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Potentials of Community-Based Initiatives in Promoting Urban Resilience to Heatwave: Lessons from Slum Communities of Rajshahi City

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ABSTRACT

This study looks at how community-based initiatives might help slum areas of Rajshahi City Corporation, Bangladesh-a region especially vulnerable to extreme heat from fast urbanization, poor infrastructure, and socioeconomic inequalities, promote urban resilience to heatwaves. This study used a mixed-methods approach. Slum dwellers' current coping strategies were determined using quantitative data from 378 households questionnaire survey. ATLAS.ti 25 software was used to analyze qualitative data collected from 6 key informant interviews in order to pinpoint the obstacles and potential areas of intervention for urban heat adaptation. The common coping mechanisms among slum dwellers are turning on fans, controlling ventilation, showering more often, and modifying daily activities. Among the most important adaptive behaviours highlighted by Principal Component Analysis are "turning on fans" and "ventilation management". Income and education levels, however, greatly restrict the efficacy of these approaches; lower-income and less educated households suffer more from limited access to cooling resources and inadequate housing. The study emphasizes the need of combined interventions improving access to inclusive urban planning, cooling, and community-led adaptation-to solve these vulnerabilities.

1. Introduction

Human exposure to heat extremes is currently reaching unprecedented levels in various places across the globe. The anticipated increase in global temperatures due to climate change is expected to result in a corresponding rise in heat exposure. Individuals residing in regions with limited access to cooling infrastructure face a range of challenges, including heat-related illnesses, compromised food and nutrition security, reduced human productivity, and, in extreme cases, loss of life [1]. According to the projections made by the Intergovernmental Panel on Climate Change (IPCC), it is anticipated that by the year 2100, the average worldwide temperature would have risen by a range of 1.4 to 5.8 degrees Celsius. Additionally, it is predicted that the levels of atmospheric carbon dioxide (CO2) will have doubled in comparison to the levels observed during the pre-industrial era [2]. The present situation is a consequence of a substantial expansion of the metropolitan area and can be attributed to several weather causes.

Rajshahi, a rapidly urbanizing city in northwest Bangladesh, is particularly vulnerable to heatwaves due to its tropical wet and dry climate. There was an observed upward trend in the annual maximum temperature and annual average humidity from 1987 to 2016 [3]. Subedi et al. (2021) found nine specific wards within the Rajshahi City Corporation (RCC) that exhibit

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a high level of exposure to heatwaves. This study is noteworthy as it is the sole investigation, subsequent to the capital city Dhaka, that focuses on elucidating the heat threshold and identifying heat hotspots within Rajshahi city. The findings of that study indicate that the maximum temperature consistently surpasses 39°C on an annual basis, while the levels of humidity may reach approximately 65 percent [4]. The city experiences temperatures of 42°C or greater on certain days throughout the summer season. Rajshahi has the highest heat index score among the regions in the southwest. Therefore, it can be argued that the city of Rajshahi is particularly susceptible to heatwaves [4, 5]. The frequency, severity, and duration of heatwaves have exhibited a notable rise, leading to a corresponding escalation in heat-related illnesses, fatalities, and economic ramifications within Bangladesh as a whole, with a special emphasis on Rajshahi City. The comprehensive examination of relevant literature pertaining to the proposed research effectively underscores the dearth of studies pertaining to the urban heatwave phenomenon in Rajshahi city. Several research have focused particularly on examining the impacts of heatwaves and ways for mitigating them in megacities and urban heat islands. Nevertheless, there is a lack of comprehensive articulation of the efficacy of local-level adaptation measures in mitigating the impacts of heatwaves, specifically for the urban underprivileged population residing in the northwestern region of Bangladesh. Most of the current research highlights technical adaptation strategies and megacities, ignoring the unofficial coping mechanisms used by the urban poor in secondary cities such as Rajshahi [6, 7]. This generates both theoretical gaps in behavioral adaptation and social learning processes and empirical gaps, especially with relation to how local government might support community-based resilience and how socioeconomic factors affect heat adaptation. The informal settlements of the city suffer compounded difficulties from limited cooling infrastructure, occupational heat exposure, and scattered institutional support; hence, research that investigates grassroots adaptation mechanisms and points out areas where regional planning and governance can improve these efforts is much needed [8]. Therefore, it is imperative for individuals within academia, governmental organizations (GOs), and non-governmental organizations (NGOs) to have a comprehensive understanding of the strategies employed by urban dwellers residing in informal settlements to cope with the challenges posed by a heatwave.

Community-based initiatives are a crucial approach to improving resilience to heatwaves by involving local people, utilizing existing resources, and encouraging group activity. These projects often focus on enabling early action against heatwaves, teaching communities about the dangers of heatwaves and the need for preparedness. Studies have shown that community health worker-led heat education programs in Karachi, Pakistan, and China's Licheng District have significantly increased heat literacy and reduced hospital visits [9]. Social networks, particularly for low-income homes and elderly groups, are crucial for heatwave resilience. Research in the Indian Sundarbans highlights the importance of group adaptive behaviors and social contacts in reducing heat stress [10]. Engaging communities in the creation of heat action plans ensures that interventions are context-specific and address local needs. Examples include the Heat Action Plan of Miami-Dade County, which involved community involvement and identified tactics like building heat resilience hubs and increasing greenspace [11]. Urban green areas can lessen the urban heat island effect and offer cover during hot waves, emphasizing the need for green space planning in community-based initiatives [12].

The primary purpose of the research is to assess the potentials and constraints of community and household adaptation programs for promoting city-level resilience. In order to fulfill the purpose this particular study (i) Explored the current coping strategies of the urban poor for heat adaptation and (ii) Examined the areas for intervention where regional planning and governing structures might assist these coping mechanisms at the city level. This particular study has been conducted taking into consideration the hypothesis “Community-based efforts play a crucial role in fostering urban resilience to heatwaves through the facilitation of community engagement, knowledge dissemination, and the implementation of adaptive strategies” and the corresponding research questions (i) what are the current coping mechanisms used by the urban poor in the target area to deal with the heat? (ii) how do these coping strategies differ based on socio-economic factors, such as household income level, education, and perception of heat risk? (iii) what are the most significant challenges urban impoverished faces in adapting to heatwaves? (iv) what are the specific areas of intervention where regional planning and governing institutions may assist and increase the heat adaption coping mechanisms of the urban poor? and (v) what city-level policies and governance approaches can be initiated to help the urban poor cope with heatwaves? The research questions explore urban poor coping strategies, their differences among socioeconomic groups, and challenges they face. These also address the need to bridge institutional and behavioral constraints in adaptation planning by investigating governance and policy interventions for community-based adaptation in global adaptation research agendas. In order to examine the validity of this hypothesis, it is recommended that a research study be undertaken, utilizing various methodologies including surveys, interviews, and observations. The study aims to

establish a correlation between the presence of community-based initiatives and urban resilience to heatwaves by comparing the level of community participation, knowledge exchange, and implementation of adaptive measures across the community.

2. Review of Literature

A heatwave is a climatic phenomenon defined by prolonged periods of unusually high temperatures, sometimes coupled with increased humidity [4]. The World Meteorological Organization (WMO) defines a heatwave as a duration of no less than five consecutive days during which the daily maximum temperature exceeds the average maximum temperature by at least 5°C (9°F) [13]. The Bangladesh Meteorological Department (BMD) defines a heatwave in Bangladesh as a meteorological event in which the maximum temperature exceeds 36°C.

Resilience refers to the inherent ability of a system to persist in a specific state while preserving its feedback mechanisms and functionalities. Additionally, it encompasses the system's capability to adapt and restructure itself in the face of disruptions that induce change [14]. The process by which societies recover and adapt to novel situations. The concept of community resilience necessitates the adoption of localized and context-specific approaches that prioritize the social aspects of sustainable development. The process in question establishes a connection between a network of adaptive capacities, which are resources characterized by dynamic features, and the subsequent adaptation that occurs in response to a disruption or adverse [15, 16]. The concept of resilience has garnered significant attention in the field of urban study and practice. However, there remains a dearth of knowledge regarding the various perspectives and approaches to resilience within diverse urban contexts and among different stakeholders. The majority of resilience frameworks exhibit a lack of congruence with the concept of transformation. Consequently, it becomes imperative to incorporate elements like as anticipation, systems thinking, and equity into the realm of resilience practice [17].

The mechanisms of resistance to the threat refer to the resources and privileges that individuals, households, or communities can utilize and control when confronted with adversity. 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 [18]. 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 [19]. 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 [20].

Community-based efforts signify a fundamental change in urban heat resilience, empowering disadvantaged people to transition from passive recipients to active participants in the development of adaptation strategies. Co-designed greening projects show how targeted interventions might lower surface temperatures and improve social cohesiveness. Through layered interventions—planting 100 drought-resistant trees, building shade structures, and turning vacant lots into community cooling hubs with play areas and seating—the Cool Block Project changed a heat-vulnerable neighborhood in Chelsea, Massachusetts [21]. Surveys conducted following implementation noted a 2.1°C drop in peak daytime temperatures and more use of outdoor areas [21]. Likewise, Austin's Heat Resilience Playbook gives "cool connections" – shaded paths connecting residential areas to cooling centers top priority through participatory design seminars involving residents in identifying priority corridors [22]. The City of Victoria's response to the 2021 heat dome highlighted the importance of community involvement in developing adaptation plans. The city collaborated with local companies, charities, and organizations to support underprivileged groups. This proactive approach could inspire other towns to increase resilience to heat events [23]. In Mendoza, Argentina, street trees and cool materials were used to lower outdoor air temperatures during heatwaves, improving urban livability and resilience [24]. South Asian communities have also built adaptive infrastructure, such as bamboo-based buildings, using local resources and traditional knowledge, to enhance resilience to climate change effects [25].

According to community resilience theory, local groups have the ability to together foresee, absorb, adjust to, and heal from negative events including heatwaves. This strategy acknowledges that social capital, participatory government, local knowledge, and physical infrastructure all contribute to resilience as well as each other. It fits the view of resilience as a dynamic network of adaptive capacities-resources, relationships, and learning processes activated in reaction to disturbance by Norris et al. [26] In low-income urban areas and informal communities, where top-down interventions sometimes neglect localized vulnerabilities and priorities, this framework is especially suited [27].

Taking into account various international experiences and other research findings, this particular study aims to explored the current coping strategies of the urban poor for heat adaptation and examined the areas for intervention where regional planning and governing structures might assist these coping mechanisms at the

city level, which has the potentials to provide a valuable contribution to the planning of heat extreme management in the context of climate change, with a particular focus on the informal settlements of Rajshahi city. This will aid in the development of proactive measures with significant policy implications at both the regional and national levels.

3. Methodology

Mixed-method research deign was used for data collection and analysis. The study used Community Resilience Theory as a conceptual framework to evaluate urban poor communities' responses to and ability to manage severe heatwaves. Inspired by the work of Norris et al. (2008) and Cutter et al. (2010), the study centers on important resilience elements including social capital, participatory governance and local knowledge. These points were intended to be captured in both the household survey and key informant interviews. A structured questionnaire survey was conducted with the household head from each household by adapting instruments that have proven effective in a variety of study contexts. The survey instrument comprised three sections highlighting (i) socio-demographic information of the respondents (ii) identification of coping strategies and (iii) need assessment. The questionnaire survey was supplemented by key informant interview.

The slum communities of Rajshahi City Corporation area are mostly concentrated in Wards 1, 2, 28, and 29. For this study, slums located in Wards 2, 19, 24, and 29 were chosen considering their higher exposure to heatwave impacts, population density, and the socio-economic vulnerability of the slum dwellers. The total residents of the selected slums are 19,495 [28]. 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 [4]. These are also the Largest Slums in terms of population and households. Simple random sampling has been done here with 95% confidence level, 5% margin of error. The total sample needed to conduct the study has been calculated using Cochran's formula for sample size which is about 378 Households (HHs). Key Informant Interviews have been conducted with 6 key informants and their valuable opinions have been evaluated.

IBM SPSS Statistics 25 and Excel were employed to analyze the collected quantitative data. In this study, while the SPSS was used to undertake fundamental statistical analysis such as descriptive statistics, the Cronbach's alpha (α) reliability test, correlation, factor analysis. Qualitative data were analyzed with the assistance of ATLAS.ti (version 25), which is a powerful qualitative data analysis (QDA) software used for analyzing textual, graphical, audio, video, and geographic data. In order to categorize the interview data transcripts into themes like coping strategies and institutional support systems, a coding framework was created and analysed the encoded data using Sankey diagrams, network analysis, content analysis. The results of the structured household questionnaire survey were combined with the qualitative findings to guarantee a thorough analysis. The theoretical integration gave a prism through which one could view not only the institutional and structural supports required to improve long-term urban resilience but also the present capacity of communities to control heat stress.

4. Results and Discussion

4.1 Exploring Coping Strategies

The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy yielded a value of 0.770, signifying a high level of adequacy in the dataset. This result indicates that the variables possess substantial intercorrelations, suggesting the data's appropriateness for PCA. A KMO value above 0.7 is generally regarded as favourable, and the obtained value further reinforces the reliability of employing PCA to unveil the underlying coping components. Bartlett's Test of Sphericity revealed a significant result, with an approximate chi-square value of 361.564 and 15 degrees of freedom (df), yielding a p-value of 0.000 (Table 1). This significant outcome indicates that the correlation matrix significantly deviates from an identity matrix, validating the use of PCA to explore latent factors in the data.

Table 1. Data suitability for principal component analysis: KMO and Bartlett's Test.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.770
Bartlett's Test of Sphericity	Approx. Chi-Square	361.564
	df	15
	Sig.	.000

Reliability Statistics	
Cronbach's Alpha	N of Items
0.716	6

The obtained Cronbach's Alpha coefficient of 0.716 signifies a reasonable degree of internal consistency for the survey instrument comprising six items. While a value of 1.0 would indicate perfect internal consistency, a moderate value of 0.716 indicates that the items are relatively interrelated but may exhibit some variability in their measurement of the targeted construct (Table 1). The result indicates that the survey instrument

demonstrates a certain level of reliability in capturing the intended construct, although it may benefit from further refinement to enhance its consistency.

The component matrix presents the factor loadings for each coping behaviour, representing the correlation between the coping strategy and the identified component. Among the coping behaviours, "Open/close window or door" exhibited the highest factor loading (0.706), indicating its strong association with the dominant coping component. Other prominent coping strategies included "Shower more often" (loading = 0.653), "Take more breaks" (loading = 0.684), and "Avoid working during warmer hours" (loading = 0.634). "Use hand fan" (loading = 0.608) and "Turn on fan" (loading = 0.568) also showed moderate positive associations with the component (Table 2).

The Principal Component Analysis yielded a single dominant component that accounted for a significant proportion of the total variance (Eigenvalue = 2.488). The scree plot confirmed the appropriateness of retaining one component based on the steep decline of Eigenvalues after the first component. The PCA results revealed five significant components, cumulatively accounting for 100% of the variance in the data. The first component, labelled "Turn on fan," emerged as the most influential strategy, explaining 41.46% of the total variance. This finding indicates that activating fans significantly contributes to alleviating heat discomfort.

Table 2. Exploring coping strategies through the Principal Component Analysis (PCA) approach.

Component Matrix		Initial Eigenvalues		Extraction Sums of Squared Loadings		
Factor	Loading	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Turn on fan	.57	41.46	41.46	2.4	41.46	41.46
Open/close window or door	.71	15.81	57.27			
Shower more often	.65	12.32	69.59			
Use hand fan	.61	11.71	81.30			
Avoid working during warmer hours	.63	10.31	91.62			
Take more breaks	.68	8.38	100			

Extraction Method: Principal Component Analysis.

The second component, "Open/close window or door," accounted for 15.81% of the variance, representing the impact of ventilation management on indoor thermal conditions. "Shower more often" and "Use hand fan" constituted the third and fourth components, explaining 12.32% and 11.71% of the variance, respectively. These findings emphasize the significance of personal cooling approaches in improving individual thermal comfort. The fifth component, "Avoid working during warmer hours," contributed to 10.31% of the variance, highlighting the importance of scheduling activities to coincide with cooler periods. Lastly, "Take more breaks" was found to be the least influential strategy in this context, explaining 8.38% of the total variance (Table 2).

4.2 Correlation among Coping Strategies, Household Income and Education

The provided table (Table 3 & 4) presents a cross-tabulation analysis that examines the relationship between individuals' levels of education, income, and coping strategies in response to hot weather conditions. The data is structured within a framework of education levels categorized as illiterate, primary, secondary, and tertiary/technical/university, with associated income brackets, and a set of coping strategies denoted as dichotomous variables.

Table 3. Relationship between household income and coping strategies.

Household Income*$Coping Strategies Crosstabulation							
		$Coping Strategies[a]					
		Turn on fan	**Open/close window or door**	**Shower more often**	**Use hand fan**	**Avoid working during warmer hours**	**Take more breaks**
Household Income	<5000	14.1%	3.6%	0.9%	7.9%	9.4%	5.7%
	5000-10000	16.8%	8.4%	4.7%	9.1%	10.5%	5.7%
	10000-15000	24.8%	29.9%	36.8%	34.8%	28.7%	30.3%
	15000-20000	26.5%	36.5%	36.8%	29.9%	34.3%	34.9%
	>20000	17.8%	21.6%	20.8%	18.3%	17.1%	23.4%
Percentages are based on responses. ***a. Dichotomy group tabulated at value 1.***							

The table reveals that among individuals classified as illiterate, those with income ranging from 5000 to 10000 exhibit a predominant utilization of coping strategies such as turning on a fan, opening or closing windows/doors, and showering more often.

On the other hand, individuals falling under the primary education category show a varied pattern across income groups, with strategies like taking more breaks and avoiding working during warmer hours being more prevalent, especially among those with higher incomes.

Table 4. Relationship between individuals' levels of education and coping strategies.

Education*$Coping Strategies Crosstabulation							
		$Coping Strategies[a]					
		Turn on fan	Open/close window or door	Shower more often	Use hand fan	Avoid working during warmer hours	Take more breaks
Education/literacy rate/awareness	Illiterate	30.2%	15.0%	11.3%	24.4%	24.3%	18.3%
	Primary	27.2%	26.3%	32.1%	32.3%	28.7%	26.9%
	Secondary	36.6%	52.7%	49.1%	37.8%	40.3%	46.9%
	Tertiary (technical, university)	6.0%	6.0%	7.5%	5.5%	6.6%	8.0%
Percentages and totals are based on responses. ***a. Dichotomy group tabulated at value 1.***							

In the secondary education group, individuals earning between 10000 to 15000 tend to employ strategies like showering more often and using hand fans. Meanwhile, within the tertiary/technical/university education category, those earning between 15000 to 20000 seem to favor strategies like using hand fans and showering more often.

4.3 Thematic Analysis

4.3.1 Challenges of Adapting to Heatwave: Network Analysis

The network study shown in the figure shows the several difficulties societies experience in adjusting to heatwaves. The graph emphasizes the connections among social, infrastructure, institutional, and environmental spheres regarding adaptation challenges. The network reveals weak or absent links between local authorities, emergency services, and community organizations, so causing delayed or ineffective responses during heatwaves. This fragmentation is a well-documented obstacle since good adaptation calls for coordinated, multi-level government and data sharing [29]. Nodes symbolizing community-based adaptation such as volunteer mobilization or local cooling centers often stand alone or are not sufficiently linked to routes of resource allocation. This reflects results showing low-income and informal communities lack infrastructure for heat adaptation, technical support, or funding [30].

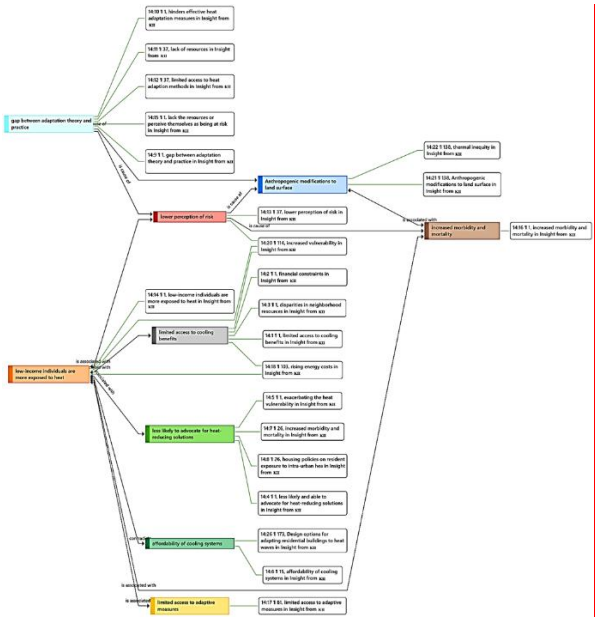

Figure 1. Network analysis of challenges in adapting to heatwaves. Source: Key Informant Interview (2024).

Especially in mapping heat-vulnerable populations and real-time monitoring, the network exposes data flow bottlenecks. As stressed in recent research on urban heat risk mapping and digital technology integration, targeted interventions are difficult to design and execute without thorough, localized data [31]. Some nodes draw attention to the fact that measures of adaptation disproportionately help better-resourced areas, so exposing underprivileged populations. This is consistent with research demonstrating unequal adaptive capacity and the need of social capital for resilience especially in underprivileged or informal communities [30]. The network notes that some rely on air conditioning and other energy-intensive practices, which are not available to all and might aggravate urban heat islands and greenhouse gas emissions. Lack of awareness and support sometimes results in underutilization of sustainable, community-driven solutions. Recent research on urban heat resilience and adaptation planning supports the need for integrated, community-cantered, and data-driven approaches to address these issues [29- 31].

4.3.2 Areas of Intervention for Urban Climate Adaptation and Resilience

The network emphasizes the importance of community-based adaptation strategies in urban climate resilience (Figure 2). It addresses the urgent issue of ensuring equitable cooling access for underprivileged urban areas during heatwaves. This is crucial as access to cooling is a basic need for human health, productivity, and well-being, yet it is disproportionately affected by underprivileged groups [32]. The network highlights the

need for financial and technical support in enabling adaptation through resources and incentives. Community-based adaptation requires large expenditures in local capacity building, training, tools, and technical support [33]. It also emphasizes the integration of grey, green, and blue infrastructure in urban planning, which requires coordinated strategies combining water management systems (blue) with nature-based solutions (green) and grey traditional infrastructure (green). The network emphasizes the importance of integrating policies for heatwave impacts and policy and institutional responses, which depend on bottom-up input from communities most affected by climate impacts. The development of transferable spatial development solutions for climate adaptation links more general urban planning processes with community-based strategies, focusing on local microclimates, sensitive populations, and social networks [34]. Heat mitigating by assessing community mobility and access to active travel options is another intervention area that directly impacts community resilience during extreme heat events. Addressing broader governance and legislative constraints is essential for community-based projects to scale and have long-lasting effects. According to the literature, tackling the structural causes of inequality that limit communities' access to resources, authority, and decision-making is necessary for transformative community-based adaptation [35].

Figure 2. Areas of Intervention for Urban Climate Adaptation and Resilience. Source: Key Informant Interview (2024).

4.3.3 Policies and Governance Approaches for Urban Climate Adaptation and Resilience

Urban heatwaves can be addressed by the implementation of policies and governance systems at the city level, which aim to assist individuals living in poverty inside urban areas. One potentials strategy is the formulation of comprehensive heat action plans that prioritize vulnerability assessment and the implementation of long-term measures tailored to urban areas. The integration of these plans into urban and regional planning endeavors is vital, as they must effectively tackle concerns pertaining to the built environment and land use/planning. Policy approaches that are suggested to enhance heat stress resilience in urban populations include the transmission of information, the provision of incentives and disincentives, and the promotion of relevant initiatives, the demonstration of effective strategies, and the implementation of legislation. Furthermore, the implementation of heat adaptation planning that is led by the community can serve to strengthen marginalized communities and effectively tackle obstacles hindering the adoption of adaptation techniques. The success of adaptation strategies relies heavily on addressing major impediments, including the identification and definition of the problem, enhancing the utilization of information, and the development, evaluation, and choice of solutions. By enacting and implementing these policies and measures, metropolitan areas can enhance their capacity to assist disadvantaged populations in mitigating the impacts of heatwaves (Figure 3).

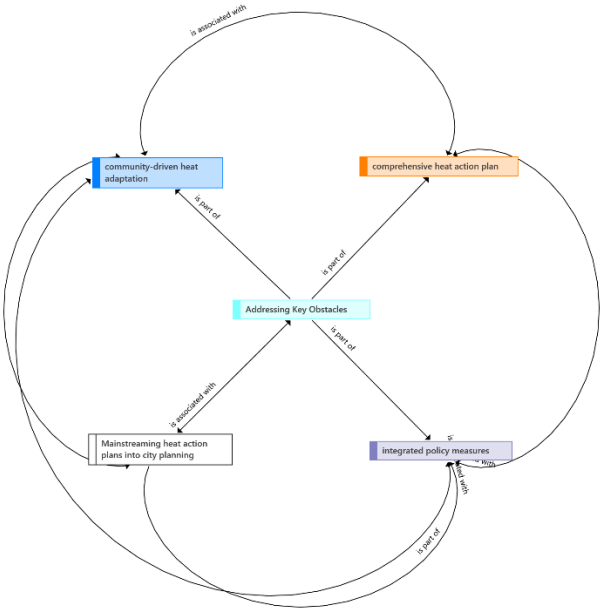

Figure 3. City-level policies and governance approaches that can be initiated for urban climate adaptation and resilience. Source: Key Informant Interview (2024).

4.3.4 Intersectionality of Challenges and Way Forward in Adapting to Heatwave

The Sankey diagram highlights the interconnected nature of heatwave adaptation challenges, emphasizing

the need for multiple approaches rather than discrete problems. It highlights the complex web of relationships in urban heat resilience, highlighting the intersectional nature of social, economic, environmental, and governance factors. The diagram acknowledges that some populations face multiple overlapping issues during extreme heat events, requiring integrated solutions targeting the underlying causes. Effective heatwave adaptation requires systemic thinking, considering various pathways and feedback loops, and aligns with the current understanding that single-sector approaches are insufficient for achieving climate resilience. The diagram's complexity underscores the need for integrated solutions (Figure 4). The diagram strongly highlighted the lack of accessibility to cooling facilities and systems as the prime challenge for the impoverished which creates hindrance in the way to adapt to heatwave. It also depicts that low-income people are mostly exposed to heat stress and therefore most vulnerable to the impact of heatwave. The aforementioned challenges can be overcome by taking some interconnected and mutually reinforcement able interventions.

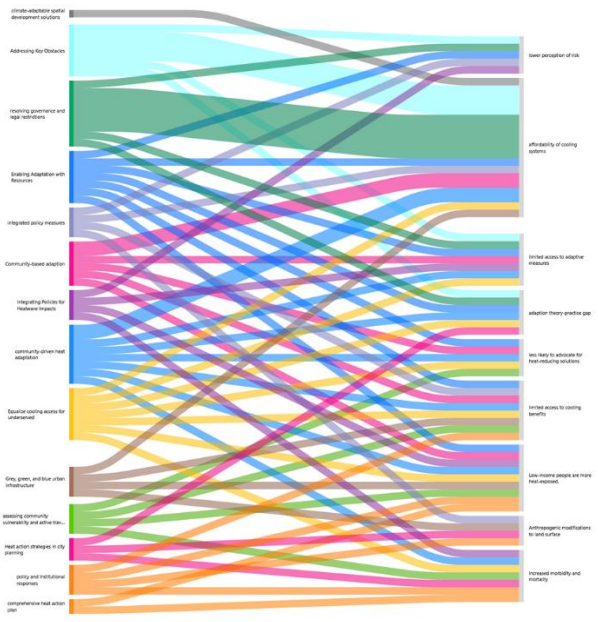

Figure 4. Code-cooccurrence Sankey Diagram regarding challenges and opportunities in adapting to heatwave nexus. Source: Key Informant Interview and Direct Observation (2024).

The establishment of efficient governance and the provision of legislative support establish a comprehensive structure for the implementation of actions. Community-based strategies play a crucial role in ensuring the inclusivity and local relevance of adaptation efforts. Spatial development solutions and infrastructure integration offer tangible methods for mitigating heat exposure. Financial support is provided by resources and incentives to facilitate these endeavors. Equitable access, the provision of active transport options, and policy cooperation are measures aimed at mitigating the unique impacts of heatwaves. Collectively, these strategies constitute a comprehensive methodology for attaining urban-level heatwave adaptation and resistance.

5. Conclusions and Implications

Particularly in economically underprivileged groups, this study shows that community-based initiatives are central to enhancing resilience against heatwaves in informal urban settlements. Predominant coping strategies—such as the collective use of low-cost measures like fans, improved ventilation, and adjusted daily routines—demonstrate the community's capacity to mobilize local assets and knowledge in response to extreme heat. However, the study also highlights that adaptive capacity remains uneven, with lower-income and less-educated households facing greater barriers, underscoring the importance of equity and social capital emphasized in community resilience theory. Initiatives such as greening projects and resilience hubs not only reduce physical exposure to heat but also strengthen social cohesion and participatory governance, aligning with theoretical perspectives that prioritize collective action and social infrastructure as pillars of resilience. Finally, the findings underscore that institutional support and multi-level governance are essential to sustain and scale community-led adaptation, reflecting the dynamic, systems-based approach at the heart of community resilience frameworks. The study also emphasizes important difficulties that underprivileged urban populations experience, including limited access to cooling resources, poor housing conditions, and inadequate social support, which taken together impede good heatwave adaptation. These results coincide with current research pointing out that heat vulnerability in urban environments is mostly determined by socioeconomic levels [36]. Moreover, because of lower green cover and higher surface temperatures, the urban heat island effect increases exposure for low-income neighbourhoods, so aggravating health risks and energy loads.

Crucially, the study points up particular areas where regional planning and governance can step in to support efforts at community adaptation. Resilience can be much enhanced by giving access to cooling facilities top priority, including heat mitigating into urban design, and implementing inclusive policies. It is absolutely vital to create thorough heat action plans including long-term adaptation strategies and vulnerability assessments including long-term adaptation measures. To remove systematic obstacles experienced by the urban poor, policies supporting information distribution, incentives

for heat mitigating, community-led adaptation planning, and legislative support are absolutely necessary. This is consistent with models supporting multi-level governance strategies combining community involvement, fair resource allocation, and infrastructure upgrades to increase urban climate resilience [37- 39]. Visited through the Sankey diagram in this study, the intersectionality of challenges and interventions emphasizes the need of coordinated, multi-dimensional strategies combining governance, spatial planning, community empowerment, and financial support. Apart from guaranteeing local relevance and inclusivity, community-based approaches help to improve social cohesiveness and knowledge sharing, which are essential for ongoing adaptation. These results align with resilience theory stressing the part social capital and participatory governance play in urban climate adaptation [40].

Finally, this study supports the fact that, especially in vulnerable groups, community-based projects are absolutely essential for fostering urban resilience against heatwaves. Targeted interventions, inclusive governance, and integrated urban planning help to address socioeconomic inequalities, so improving the adaptive capacity of underprivileged areas. Scaling participatory, context-specific adaptation strategies that synergize technological, ecological, and social dimensions to build sustainable and fair heat-resilient cities should be the main emphasis of future research and policy.

References

[1] C. Demidchuk, D. G. Santoyo, G. G. Cushman, J. W. L. Eng Luz, A. Gil, and M. R. Blessing, "Sustainable cooling and heat adaptation: Cool roofs as a potential strategy for Dhaka, Bangladesh EE Practicum Report," 2019.

[2] C. Roberts *et al.*, "Enhanced monitoring of atmospheric methane from space over the Permian basin with hierarchical Bayesian inference," *Environmental Research Letters*, vol. 17, no. 6, Jun. 2022, doi: 10.1088/1748-9326/ac7062.

[3] Md. S. Salan and Md. S. Reza, "CLIMATE CHANGE AND SEASONAL BEHAVIORAL DISRUPTION OF CLIMATE PARAMETERS: A STUDY OF RAJSHAHI CITY," in *Proceedings, International Conference on Disaster Risk Management*, 2019. [Online].

[4] A. Subedi, T. Islam, R. Khan, Dr. A. and Hassan, and S. Hogesteeger, "Identification of Heat Threshold and Heat Hotspots," 2021.

[5] S. Shahid, X. J. Wang, S. Bin Harun, S. B. Shamsudin, T. Ismail, and A. Minhans, "Climate variability and changes in the major cities of Bangladesh: observations, possible impacts and adaptation," *Reg Environ Change*, vol. 16, no. 2, pp. 459–471, Feb. 2016, doi: 10.1007/s10113-015-0757-6.

[6] H. Nissan, K. Burkart, E. C. de Perez, M. Van Aalst, and S. Mason, "Defining and Predicting Heatwaves in Bangladesh," *J Appl Meteorol Climatol*, vol. 56, no. 10, pp. 2653–2670, Oct. 2017, doi: 10.1175/JAMC-D-17-0035.1.

[7] M. Wannewitz *et al.*, "Progress and gaps in climate change adaptation in coastal cities across the globe," *Nature Cities 2024 1:9*, vol. 1, no. 9, pp. 610–619, Aug. 2024, doi: 10.1038/s44284-024-00106-9.

[8] R. Khan and C. Blackwell, "Reducing Heat Impacts in Rajshahi City, Bangladesh." Accessed: Jun. 02, 2025. [Online].

[9] J. A. Razzak *et al.*, "Impact of community education on heat-related health outcomes and heat literacy among low-income communities in Karachi, Pakistan: a randomised controlled trial Handling editor Seye Abimbola," *BMJ Glob Health*, vol. 7, p. 6845, 2022, doi: 10.1136/bmjgh-2021-006845.

[10] T. Mondal, J. Sen, R. Goswami, and P. K. Nag, "Community Adaptation to Heat stress − Social Network Analysis," *Clim Risk Manag*, vol. 44, p. 100606, Jan. 2024, doi: 10.1016/J.CRM.2024.100606.

[11] C. K. Uejio, J. Gilbert, Y. Ahn, L. Martella, L. Hu, and J. Marturano, "Rapidly Developing a Community-and Evidence-Based Heat Action Plan," 2024, doi: 10.1175/BAMS-D-23-0055.1.

[12] S. Sha and Q. Cheng, "Built or Social environment? Effects of perceptions of neighborhood green spaces on resilience of residents to heatwaves," *Urban For Urban Green*, vol. 94, p. 128267, Apr. 2024, doi: 10.1016/J.UFUG.2024.128267.

[13] J. P. Rafferty, "heatwave," *Encyclopaedia Britannica*. 2023.

[14] B. Walker *et al.*, "Resilience Management in Social-ecological Systems: a Working Hypothesis for a Participatory Approach," 2002. [Online].

[15] L. Brogden *et al.*, "A learning design framework for community resilience: International and transdisciplinary perspectives on a boundary object," *International Journal of Educational Research Open*, vol. 3, Jan. 2022, doi: 10.1016/j.ijedro.2022.100200.

[16] F. H. Norris, S. P. Stevens, B. Pfefferbaum, K. F. Wyche, and R. L. Pfefferbaum, "Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness," *Am J Community Psychol*, vol. 41, no. 1–2, pp. 127–150, Mar. 2008, doi: 10.1007/s10464-007-9156-6.

[17] T. A. Muñoz-Erickson *et al.*, "Beyond bouncing back? Comparing and contesting urban resilience frames in US and Latin American contexts," *Landsc Urban Plan*, vol. 214, Oct. 2021, doi: 10.1016/j.landurbplan.2021.104173.

[18] C. O. N. Moser, "Reassessing urban poverty reduction strategies: The asset vulnerability framework."

[19] M. Roy, D. Hulme, and F. Jahan, "Contrasting adaptation responses by squatters and low-income tenants in Khulna, Bangladesh," *Environ Urban*, vol. 25, no. 1, pp. 157–176, Apr. 2013, doi: 10.1177/0956247813477362.

[20] D. Archer, W. Marome, B. Natakun, P. Mabangyang, and N. Phanthuwongpakdee, "The role of collective and individual assets in building urban community resilience," *International Journal of Urban Sustainable Development*, vol. 12, no. 2, pp. 169–186, May 2020, doi: 10.1080/19463138.2019.1671425.

[21] I. Gambill, "HOW BOSTON ORGANIZATIONS AND INSTITUTIONS CAN ENGAGE IN COMMUNITY HEAT RESILIENCE INITIATIVES," 2023.

[22] Office of Resilience, "Heat Resilience Playbook," 2023.

[23] K. Signer, S. Formosa, and T. Seal-Jones, "Building community resilience: The City of Victoria's approach to climate change adaptation and extreme heat response," *J Bus Contin Emer Plan*, vol. 17, no. 2, pp. 116–129, Dec. 2023, doi: 10.69554/ISXJ1803.

[24] M. B. Sosa, M. A. Cantón, and E. Correa, "Neighborhood's scale resilience facing heatwave events. Metropolitan area of Mendoza—Argentina as an study case," *Resilient and Sustainable Cities: Research, Policy and Practice*, pp. 457–471, Jan. 2023, doi: 10.1016/B978-0-323-91718-6.00012-8.

[25] F. Amin, S. Baidya, and A. K. Gupta, "Community-Based Disaster Reduction for Climate Resilience in Developing World," *The Palgrave Handbook of Socio-Ecological Resilience in the Face of Climate Change: Contexts from a Developing Country*, pp. 11–19, Jan. 2023, doi: 10.1007/978-981-99-2206-2_2.

[26] F. H. Norris, B. Pfefferbaum, and K. Wyche, "Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness," *Article in American Journal of Community Psychology*, 2008, doi: 10.1007/s10464-007-9156-6.

[27] Q. Fu, Z. Zheng, M. N. I. Sarker, and Y. Lv, "Combating urban heat: Systematic review of urban resilience and adaptation strategies," *Heliyon*, vol. 10, no. 17, p. e37001, Sep. 2024, doi: 10.1016/J.HELIYON.2024.E37001.

[28] S. Pijon, S. Hasan, M. Mubin, and T. Akther, "Assessment of Water Quality and Sanitation Systems in Urban Slums: A Case Study of Rajshahi City Corporation, Bangladesh," *American Journal of Environmental Protection*, vol. 14, no. 1, pp. 12–20, Feb. 2025, doi: 10.11648/J.AJEP.20251401.12.

[29] S. Dr. Kafka, "Urban Climate and Necessity for Adaptation in Cities - An Information Statement of the American Meteorological Society." Accessed: Jun. 02, 2025. [Online].

[30] M. Yazdani and M. Haghani, "Enhancing community resilience to urban heatwaves: A simulation-based approach for volunteer management and shelter selection," *Progress in Disaster Science*, vol. 23, Oct. 2024, doi: 10.1016/j.pdisas.2024.100331.

[31] World Bank, "URBAN OVERHEATING & ADAPTATION MEASURES: An analysis at EU, national, and local level."

[32] Sustainability Directory, "Equitable Cooling Access in a Warming Climate → Scenario." Accessed: Jun. 03, 2025. [Online].

[33] Sustainability Directory, "Community-Based Climate Adaptation in Vulnerable Urban Areas → Scenario." Accessed: Jun. 03, 2025. [Online].

[34] European Union, "Adapting to climate change through spatial planning," Mar. 2024. Accessed: Jun. 03, 2025. [Online].

[35] H. Reid, "Ecosystem- and community-based adaptation: learning from community-based natural resource management," *Clim Dev*, vol. 8, no. 1, pp. 4–9, Jan. 2016, doi: 10.1080/17565529.2015.1034233.

[36] S. Chen, S. Bruhn, and K. C. Seto, "Trends in socioeconomic disparities in urban heat exposure and adaptation options in mid-sized U.S. cities," *Remote Sens Appl*, vol. 36, p. 101313, Nov. 2024, doi: 10.1016/j.rsase.2024.101313.

[37] I. Anguelovski *et al.*, "Equity Impacts of Urban Land Use Planning for Climate Adaptation," *J Plan Educ Res*, vol. 36, no. 3, pp. 333–348, Sep. 2016, doi: 10.1177/0739456X16645166.

[38] S. Meerow, J. P. Newell, and M. Stults, "Defining urban resilience: A review," *Landsc Urban Plan*, vol. 147, pp. 38–49, Mar. 2016, doi: 10.1016/j.landurbplan.2015.11.011.

[39] Md. S. A. Salan, "Dynamics of Urban Heatwave and Its Impacts on Slum Communities: A Case Study of Rajshahi City Corporation, Bangladesh," 2024. [Online]. Available: www.jeas.ruet.ac.bd

[40] D. P. Aldrich and M. A. Meyer, "Social Capital and Community Resilience," *American Behavioral Scientist*, vol. 59, no. 2, pp. 254–269, Feb. 2015, doi: 10.1177/0002764214550299.