



Dynamics of Urban Heat Wave and Its Impacts on Slum Communities: A Case Study of Rajshahi City Corporation, Bangladesh

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ABSTRACT

A severe heatwave is impacting Bangladesh, with Rajshahi's underserved populations being particularly vulnerable. Urban slum residents, such as auto-rickshaw drivers, construction laborers, and street vendors, face heightened exposure to heat-related risks. This study examines perceptions of heatwaves and the adaptive capacities of these vulnerable groups, utilizing a mixed-methods approach that includes key informant interviews, household surveys, and secondary data analysis. Findings indicate that high temperatures and heatwaves are significant concerns for most respondents, with excessive sweating and dehydration being common health challenges that disrupt daily life. Coping strategies include using fans and wearing damp clothing to adapt routines. Variations in physical, natural, financial, human, and social capital influence the community's adaptive capacities, highlighting targeted and effective urban development policies. The insights from this study aim to inform climate adaptation strategies, fostering proactive responses and shaping policies at both regional and national levels to manage heat extremes in Rajshahi's informal settlements.

1. Introduction

In many regions of the world, human exposure to heat extremes is at all-time high. Heat exposure is projected to grow as global temperatures rise owing to climate change. Heat-related disease, uncertain food and nutrition security, diminished human productivity, and, in severe circumstances, mortality is among concerns that people in areas where cooling is not widely available confront [1]. By 2100, the Intergovernmental Panel on Climate Change (IPCC) predicts that the average global temperature would have increased by 1.4 to 5.8 degrees Celsius and atmospheric CO₂ levels will have doubled

relative to pre-industrial levels [2]. This entire scenario is brought on by a large increase in the urban footprint and can be explained by a number of meteorological factors. Rajshahi division, located on the north western part of Bangladesh has a tropical wet and dry climate [3]. The annual maximum temperature and the annual average humidity of 1987-2016 showed an increasing trend [3]. A study has been carried out focusing the climate change derived urban heat index. The study identified nine wards of Rajshahi City Corporation (RCC) (3, 4, 11, 14, 19, 24, 25, 28 and 30) as highly exposed to heat wave and ten wards of RCC (1, 2, 4, 7, 16, 17, 19, 24, 28 and 29) as the highly susceptible and

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heat hotspots wards. The study also revealed that, the maximum temperature exceeds 39°C in almost every year and humidity levels might approach 65 percent [4]. On some of the warmest days in the summer, temperatures in the city can reach 42°C or even higher [5]. Rajshahi has the highest heat index score after the southwest region [4]. Hence, Rajshahi city is particularly vulnerable to heat waves. As a northern city, Rajshahi experiences hot, muggy summers, with recent years seeing an increase in the frequency of heat waves. There is a substantial amount of research present dealing with the thermal characteristics and the reason associated with the major transition between various land covers. But there is a major gap in exploring the community-level in-depth study of heat wave perceptions, its impacts as well as the capacity assessment of the vulnerable community for heat adaptation in Rajshahi.

Recent researches conducted on urban heat waves highlighted the complex interplay between human perception, vulnerability, and adaptive capacity. Risk perception varies geographically and is typically higher among vulnerable subgroups [6]. Urban overheating significantly impacts human health, energy consumption, and urban livability, necessitating integrated assessments across disciplines [7]. The findings of one study also revealed significant correlations between socio-economic factors, heat vulnerability, and adaptive capacities, emphasizing the need for tailored transformation programs [8]. Urban heat islands can increase temperatures by 4-5°C on average and up to 10°C at peak, severely affecting cooling energy consumption, peak electricity demand, and heat-related mortality [9]. Based on the findings of their study numerous researchers directed to focus on refining risk communication strategies and developing comprehensive approaches to address the multifaceted challenges of urban overheating [6 - 8].

Heat waves have become increasingly common, intense, and long, resulting in an increase in heat-related sickness, mortality, and economic losses in Bangladesh in general and Rajshahi City in particular. The critical review of related studies regarding the proposed research clearly highlights the lack of Studies regarding the urban heat wave of Rajshahi city. A study has been carried out regarding the heat study of Rajshahi City Corporation which is the only study after the capital city Dhaka that illustrates specifically the heat threshold and heat hotspots of Rajshahi city [4]. There exists no such study that focuses on the in-depth impacts of heat wave and the assessment of the existing capacity of the community to combat the extreme effects of the heat wave. Therefore, the author was motivated to conduct this research. Hence, it is necessary to undertake an in-depth analysis of the risk perceptions of the urban heat wave and its impacts. At the same time, assessment of the existing capacity of the community to adapt to heat wave can also

help the policy maker in formulating heat wave management plan for the vulnerable community of the city in future [1, 10, 11].

Taking into account various international experiences and other research findings, this particular study aims to comprehensively understand the dynamics of heat waves in the urban context of Rajshahi City, Bangladesh, with a specific focus on slum communities. In order to fulfill the purpose this particular study (i) Explored the local level heat wave perceptions and its impacts on the vulnerable community and (ii) Assessed the capacity of the vulnerable community for heat adaptation

This particular study has been conducted taking into consideration the hypothesis “Communities in at-risk locations, particularly those in the urban area, are already experiencing a heat wave that is directly harming their health and way of life, and the growing frequency and severity of heat waves may outstrip the capacity of vulnerable communities to adapt.” and the corresponding research questions are (i) How do different individuals and social groups in vulnerable communities perceive and interpret climatic and socioeconomic changes? (ii) What are the major climatic and socioeconomic impacts of these changes on the physical health and livelihoods of vulnerable communities? (iii) How do vulnerable communities respond to the perceived changes, and are these responses adequate and sufficient? (iv) What are the main livelihood assets of vulnerable communities for coping with, and adapting to, environmental and socioeconomic changes, and what are their needs? In order to examine the validity of this hypothesis, it is recommended that a research study be undertaken, utilizing various methodologies including household questionnaire surveys, key informant interviews, and direct observations.

2. Key Concepts

A heat wave is a meteorological occurrence characterized by extended durations of abnormally high temperatures, occasionally accompanied by elevated levels of atmospheric moisture [4]. As per the definition provided by the World Meteorological Organization (WMO), a heat wave is characterized as a period of at least five consecutive days where the daily maximum temperature surpasses the average maximum temperature by a margin of 5°C (9°F) or greater [12]. As per the Bangladesh Meteorological Department (BMD), a heat wave is defined in Bangladesh as a meteorological phenomenon characterized by the occurrence of the greatest temperature surpassing 36°C [4].

The concept of vulnerability is intricately connected to the ownership of assets. Individuals who possess a higher number of assets experience a reduced level of vulnerability, but the depletion of their assets leads to an

increase in their level of insecurity [13]. Low-income communities and households are implementing strategies to mitigate the effects of climate change in order to safeguard their assets. Assets play a vital role in supporting individuals' livelihoods and ensuring their financial security [14]. They contribute significantly to the elimination of urban poverty and facilitate transformative adaptation by fostering long-term planning, enhancing financial literacy, and promoting social and political involvement [15].

Coping strategies commonly involve the utilization or liquidation of assets and reserves. Temporary measures are implemented with the purpose of mitigating immediate danger, rather than adapting to ongoing or permanent dangers or changes. Coping mechanisms can consist of a recurring collection of techniques that have been previously utilized. The utilization of coping mechanisms in response to stress is likely to result in an increase in long-term susceptibility [11].

Furthermore, Assets play a critical role in the mitigation of hazards and the implementation of coping strategies, whereas adaptation entails the formulation of strategies over an extended period of time. The adaptation strategies of individual homes and low-income communities can be implemented independently, without the active participation of broader urban stakeholders [14]. The presence of property titles and the assurance of tenure security have been found to positively influence the inclination of individuals to invest in adaptive mechanisms [15].

The utilization of community-based activities has the capacity to enhance the resistance of urban populations living in poverty towards heatwaves [16]. These programs have the potential to effectively cater to the requirements of low-income and marginalized populations, who often encounter restricted availability of cooling advantages and encounter obstacles in implementing adaption methods [17]. Through active involvement with marginalized populations, the aforementioned programs seek to enhance their agency and transform the dynamics around heat adaption [18]. According to the cited source, these structures have the potential to enhance thermal comfort in the most sweltering and socioeconomically disadvantaged areas [19]. The utilization of the asset-based community development method has demonstrated efficacy in enhancing the living conditions of urban slum communities and mitigating poverty at the household level [10]. Urban farming is a community-based initiative that has the potential to enhance community resilience, particularly in relation to food and nutrition security in times of calamities. The significance of grassroots resilience and its compatibility with top-down urban regeneration programs is exemplified by these community-led efforts [18].

3. Methodology

Research Area and Research Procedure

The study area for the proposed research is the slum communities of Rajshahi city corporation area mostly concentrated in ward 2, 29, 1 and 28, of which the slum of ward no 2, 19, 24 and 29 have been selected randomly to conduct this study. The selected slums have aligned with the most vulnerable regions according to a recent study conducted on climate vulnerability hotspots in terms of socio-economic and physical vulnerability factors [20]. These are also the Largest Slums in terms of population and households. The research is a mixed-methods approach, supported by both quantitative and qualitative data as needed. The proposed research is primarily exploratory in nature, and mixed method research is the main research technique that frames the research procedure.

Research Design

The research employed a mixed-method design, utilizing multiple methods of data collection, including household questionnaire surveys conducted with the KOBO toolbox, key informant interviews, and secondary data analysis. As a mixed method research, it focused on collecting, analysing, and mixing both quantitative and qualitative data. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either adopting the approach alone.

Sampling Framework

In Rajshahi City, there are 32 slums, most of which are grouped in wards 2, 29, 1, and 28. In the slum regions of Rajshahi Metropolitan City, there are 23,261 households with a total population of 89,050. The city's biggest slum, Baze Kazla in ward 24, has 1,562 households and 5,920 residents. Probabilistic sampling has been done here with 95% confidence level, 5% margin of error. The total sample surveyed is about 378 Households (HHs). Key Informant Interviews have been conducted with 6 key informants and their valuable opinions have been evaluated.

Data Analysis and Validation

After collecting the necessary data, all data were assembled and processed manually for analysis. 'Descriptive' and 'Correlation' analyses were used as the analytical strategies for the quantitative data. 'Descriptive' analysis summarized the samples, while 'Correlation' analysis quantified the associations between the research variables. For the qualitative data gathered from key informant interviews (KII), 'Content' and 'Narrative' analyses were employed. Content analysis categorized verbal data for classification,

summarization, and tabulation, while Narrative analysis was used to reformulate or transcribe the community's experiences into a revised form. The accuracy, clarity, and quality of the datasets were strictly ensured by maintaining data justification, triangulation, and validation with relevant literature.

Data Processing Method

In this study, index method has been used to measure the adaptive capacity. Indicators adopted from the community disaster resilience index (CDRI) have been modified with the socio-economic context of the slum communities of Rajshahi to construct the index. There are 28 indicators based on community capital that are theoretically pertinent to various heat wave activities. The selection of these variables is based on two considerations: existing literature concerning urban heat waves and the availability of data from pertinent institutional data sources. When figuring out sub-indices and adaptive capacity scores, there are four steps (1) standardization or normalization, (2) Validity test (3) figuring out sub-indices, and (4) figuring out adaptive capacity index.

Normalization

It is essential to a standardize or normalize the data used to measure indicators, as they are derived from a variety of sources and statistical units. The indicators are normalized so as to prevent extreme values and reduce certain data quality issues [21]. The Min-Max method has been used to normalize indicators in this study.

$$X_n = \frac{X_0 - X_{min}}{X_{max} - X_{min}}$$

Where,

X_n = Indicator index

X_0 = Original value of the indicator for the household

X_{min} = Minimum value of the indicator for the household

X_{max} = Maximum value of the indicator for the household

Calculation of Sub-Indices

In this study, eight sub-indices (physical capital, natural capital, human capital, financial capital and social capital) have been used. In order to get the score of each sub-index, the following equation has been used to calculate the mean score of the indicators [21].

$$SI = \frac{\sum_{i=1}^N Z}{N}$$

Where,

SI= Sub-index score

Z= Standardized score of an indicator

N= Number of indicators of a sub-index

Calculation of Adaptive Capacity Index (ACI)

The community capital-based approach has been used to calculate the overall adaptive capacity index using the following formula [22] [23].

$$ACI = \frac{PC + NC + FC + HC + SC}{5}$$

Where,

PC= Physical capital sub-index

NC= Natural capital sub-index

FC= Financial capital sub-index

HC= Human capital sub-index

SC= Social capital sub-index

4. Results and Discussions

Heat Wave Perception

The data analysis highlights notable trends in the local perception of weather. A vast majority of respondents (99.2%) indicated a perception of "Hot" weather, signifying an overwhelming consensus on the prevailing temperature conditions. In contrast, a mere 0.5% of participants described today's weather as "Cool," suggesting that cooler weather patterns were scarcely observed or experienced. Only 0.3% of respondents reported a "Neutral" perception of today's weather, which implies that a negligible proportion of individuals were unsure or ambivalent about the prevailing temperature conditions (Table 1).

Table 1. Local perception of Weather

local perception of weather	Frequency	Percentage
Cool	2	.5
Hot	376	99.2
Neutral	1	.3
Total	379	100.0

The analysis of responses reveals notable patterns regarding the prevalence of heat hotspots within the studied urban setting. Living spaces emerged as the most frequently perceived heat hotspot, with 44.1% of participants identifying these areas as experiencing elevated temperatures. Transport modes were also prominently associated with heat hotspots, with 34.0% of respondents reporting this perception. City centers and worksites were similarly identified as heat hotspots, with 32.7% and 37.5% of respondents, respectively, acknowledging elevated temperatures in these locations. In contrast, open spaces/parks were perceived as heat hotspots by only 2.4% of participants, indicating a lower

prevalence of heat-related concerns in these areas (Table 2).

Table 2. Hotspots of perceived heat stress

		Responses		Percent of Cases
		N	Percent	
Heat Hotspots ^a	Transport modes	129	22.6%	34.0%
	City center	124	21.7%	32.7%
	Works	142	24.9%	37.5%
	Living space	167	29.2%	44.1%
	Open spaces/parks	9	1.6%	2.4%
Total		571	100.0%	150.7%

a. Dichotomy group tabulated at value 1.

Health Impact

The findings (Table 3) reveal a diverse array of health problems associated with heat waves. Excessive sweating, reported by 18.0% of cases, emerged as the most prevalent issue, accompanied by dehydration from sweating (20.9%).

Table 3. Health Problem Related to Heat Wave

\$Health Problem due to Heat Wave Frequencies ^a			
	Responses		Percent of Cases
	N	Percent	
Excessive Sweating	240	18.0%	63.3%
Dehydration	200	20.9%	73.6%
Feeling weak	179	13.4%	47.2%
Discomfort	144	10.8%	38.0%
Sleeping disorder	78	5.9%	20.6%
Fever	41	3.1%	10.8%
Cold	9	0.7%	2.4%
Lack of Concentration	51	3.8%	13.5%
Fatigue	74	5.6%	19.5%
Skin Disease	61	4.6%	16.1%
Water Borne Disease	82	6.2%	21.6%
Vomiting	17	1.3%	4.5%
Headache	29	2.2%	7.7%
Respiratory Problem	20	1.5%	5.3%
Heat Stroke	28	2.1%	7.4%
Total	1332	100.0%	351.5%

a. Dichotomy group tabulated at value 1.

The intensity of symptoms varies, with some individuals experiencing milder discomfort, such as feeling weak from sweating (13.4%), while others contend with more severe conditions like heat stroke (2.1%).

Table 4. Additional Medical Expenditure During Heat Wave Days

Additional Medical Expenditure During Heat Wave Days		
	Frequency	Percent
<25%	284	74.9
25%-50%	95	25.1
Total	379	100.0

The majority of cases (74.9%) fell within the category of expenditures constituting less than 25% of the overall medical costs. In contrast, a smaller portion (25.1%) incurred costs representing 25% to 50% of the total medical expenditure.

In summary, the data suggests that a significant proportion of the population experienced relatively lower additional medical costs during heat wave days, while a smaller subset had higher medical expenses, constituting a quarter of the total cases under consideration (Table 4).

The analysis (Table 5) revealed that the most common strategy employed by respondents was "Increase Working Hours," with 185 cases, accounting for 32.5% of the total sample. This was followed closely by "Reduce Other Costs," with 177 cases, representing 31.1% of the cases. The strategy of "Savings" was chosen by 93 individuals (16.3%), while "Loan" was preferred by 67 individuals (11.8%). "Involvement in other Works" was the least common strategy, chosen by 47 individuals (8.3%).

Table 5. Additional Medical Expenditure for Heat Adjustment

\$ Adjust Additional Medical Expenditure Frequencies ^a			
	Responses		Percent of Cases
	N	Percent	
Savings	93	16.3%	25.5%
Loan	67	11.8%	18.4%
Reduce Other Cost	177	31.1%	48.6%
Increase Working Hours	185	32.5%	50.8%
Involvement in other Works	47	8.3%	12.9%
Total	569	100.0%	156.3%

a. Dichotomy group tabulated at value 1.

Notably, the cumulative percentages of the strategies exceeded 100%, indicating that some participants utilized multiple strategies simultaneously to manage their medical expenses. The dichotomy group was tabulated at value 1, suggesting that respondents may have applied more than one strategy concurrently.

Impact on Livelihood

Table 6. Main difficulties women and men are facing in their daily lives

\$main difficulties Frequencies ^a			
	Responses		Percent of Cases
	N	Percent	
Lack of access to safe drinking water	196	30.2%	51.7%
Poor sanitation facilities	114	17.6%	30.1%
Limited access to electricity and cooling facilities	86	13.3%	22.7%
Lack of shaded areas	69	10.6%	18.2%
Limited access to healthcare	64	9.9%	16.9%
Poverty	120	18.5%	31.7%
Total	649	100.0%	171.2%

a. Dichotomy group tabulated at value 1.

The table 6 outlines the prevalence of various difficulties in the lives of the respondents. Notably, "Lack of access

to safe drinking water" is the most frequently mentioned challenge, with 30.2% of the cases. "Poor sanitation facilities" and "Poverty" are also significant concerns, affecting 17.6% and 18.5% of respondents, respectively. These findings highlight the multifaceted nature of the difficulties people face in their daily lives, ranging from basic necessities like clean water to broader issues such as poverty. It is important to note that the percentages in the "Percent of Cases" column do not add up to 100% due to the option for respondents to select multiple difficulties. The "Percent of Total" column demonstrates the cumulative impact of these difficulties, which adds up to 171.2%.

Table 7. Reduction of Income During Heat Wave Days

Reduction of Income Frequencies		
	Frequency	Percent
<25%	237	62.5
25%-50%	136	35.9
51%-75%	6	1.6
Total	379	100.0

The majority of respondents (62.5%) experienced income reductions of less than 25%, indicating a significant prevalence of relatively modest income contractions within the surveyed cohort. Conversely, 35.9% of participants reported a more substantial decrease in income falling within the range of 25% to 50%. These findings underscore the substantial economic implications faced by a noteworthy proportion of the population. A relatively limited proportion of respondents (1.6%) reported income reductions between 51% and 75%, underscoring the comparatively rare occurrence of severe income diminishment within the sample (Table 7).

This research illustrates a clear and asymmetric distribution of income reductions, with the majority of individuals experiencing milder reductions in income. Such variations in income reduction frequencies may reflect the diversity of economic conditions and individual experiences within the broader context of financial insecurity. Furthermore, these results may have significant implications for policymakers and organizations tasked with addressing economic hardships and developing strategies to mitigate income losses among affected individuals. Further in-depth investigations are warranted to explore the underlying determinants and consequences associated with these diverse income reduction patterns.

Identification of Coping Strategies

The most common personal activity reported was "Using Umbrella/Cap/Covering Head" at 18.8% (n=180), followed by "Drinking Water/Saline/Drinks" at 17.6% (n=169), and "Avoid Sun/Working at Noon" at 14.1% (n=135). Actions like "Visiting Doctor/Taking Medicine" and "Sleep" were reported with low rates of

0.5% and 0.9%, respectively, suggesting that these are fewer common tactics among respondents (Table 8).

A range of coping methods were used, from basic behavioural changes like finding shade or utilizing handheld fans to more significant actions like seeking medical help or changing eating choices. These findings highlight the various strategies individuals use to reduce the negative impacts of hot weather. Respondents often use many techniques at the same time, leading to a cumulative frequency that surpasses 100%. This demonstrates the intricate nature of individual reactions to hot weather circumstances.

Table 8. Respondents Personal Actions to Protect Themselves in Response to Hot Weather.

\$ Personal Actions Frequencies ^a			
	Responses		Percent of Cases
	N	Percent	
Using Umbrella/Cap/Covering Head	180	18.8%	48.1%
Drinking Water/Saline/Drinks	169	17.6%	45.2%
Avoid Sun/Working at Noon	135	14.1%	36.1%
Visiting Doctor/Taking Medicine	5	0.5%	1.3%
Taking Rest in Shed	95	9.9%	25.4%
Use hand held fan	103	10.8%	27.5%
Shower multiple times	26	2.7%	7.0%
Sleep	9	0.9%	2.4%
Stay indoors in cooler place	127	13.3%	34.0%
Take food & drink to keep cool	73	7.6%	19.5%
Doing Nothing	36	3.8%	9.6%
Total	958	100.0%	256.1%

a. Dichotomy group tabulated at value 1.

Coping Strategies: Validity Assessment

The correlation study provided valuable insights into the effectiveness of various capital metrics in supporting coping methods within the community (Table 9). Safe drinking water sources, direct access to water bodies, and ownership of agricultural land showed strong associations with coping mechanisms across many natural capital indicators, emphasizing their crucial role in enhancing community resilience. Human capital variables such as education/literacy rates, access to healthcare facilities, and the number of disabled persons in homes showed significant connections with coping techniques, emphasizing the crucial significance of human resources in adaptive capabilities.

Housing structure, roof characteristics, insulation tactics, and sanitary facilities were identified as key factors in coping mechanisms, highlighting the crucial role of proper shelter and infrastructure in improving resilience. Financial capital indicators such household income, savings/deposits, and participation in revenue-earning activities showed strong connections with coping

mechanisms, highlighting the important importance of financial resources in protecting against hardships. Social capital measures such as membership in community-based organizations (CBOs)/NGOs, social networks, and support from local community development committees (CDCs) showed significant connections with coping strategies, emphasizing the importance of social cohesion and support networks during crises.

Table 9. Validity Test Results for Different Coping Strategies

Validity Measures	Correlation Value
Natural Capital	
(1) Availability of safe drinking water source (tab, tube well) round the year	.482**
(2)Direct access to water body (Pond/Ditch, Canal/River)	.240**
(3)Ownership of Agriculture land	.357**
(4)Access to spaces	.801**
Human Capital	
(1)Education/literacy rate/awareness	.866**
(2)Number of disable (physically challenged) person in the household	.468**
(3)Access to healthcare facilities	.786**
Physical Capital	
(1)Housing structure	.447**
(2)Roof characteristics	.488**
(3)Roof condition	.741**
(4)Current insulation strategy in place	.461**
(5)Flooring	.657**
(6)Access to electricity	.516**
(7)How often do you experience load shedding?	.120*
(8)Sanitation facility	.449**
(9)Presence of fan	.293**
(10)Presence of refrigerator	.189**
Validity Measures	Correlation Value
(11)Available resources for getting access to weather information	.113*
Financial Capital	
(1)Number of family members engaged in income earning activities	.788**
(2)Median household income	.690**
(3)Median household expenditure	-.384**
(4)Savings/deposits	.634**
(5)Household with health insurance	.068
Social Capital	
(1)Registered member of any CBO/NGO	.432**
(2)Registered voter	.033
(3)Presence of religious organization within the community	.502**
(4)Social network (Assistance obtained during crisis)	.748**
(5)Support from local CDC	.767**

*. Correlation is significant at the 0.05 level (2-tailed).

** . Correlation is significant at the 0.01 level (2-tailed).

Adaptive Capacity

The figure 1 presents an overview of different slum communities and their respective sub-indices and ranks in various capital categories. The sub-indices are used to measure the physical, natural, financial, human, and social capital, as well as the adaptive capacity of each community.

Among the communities listed, Baze Kazla holds the highest rank (1) and exhibits relatively high scores in the physical capital (0.58), financial capital (0.45), human capital (0.75), and adaptive capacity (0.52) sub-indices. However, its scores in the natural capital (0.37) and social capital (0.43) sub-indices are comparatively lower.

Ashrayan follows closely with a rank of 2 and demonstrates similar strengths in physical capital (0.58) and human capital (0.84). However, it has lower scores in natural capital (0.27), financial capital (0.43), social capital (0.31), and adaptive capacity (0.49).

Char Satbari East ranks third with its relatively weaker scores in physical capital (0.47), financial capital (0.35), and adaptive capacity (0.47). However, it shows more balanced performance in natural capital (0.45), human capital (0.56), and social capital (0.49).

Choto Bonogram ranks fourth and showcases relatively low scores across all sub-indices, including physical capital (0.44), natural capital (0.41), financial capital (0.32), human capital (0.51), social capital (0.43), and adaptive capacity (0.42).

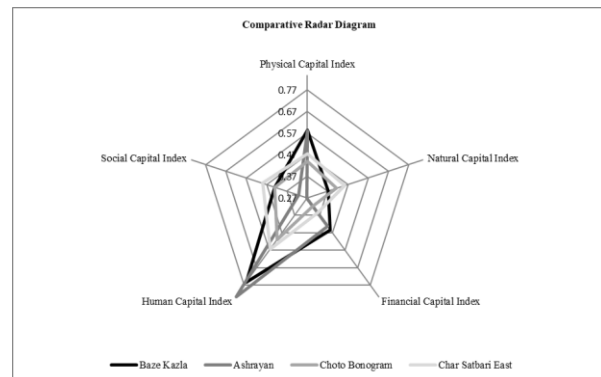


Figure 1. Comparative Radar Diagram Representing Various Capitals Based Index Value of the Slum Communities.

Figure 1 provides an overview of the performance and ranking of different slum communities based on their capital indicators. It highlights the strengths and weaknesses of each community, indicating variations in their physical, natural, financial, human, and social capital, as well as their adaptive capacity, offering a foundation for more targeted and effective urban development policies.

5. Conclusions and Implications

This study provides valuable insights into the perceptions, impacts, and coping strategies related to urban heat waves in Rajshahi City, Bangladesh. The findings reveal a high level of awareness regarding increasing temperatures. This aligns with global trends of rising temperatures in urban areas, as documented in numerous studies [8, 9]. The identification of heat hotspots within urban settings, including living spaces, transport modes, city centers, and worksites, underscores the need for targeted interventions in these areas. The low perception of open spaces/parks as heat hotspots suggests potential opportunities for urban green space development as a heat mitigation strategy. This finding is consistent with research highlighting the cooling effects of urban green spaces [1, 10].

Health impacts associated with heat waves, such as excessive sweating, dehydration, and heat stroke, emphasize the public health implications of rising temperatures. The economic burden of these health issues is evident. This highlights the need for preventive measures and improved healthcare access during extreme heat events [2]. The diverse coping strategies employed by residents, including increasing working hours, reducing other costs, and seeking loans, reflect the economic challenges posed by heat waves. The finding that 35.9% of respondents experienced income reductions of 25% to 50% underscores the significant economic impact of extreme heat on vulnerable populations. This aligns with research on the disproportionate effects of climate change on low-income communities [10, 15, 21]. The prevalence of behavioural adaptations, such as modifying daily activities and employing physical cooling strategies (e.g., using fans, drawing curtains), demonstrates the community's resilience in the face of extreme heat. However, the reliance on simple, low-cost measures suggests limitations in access to more advanced cooling technologies. This highlights the need for affordable and sustainable cooling solutions in urban planning and development. The variations in adaptive capacity scores among the communities indicate differing levels of preparedness and ability to respond to challenges. This supports the notion that adaptive capacity is influenced by multiple factors and varies significantly even within similar socio-economic contexts [8].

These findings have several implications for policy and practice such as: urban planning should prioritize heat-resilient design, incorporating green spaces and passive cooling strategies in buildings and public areas, public health interventions should focus on raising awareness about heat-related health risks and promoting effective coping strategies, investment in sustainable and affordable cooling technologies is crucial to enhance

resilience, particularly for low-income communities. In conclusion, this study underscores the complex interplay between urban heat waves, public health, economic stability, and adaptive behaviour in Rajshahi City. The findings contribute to the growing body of knowledge on climate change impacts in urban settings and provide valuable insights for developing context-specific heat resilience strategies in Bangladesh and similar developing urban contexts. Further research is needed to explore the long-term impacts of heat adaptation strategies on health, productivity, and social dynamics.

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