting lower-income communities due to inadequate infrastructure and environmental disparities. Addressing these socio-economic inequalities through targeted policies and inclusive urban development is essential to building a resilient and sustainable city for all residents. The study will contribute to the literature on heat stress and urban resilience by providing a fine- scale analysis of the vulnerability and adaptive capacity of different socio-economic groups in Dhaka, and by exploring the role of green roofs and vegetation in mitigating heat stress and improving adaptive capacity. The study also provide practical implications and recommendations for policymakers, planners, and practitioners to address heat stress and promote urban resilience in Dhaka and other similar cities.

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