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"It is getting too hot lately": Urban households' knowledge, experiences and governance of extreme heat events in Accra, Ghana

Yaw Agyeman Boafo [a,*], Ebenezer Forkuo Amankwaa [b], Catalina Spataru [c], Priscila Carvalho [c]

[a] Centre for Climate Change and Sustainability Studies, College of Basic and Applied Sciences, University of Ghana, Legon, Ghana
[b] Department of Geography and Resource Development, College of Humanities, University of Ghana, Legon, Accra, Ghana
[c] The Bartlett School of Environment, Energy and Resources, University College London, 14 Upper Woburn Place WC1H 0NN, United Kingdom

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ABSTRACT

As climate change accelerates, extreme heat events have become one of the most pervasive and dangerous threats to urban populations worldwide, disproportionately affecting vulnerable communities. This study investigates household awareness, experiences, and governance responses to extreme heat in the Greater Accra Metropolitan Area, Ghana. A mixed-methods approach, involving household surveys ($n = 413$) and focus group discussions ($n = 3$), was used to assess three neighbourhoods: Dansoman, Osu, and Ashaley Botwe. The findings show high levels of awareness of extreme heat across all neighbourhoods, but Ashaley Botwe reported the greatest disruption to daily life, driven by rapid urbanisation and economic vulnerability. Health concerns, discomfort, and sleep disruptions emerged as the most common impacts. Further analyses revealed that age, generation group, and income significantly influenced household awareness and adaptive responses to extreme heat. Older residents and higher-income households were more likely to invest in cooling systems, while education positively correlated with increased awareness of extreme heat risks. Despite the clear recognition of extreme heat as a major issue, government-led strategies and local engagement in heat governance were found to be largely absent, highlighting a governance gap. This study highlights the necessity for targeted, community-specific climate resilience strategies that consider demographic and socio-economic vulnerabilities. The findings advocate for the integration of localized climate adaptation measures into urban planning frameworks to mitigate the adverse effects of extreme heat in fast-growing cities like Accra.

1. Introduction

As climate change accelerates, global temperatures continue to rise, reshaping urban environments and leading to more frequent, intense, and prolonged extreme heat events (Fischer et al., 2021; IPCC, 2018, 2022, 2023). In urban areas, the urban heat island (UHI) effect, driven by dense construction, minimal green spaces, and large populations, intensifies heat, increasing energy demands,

* Corresponding author.
E-mail address: yboafo@ug.edu.gh (Y.A. Boafo).

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degrading air quality, and heightening health risks (Arnfield, 2003; Zhou et al., 2022; Freychet et al., 2022; Cao et al., 2021).

Extreme heat in the tropics and sub-Saharan Africa typically refers to prolonged periods of unusually high temperatures that significantly exceed the regional climate norms. These regions, characterised by consistently warm temperatures, experience extreme heat when daytime maximum air temperatures rise above 35 °C, often accompanied by elevated night-time temperatures that hinder heat dissipation (Marcotullio et al., 2021; Nicholson, 2018). In sub-Saharan Africa, extreme heat events are often exacerbated by the UHI effect (Ayanlade, 2016). For this research, extreme heat is considered as daily maximum temperatures exceeding 35 °C, compounded by high mean radiant temperature, a metric used to capture the combined effects of direct sunlight and air temperature (Codjoe et al., 2014; Wilby et al., 2021). These heat conditions, especially when persistent, can disrupt human activities, strain infrastructure, and pose significant health risks, particularly to vulnerable populations (Codjoe et al., 2020; Jagarnath et al., 2020; Kayaga et al., 2021).

Extreme heat poses significant health, economic, and social challenges for vulnerable communities worldwide, particularly in urban areas of the global North and South (Dickinson et al., 2020; Laranjeira et al., 2021; Niu et al., 2022; Tuholske et al., 2021). Factors such as geography, climate, infrastructure, and socioeconomic status heavily influence susceptibility to heat, with vulnerable groups like the elderly, children, and low-income families facing heightened risks (Ellena et al., 2020; Jagarnath et al., 2020).

In Africa, extreme heat is becoming a critical challenge as rapid urbanisation collides with climate-induced temperature increases. Several studies highlight that extreme heat events are growing in frequency and severity across the continent, especially in cities like Lagos, Johannesburg, Durban and Cairo, where urban planning has often struggled to keep pace with rapid growth (Dabaieh et al., 2024; Laue et al., 2022; Manyuchi et al., 2022). The continent's socio-economic vulnerabilities, including widespread poverty and limited access to infrastructure, exacerbate the impacts of extreme heat on marginalized populations (Muyambo et al., 2023; Olaniyan et al., 2019). Some recent studies have reported that, the compounding effects of climate change on urban heat disproportionately affect low-income groups, increasing their risk of heat-related illnesses and economic strain (Adegun and Ayoola, 2022; Pasquini et al., 2020; Jagarnath et al., 2020). Despite these challenges, extreme heat in Africa remains an underexplored area, especially in terms of urban governance and community responses.

Ghana, and particularly its capital Accra, is highly vulnerable to extreme heat due to rapid urbanisation, dense construction, and shrinking green spaces, all of which exacerbate the UHI effect (Adjetey et al., 2023; Poku-Boansi, 2021; Wilby et al., 2021). Observational data from Ghana indicate a trend of rising temperatures over the years, with more frequent and intense extreme heat events (Adu-Prah et al., 2019; Ankrah et al., 2023; Wemegah et al., 2020). Rapid urban development often surpasses the pace of green infrastructure implementation, leaving many urban communities vulnerable to heat-related illnesses and increased energy costs (Amankwaa and Ampomah, 2024; Mensah et al., 2021). The Local Climate Zones (LCZ) framework provides a standardized approach for analyzing urban heat dynamics by categorizing areas based on land cover, urban morphology, and thermal properties. This framework improves the understanding of heat exposure in heterogeneous urban environments like Accra, aiding targeted interventions (Stewart and Oke, 2015).

In cities like Accra, higher heat risks stem from both the general characteristics of urban environments and are further intensified during heatwaves. A study confirms the UHI's existence, magnitude, and impact on temperature extremes using Landsat imagery from 1991, 2002, and 2017, alongside temperature data from 1980 to 2017, which revealed UHI effects with temperature increases of 4.07 °C, 5.79 °C, and 4.86 °C, respectively (Gyimah, 2023). The built-up and bare land areas were most affected (Wemegah et al., 2020). UHI intensified warm temperature extremes and reduced diurnal temperature range, while continued urban growth is expected to increase warming, climate extremes, and health risks (ibid.).

Despite efforts to mitigate these impacts through smart city designs, urban greening and improved planning, Accra's infrastructural challenges, unplanned developments, and the rise of informal settlements leave many areas vulnerable to extreme heat (Asibey et al., 2022). The increasing frequency of heat events, compounded by socio-economic disparities, highlights the importance of studying extreme heat in Accra as a representative case for African cities facing similar challenges. One critical factor is the imbalance between the implementation of Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) measures. While these frameworks are intended to work synergistically to achieve the sustainable development goals, Ghana's national approach often prioritizes CCA initiatives, driven largely by access to more substantial international funding pools for climate adaptation. This focus leaves DRR initiatives underfunded and slower to advance, reducing the overall effectiveness of both frameworks (UNDRR, 2023). In response to these challenges, Ghana has integrated disaster risk reduction into its Medium-Term Development Framework to embed DRR into sectoral plans. However, the persistent under-resourcing of DRR programmes remains a significant hurdle, especially in rapidly urbanizing areas like Accra.

The Sendai Framework for Disaster Risk Reduction (2015–2030) provides a valuable framework for understanding and addressing the risks associated with extreme heat. The framework emphasizes the importance of understanding disaster risks (Priority 1) and strengthening disaster risk governance (Priority 2), which are directly relevant to this study. Through the assessment of urban residents in Accra's awareness and governance responses to extreme heat, this research aligns with the Sendai Framework's objectives of building resilience to climate-induced disasters through proactive governance and community engagement (Kelman, 2017; UNISDR, 2015).

This study aims to assess urban households' awareness, personal experiences, perceived impacts, and governance responses to extreme heat in the Greater Accra Metropolitan Area (GAMA). By bridging local experiences of extreme heat with broader governance frameworks, the study seeks to uncover actionable insights that can inform evidence-based policy and urban planning strategies. These findings are intended to benefit not only Accra but also other rapidly urbanizing cities across Africa, addressing a critical gap between community-level heat resilience and broader governance mitigation efforts.

2. Method and materials

2.1. Study area description and site selection

This study was conducted in the GAMA, located in the Greater Accra Region (GAR) of Ghana (Fig. 1). GAR, according to the Köppen classification, experiences a tropical savanna climate (Aw) with distinct wet and dry seasons. The wet season, from May to September, brings heavy rainfall, while the dry season, from November to March, sees little to no rain. Temperatures average between 25 °C and 31 °C year-round. The coastal location results in high humidity, especially during the wet season.

GAMA extends from 5.09°N to 5.47°N latitude and 0.08°E to 0.62°W longitude. It covers 1079 km^2 and is home to approximately 5.4 million people. This makes GAMA the most urbanised metropolis in Ghana (GSS, 2021). GAMA's geography includes a mix of coastal savannah and urbanised areas, with green spaces being rapidly replaced by concrete and asphalt (Puplampu and Boafo, 2021). Rising temperatures and ongoing urbanisation, coupled with the loss of vegetation, increase strain on infrastructure and healthcare systems, posing significant challenges for disaster risk reduction and climate adaptation (Ghana Meteorological, 2022).

In the GAMA, infrastructure development varies significantly, with some areas benefitting from planned roads and drainage systems, while others face congestion and flooding, particularly during the rainy season. Rapid urbanisation and the reduction of green and blue spaces further increase the vulnerability of GAMA to climate-related stressors, such as floods and extreme heat (Akubia et al., 2020; Poku-Boansi, 2021; Puplampu and Boafo, 2021). Although the Ghana Meteorological Agency (GMet) has not officially classified extreme heat as a health issue, rising temperatures necessitate investigation into their potential impacts on urban populations.

Three neighbourhoods—Osu, Dansoman, and Ashaley Botwe—were selected for this study to provide a comprehensive view of the heat challenges in diverse urban settings within the Greater Accra Metropolitan Area (GAMA) (Fig. 2). Osu and Dansoman, as densely urbanised, coastal neighbourhoods, feature high concentrations of heat-absorbing surfaces, such as asphalt and concrete, with limited green spaces, making them particularly susceptible to extreme heat (Adomako et al., 2021; Owusu, 2018). Ashaley Botwe, a peri-urban area experiencing rapid and unplanned development, offers a contrasting landscape, ideal for examining the effects of urban sprawl on heat exposure.

These neighbourhoods were selected based on their distinct geographic, socio-economic, and environmental characteristics, enabling an in-depth analysis of extreme heat experiences and governance responses. Empirical field observations and existing studies have established their thermal properties, highlighting variations in land use, population density, and income levels, which influence their vulnerability to extreme heat (Adomako et al., 2021; Gyasi-Addo, 2021). Osu, characterised by its high population density and limited green spaces, exemplifies the intensifying urban heat island effect in densely built areas. Dansoman, with relatively greater green cover and moderate population density, experiences less pronounced heat exposure (Owusu & Boamah, 2015). Meanwhile, Ashaley Botwe's unplanned development and reduced vegetation exacerbate its heat risks, highlighting the challenges of peri-urban growth (Poku-Boansi, 2021). Income levels also vary significantly, with Dansoman having wealthier households, while Osu and

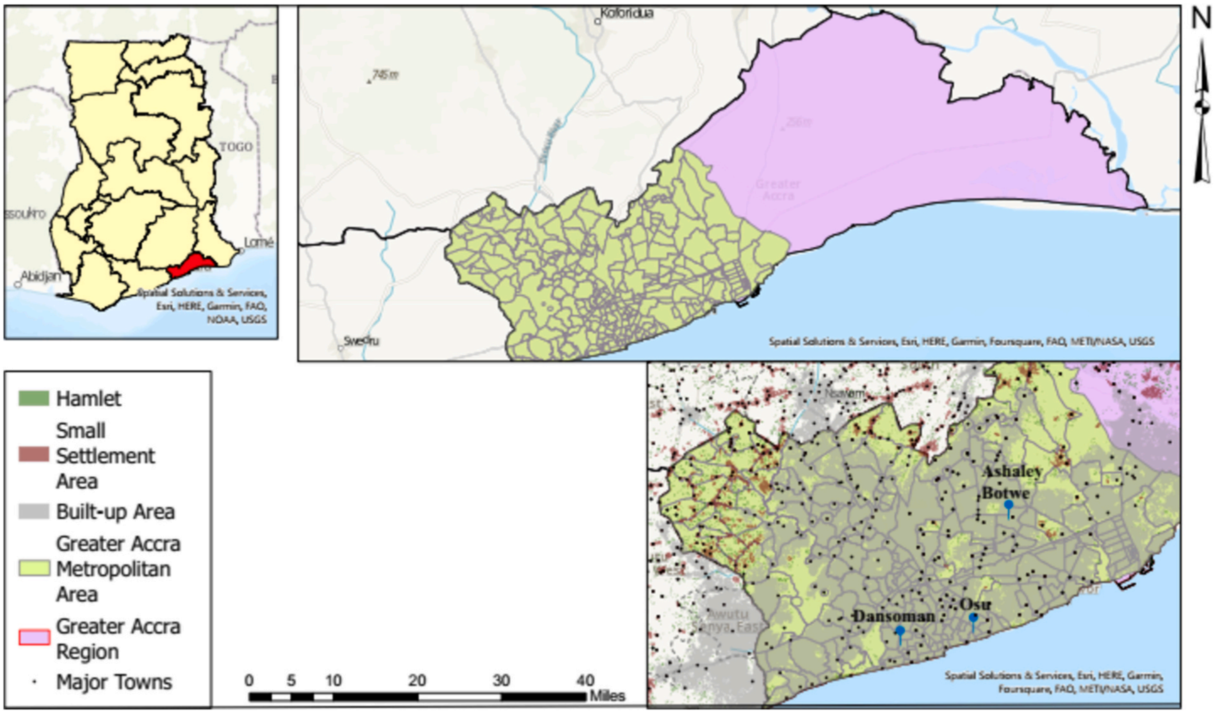

Fig. 1. Map of Greater Accra Region of Ghana showing GAMA and the studied neighbourhoods.

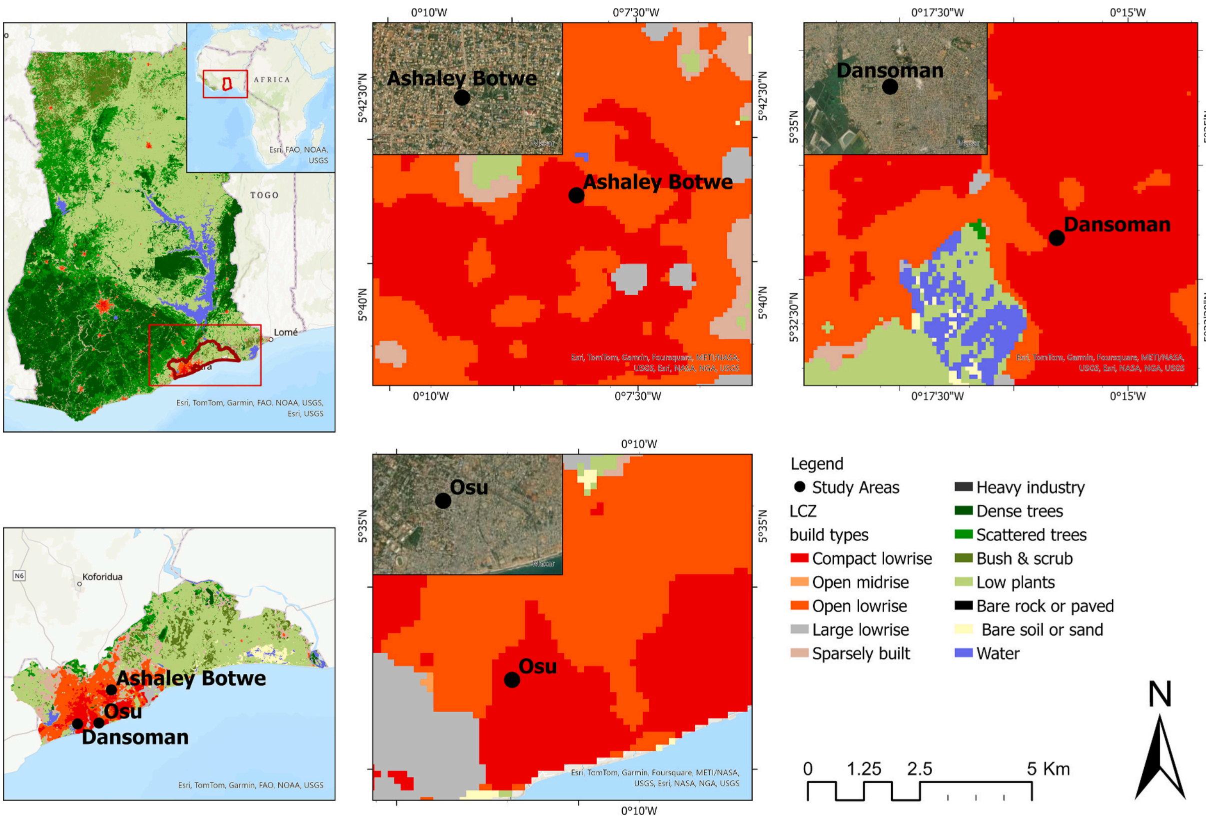

Fig. 2. Local Climate Zones (LCZ) map of Accra with integrated Google Earth imagery for the studied neighbourhoods. Google Earth imagery, retrieved December 7, 2024.

Ashaley Botwe exhibit greater economic vulnerability, limiting adaptive capacity (GSS, 2021).

To further contextualise these neighbourhoods, the Local Climate Zones (LCZs) framework was employed, offering a standardized approach for categorizing urban areas based on their physical structure, land cover, and thermal properties. Osu aligns with compact mid-rise zones (LCZ 2), Dansoman corresponds to open low-rise developments (LCZ 6), and Ashaley Botwe reflects mixed-use spaces typical of peri-urban dynamics. This framework is particularly relevant for Accra, where rapid urbanisation and shrinking green spaces exacerbate heat-related vulnerabilities. By integrating LCZ classifications with socio-economic and environmental data, the study gains a nuanced understanding of how urban morphology and land use contribute to heat exposure and vulnerability in GAMA (Dodoo and Ayarkwa, 2019; Wemegah et al., 2020).

2.2. Methodology

This study utilized a survey approach to gather comprehensive data on the awareness, experiences, perceptions, and governance responses of GAMA's residents to extreme heat. Surveys are effective in capturing the diverse experiences of different demographic groups, allowing for a nuanced understanding of how various segments are affected (McKim, 2017). Both primary and secondary data collection methods were utilized. Primary data were gathered through household questionnaire surveys, focus group discussions, and field observations. Secondary data sources included climate and meteorological records from the Ghana Meteorological Agency, demographic data from the Ghana Statistical Service, and relevant literature on urban heat impacts and governance from peer-reviewed articles and reports.

2.2.1. Data collection

Primary data collection occurred between June and July 2022. Before the main survey, a pilot study was conducted in the Legon-Staff Village in Accra to familiarize enumerators with the questionnaire and assess its feasibility. Feedback from the pilot informed refinements to the survey tools, improving their ability to effectively capture respondents' experiences of extreme heat.

2.2.1.1. Household questionnaire survey. The household survey was facilitated using REDCap (Research Electronic Data Capture), a secure, web-based platform designed for research data capture, providing features such as a user-friendly interface, audit trails, automated export to statistical software, and data integration with external sources (Harris et al., 2019). The survey was conducted by four trained graduate student enumerators to ensure consistency and data reliability.

The questionnaire gathered data across five key domains: demographic characteristics, perceptions of extreme heat (frequency, severity, and personal experience), health impacts (self-reported symptoms such as exhaustion and dehydration), coping strategies (cooling mechanisms and behavioural adaptations), and governance responses (awareness of government interventions and household investments). These variables were selected to comprehensively assess the multifaceted impacts of extreme heat on urban households, informing heat resilience interventions. Respondents were grouped by age (18–30, 31–50, and 51–70+ years) and by generation (Baby Boomers/Jones, Generation X, Millennials, and Generation Z) to analyse the influences of life stage and generational experiences on perceptions of extreme heat.

A total of 413 households from Dansoman (n = 173), Osu (n = 120), and Ashaley Botwe (n = 120) were surveyed, ensuring the inclusion of diverse age groups, genders, and educational levels. This sample size was determined using Cochran's formula, accounting for a 5 % margin of error (e) and a 95 % (Z = 1.96) confidence level.

$$n_0 = Z\hat{}2^{*}\ p^{*}\ (1 - p)/e\hat{}2$$

Given limited prior data, we conservatively estimated that 50 % of the population, represented by the variable 'p', would exhibit characteristics relevant to the study. This approach ensures the maximum sample size necessary to accurately represent the population's attributes.

The pre-determined sample size was 385 households across the neighbourhoods, with an additional buffer to account for potential unusable data, bringing the total to 413. The sample size allocation was proportional to the population sizes of the municipalities and neighbourhoods, ensuring that the findings reflect the experiences of residents in these varied urban contexts (GSS, 2021).

Households were selected using stratified sampling, where each neighbourhood was divided into four zones—East, West, North, and South—to ensure proportional representation based on spatial considerations and socio-demographic factors such as population size, age, gender, income, and education levels. This approach aimed to capture a broad range of perceptions on extreme heat, ensuring that the experiences of various socio-economic and demographic groups were represented. Stratified sampling also enabled a more accurate and nuanced understanding of how different neighbourhoods experience and respond to extreme heat (Turner, 2003).

2.2.1.2. Focus group discussions. In each sampled neighbourhood, one focus group discussion (FGD) was conducted with seven participants, selected during the questionnaire survey based on their reported exposure, sensitivity, and adaptive capacity to extreme heat. Participants were deliberately chosen to capture diversity across various demographic and socio-economic categories such as age, gender, education level, and income, ensuring a wide spectrum of experiences and perspectives related to extreme heat. Each FGD lasted between 1½ to 2 h and was conducted in adherence to ethical guidelines and within an environment conducive to open sharing. Sessions were digitally recorded (with consent), translated, if necessary, transcribed, and subsequently coded for analysis.

2.2.2. Data analysis

The quantitative data were pre-processed to address missing values and ensure consistency. Missing data were either imputed or removed based on the extent of missingness. Continuous variables were inputted based on their central tendency (mean or median), while categorical variables were handled using mode imputation. The data covered demographic information, perceptions of extreme heat, adaptive behaviours, and reported health impacts, collected through a household questionnaire survey. Missing data, particularly in questions about household income or health impacts, were addressed using appropriate imputation techniques. Supplementary S1 summarizes the key sections of the questionnaire, outlining the types of questions used to assess residents' experiences and responses to extreme heat. The data were then normalized to account for variations across different scales, ensuring comparability across different scales, particularly for awareness levels, socio-demographic factors, and heat perceptions.

For quantitative analysis, Microsoft Excel (version 2022) and R software (version 4.1.1) were used for both descriptive and inferential analyses. Descriptive statistics, including chi-square tests and ANOVA (Analysis of Variance), were employed to explore relationships between variables such as extreme heat, demographics, and the respondents' communities. Auto-correlation tests using the auto-correlation function (ACF) were conducted to check for temporal dependencies, and multicollinearity tests addressed covariate relationships. The study ensured that the correlations presented are robust and accurately reflect the relationships between variables, independent of any collinearity effects. Data were grouped by neighbourhood and demographic characteristics, with a p-value less than the alpha threshold 0.05 indicating significant differences, leading to the rejection of the null hypothesis. Metrics included awareness levels (measured on a Likert scale of 1 to 5), perceptions of extreme heat (categorized variables), socio-demographic factors (e.g., age, income, education), health impacts (e.g., dehydration, heat exhaustion), and adaptive responses (e.g., cooling mechanisms). Results above the p-value threshold suggested no significant difference, thus, we failed to reject the null hypothesis.

Qualitative data from focus group discussions were transcribed, coded, and thematically analyzed to uncover patterns related to personal experiences, governance mechanisms, and socio-cultural responses to extreme heat. Emerging themes included neighbourhood awareness, access to cooling infrastructure, and perceptions of government involvement in heat-related issues. These qualitative insights complemented the quantitative findings, providing context and depth. Participant quotes were used to illustrate key points, shedding light on personal experiences and attitudes toward extreme heat adaptation and governance.

2.3. Ethical considerations

Ethical clearance was obtained from the Ethics Committee for Basic and Applied Sciences (ECBAS), University of Ghana (ref. ECBAS 070/21–22). This clearance ensured that the research was conducted ethically and adhered to the principles of respect, fairness, and confidentiality in dealing with the respondents. Participants were informed about the study's purpose, procedures, and potential risks, and their participation was voluntary. They had the right to withdraw from the study without any consequences. Data sharing with UK co-authors adhered to General Data Protection Regulation (GDPR) and local data protection regulations. All data were anonymized prior to sharing, and access was restricted to the research team through a secure, password-protected online platform. Data were transferred in encrypted formats, and team members adhered to confidentiality agreements as per the ethical approval.

3. Results

3.1. Socio-demographic characteristics of respondents

The demographic characteristics of the respondents from the three neighbourhoods surveyed reveal significant differences across key variables (Table 1). In terms of age distribution, the majority of respondents across all locations fall within the 31–50 years age bracket, with an average of 49.2 %. However, Ashaley Botwe has a notably higher proportion of younger respondents (18–30 years) at 35 %, compared to 26 % and 25 % for Osu and Dansoman, respectively. Regarding generational breakdown, Millennials (born 1981–1996) form the most significant portion of the sample, particularly in Ashaley Botwe, where they constitute 45 % of respondents. This contrasts with Osu and Dansoman, which have slightly lower representations of Millennials at 30.1 % and 27.6 %, respectively. Interestingly, Baby Boomers and the Jones generation (born 1946–1965) are more prevalent in Dansoman (24.1 %) compared to Osu (8.2 %) and Ashaley Botwe (10.0 %).

Marital status reveals that the majority of respondents in Osu are married (67.1 %), while Dansoman and Ashaley Botwe share similar proportions, with 48.3 % of respondents married in each neighbourhood. A higher percentage of respondents in Dansoman reported being "ever married" (18.3 %) compared to Osu (5.5 %) and Ashaley Botwe (15 %). The household income distribution shows significant variation across the three neighbourhoods ($p = 0.003$). Ashaley Botwe has the highest percentage (70 %) of households earning GHS 1000 or less monthly. In contrast, Dansoman has the highest proportion of households earning GHS 2001 and above (27.3 %). Educational levels also reveal some differences, though not statistically significant ($p = 0.592$). Respondents in Dansoman and Osu report higher levels of secondary and tertiary education, while Ashaley Botwe has a slightly higher proportion of respondents with only basic education or less (21.7 %).

Table 1
Socio-demographic Characteristics of the Study (household survey) Participants.

Personal characteristic	Osu	Dansoman	Ashaley Botwe	Mean	P-value
	%	%	%	%	
Respondents Age					
18–30 years	26.0	25.0	35.0	28.5	
31–50 years	52.1	46.7	48.3	49.2	0.500
51–70+ years	21.9	28.3	16.7	22.3	
Generation Type					
Baby boomers and Jones generation: born 1946–1965	8.2	24.1	10.0	13.6	
Generation X: born 1965 to 1980	28.8	27.6	18.3	25.1	
Xennials: born 1977 to 1983	21.9	13.8	13.3	16.8	0.084
Millennials: born 1981 to 1996	30.1	27.6	45.0	35.1	
Generation Z: born 1997 or after	11.0	6.9	13.3	10.5	
Marital Status					
Married	67.1	48.3	48.3	55.4	0.070
Never Married	27.4	33.3	36.7	32.1	
Ever Married	5.5	18.3	15.0	12.4	
Household Income (Monthly)$^{\infty}$					
GHS 1000 or less	58.9	55.0	70.0	61.1	0.003
GHS 1001–2000	26.0	11.7	21.7	20.2	
GHS 2001 and above	15.1	27.3	8.3	18.7	
Educational Level					
Basic education or less	21.9	15	21.7	19.7	0.592
Secondary education	37.0	43.3	46.7	42.0	
Tertiary	41.1	41.7	31.7	38.3	

Source: Field Survey, 2022.
∞USD 1 = GHS 7.67 (Bank of Ghana). June 2022.

3.2. Extreme heat awareness and experience

3.2.1. How do neighbourhoods awareness and experience of extreme heat differ?

Figs. 3a & b show the perception and experience of extreme heat across Dansoman, Osu, and Ashaley Botwe. In Osu, 90 % of respondents perceive extreme heat as a problem, while 98.3 % report experiencing it. In Dansoman, 65.8 % of respondents perceive extreme heat as a problem, with 80.8 % reporting actual experience of extreme heat. In Ashaley Botwe, 86.7 % perceive extreme heat as a problem, and 78.3 % report experiencing it.

The duration of extreme heat varied across neighbourhoods (Fig. 4c). In Dansoman, 23.3 % of respondents reported experiencing heat for less than an hour, while 15.1 % noted it lasted over a month. In Osu, 18.3 % experienced heat for 3–6 h, with 15 % reporting it lasted for up to a month. In Ashaley Botwe, 25 % experienced heat lasting between 6 and 12 h, and 18.3 % reported it lasted for 12–24 h. A participant from the focus group discussion in Dansoman echoed this, saying, *"Recently, there has been a clear trend of increasing extreme heat in Dansoman, a shift that significantly surpasses what we have encountered in the past. I know this because I have lived here for more than 30 years."* (See Fig. 5.)

Regarding the perception of change in extreme heat (Fig. 4d), in Dansoman, 47.9 % felt there was no change, while 30.1 % believed it had worsened. In Osu, 35 % believed conditions had worsened, and in Ashaley Botwe, 53.3 % perceived no change. A participant in Ashaley Botwe's focus group discussion remarked, *"It is getting too hot lately. I can confidently tell you that it is becoming uncomfortably hot, more so than usual."* Similarly, a resident from Osu shared, *"The days have become warmer, and we are feeling the heat more than before"*.

Further analyses reveal that some demographic factors including age, education, and income play a significant role in shaping awareness and experience of extreme heat. Age and generation group strongly influence the perception of extreme heat as a problem, with older individuals and specific generations more likely to recognize it as a serious issue ($p = 0.0002$, $p = 0.0027$). Additionally, educational status is a key factor in how frequently residents experience extreme heat, as those with higher education levels tend to report greater awareness of heat events ($p = 0.0022$). Household income is also significant, affecting both the perceived duration of extreme heat and whether residents feel the situation is worsening ($p = 0.0069$, $p = 0.0333$). Lower-income households may experience heightened vulnerability to prolonged heat exposure.

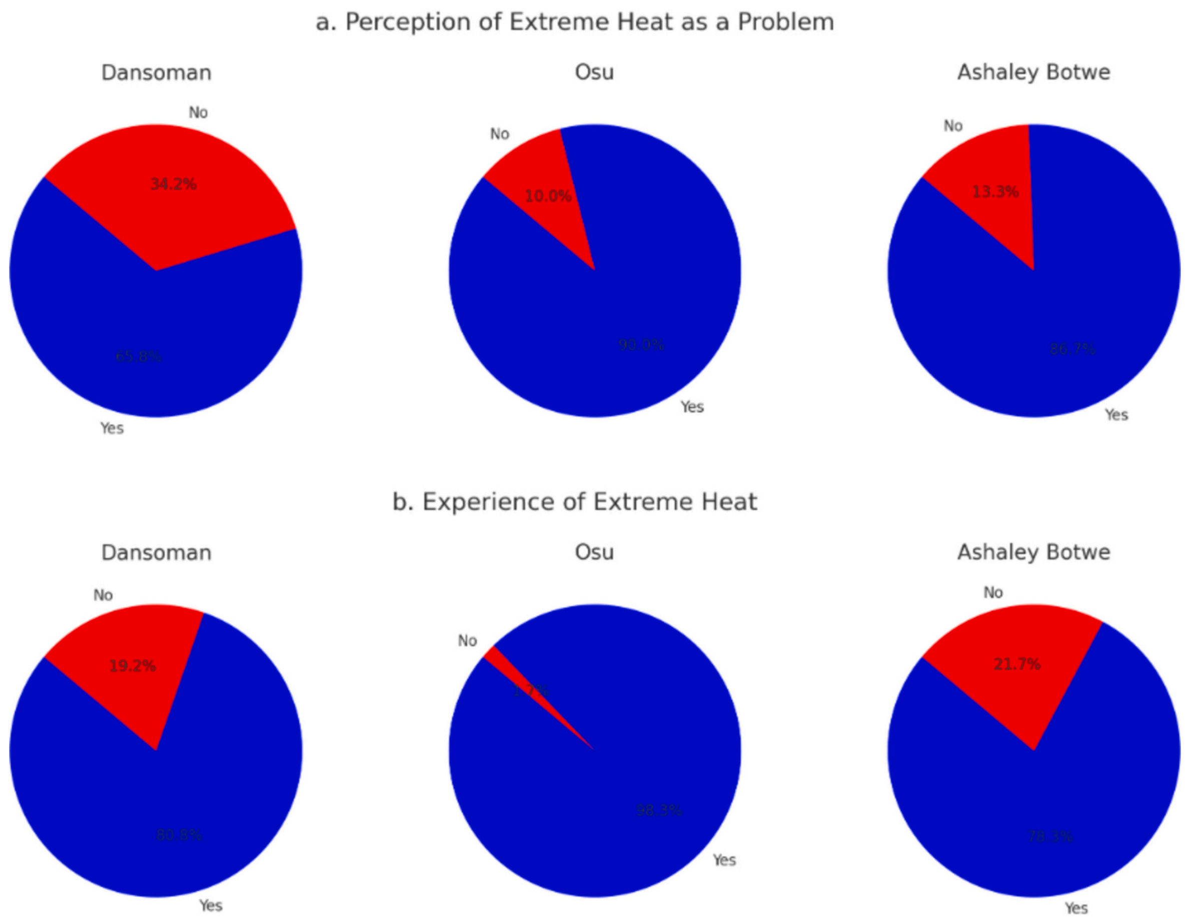

Fig. 3. Households (a) Awareness and Perception of Extreme Heat as a Problem (b) Experiences of Extreme Heat.

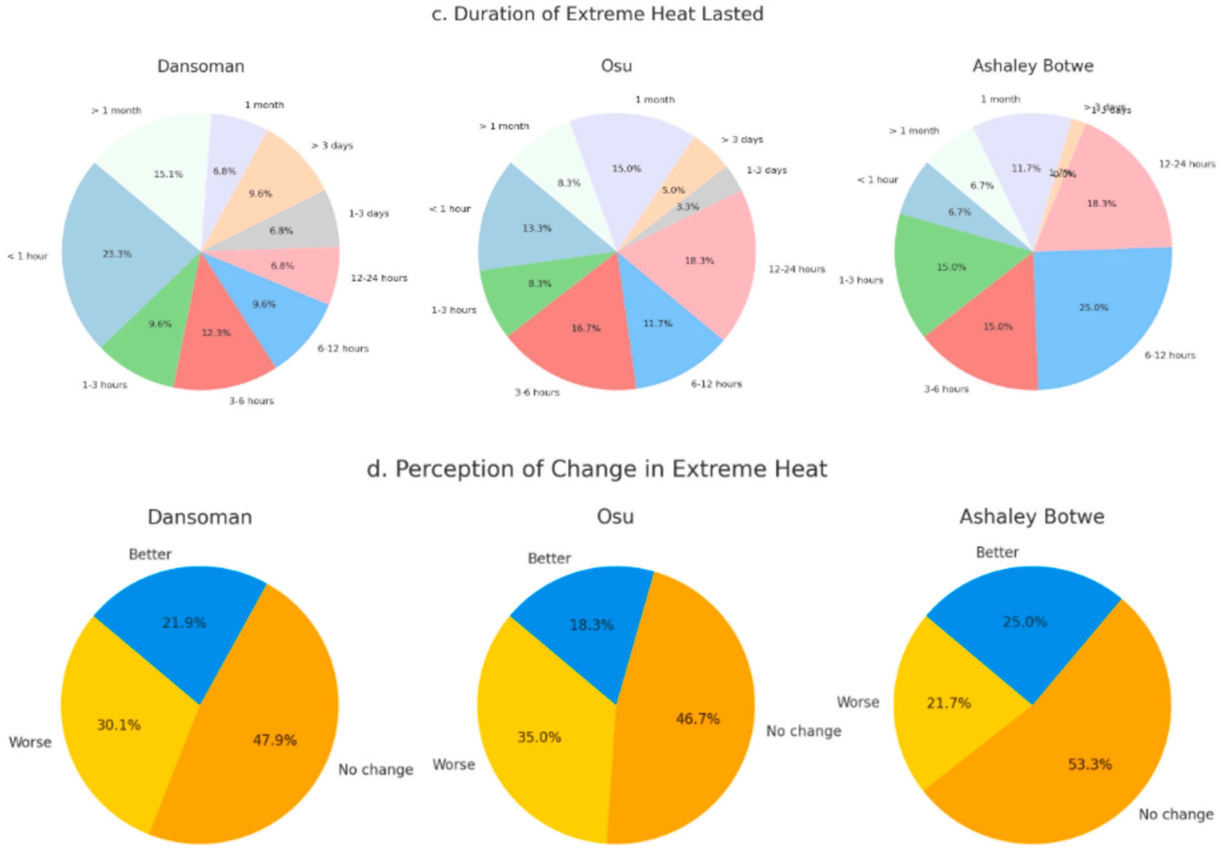

Fig. 4. Households (c) Report on the Duration of Extreme Heat Events (d) Perception of Change in Extreme Heat.

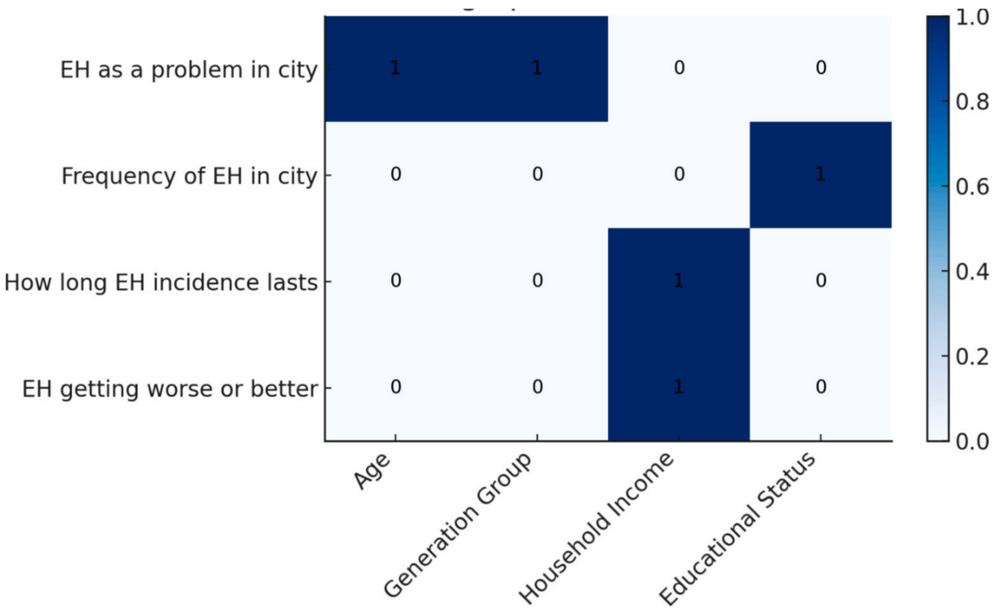

Fig. 5. Significant Associations Between Socio-demographic Factors and Extreme Heat Awareness and Experience. (Blue intensity represents significance, where darker shades indicate stronger associations).

3.3. Extreme heat impact and vulnerabilities

3.3.1. How do neighbourhoods differ in their concerns and vulnerabilities to extreme heat?

The results (Table 2) show that concerns about health, personal comfort, and sleeping during extreme heat are prevalent across all neighbourhoods, with Ashaley Botwe reporting the most significant disruption to sleep (mean = 26.7, $p = 0.011$). Excessive sweating was a key issue in Dansoman (mean = 28.6, $p = 0.018$), and water shortages were a notable concern in this area ($p = 0.036$). In Osu, focus group participants emphasized the removal of vegetation including trees as a major contributor to heat impacts, saying: "*When the heat comes, we suffer. They have cut down all the trees, so when the heat comes, we suffer. We can't sleep; we sweat a lot.*" This aligns with higher reported concerns about energy disruptions ($p = 0.014$) and economic losses (p = 0.036) in Osu.

Residents in Ashaley Botwe perceived the highest moderate (mean = 60, $p = 0.038$) and high risks (mean = 31.7, $p = 0.023$) related to extreme heat, reflecting heightened vulnerability in this community. Outdoor activities were also significantly impacted in Ashaley Botwe (mean = 12.5, $p = 0.056$), indicating that prolonged exposure to heat was a concern in this suburban neighbourhood.

3.3.2. How do socio-demographic factors influence vulnerability and impact during extreme heat?

The analysis (Table 3) reveals significant associations between socio-demographic factors and the impact of extreme heat. Exhaustion during extreme heat is more prevalent among older individuals ($p = 0.0413$) and married respondents ($p = 0.0143$), while interruption of essential services is strongly linked to educational status ($p = 0.0006$), suggesting that those with higher education levels are more aware or affected by such disruptions. Additionally, household income is a key factor in the disruption of daily activities ($p = 0.0122$), with lower-income households facing more significant challenges during extreme heat events. Respondents cited examples of daily activity disruption to include commuting, outdoor work, market activities, and household chores.

Table 2
Neighbourhoods' Differences in Concerns and Vulnerabilities to Extreme Heat.

Impact Question and responses	Neighbourhood			Mean	CI Lower	CI Upper	P-Value
	Dansoman	Osu	Ashaley Botwe				
What are your important concerns during extreme heat?							
• Health	17.5	11.9	11.4	13.6	9.8	17.4	0.071
• Outdoor activities	5.1	8.6	12.5	8.7	4.5	12.9	0.056
• Personal comfort	28.1	27.6	27.3	27.7	27.2	28.1	0.059
• Sleeping	22.1	25.4	26.7	24.7	22.1	27.4	0.011
• Relatives	4.6	2.7	4.5	3.9	2.7	5.1	0.017
• Elderly community	2.3	2.1	1.7	2	1.7	2.4	0.051
• Income generation activities	1.8	3.2	2.8	2.6	1.8	3.4	0.08
• Transport	4.1	5.9	4.5	4.8	3.8	5.9	0.056
• Water shortage	1.8	1.6	1.1	1.5	1.1	1.9	0.036*
• Lack of ventilation and cooling options	7.8	3.8	1.7	4.4	0.9	7.9	0.083
• Foot shortage	0.5	1.6	0	0.7	−0.2	1.6	0.083
• Energy disruptions	0.5	1.1	1.7	1.1	0.4	1.8	0.014*
• Others	3.7	4.3	4	4	3.7	4.3	0.024*
What kind of impact does extreme heat have on your household?							
• Excessive sweating	28.6	26.8	24	26.5	23.8	29.1	0.018*
• Headache	12.1	11.9	12.6	12.2	11.8	12.6	0.037
• Dehydration	10.7	9.3	10.4	10.1	9.3	11	0.08
• Extreme thirst	23.8	23.2	25.1	24	22.9	25.1	0.071
• Accelerated pulse	1	2.6	3.8	2.5	0.9	4.1	0.051
• Exhaustion	9.7	11.3	10.4	10.5	9.6	11.4	0.091
• Disruptions to daily activities	5.8	5.7	4.4	5.3	4.4	6.2	0.084
• Interruption of essential services	1.9	4.1	2.7	2.9	1.6	4.2	0.082
How do you rate the risk or threat of extreme heat in your neighbourhood							
• Low Risk	27.4	11.7	16.7	18.6	9.5	27.7	0.072
• Moderate Risk	49.3	56.7	60	55.3	49.1	61.5	0.038*
• High Risk	23.3	31.7	23.3	26.1	20.6	31.6	0.023*
Are you able to undertake your primary livelihood activity in case of extreme heat							
• Yes	83.6	68.3	78.3	76.7	67.9	85.5	0.096
• No	16.4	31.7	21.7	23.3	14.5	32.1	0.075
Do you (or any of your household) face any loss due to extreme heat?							
• Loss Yes	30	33.3	16.3	26.5	16.3	36.7	0.036*
• Loss No	70	66.7	83.3	73.3	63.4	83.3	0.052

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.
Source: Field Survey, 2022.

Table 3
Demographic Factors Influencing Vulnerability and Impact During Extreme Heat.

EH Impact	Demographic Variable				
	Age	Marital Status	Generation Group	Household Monthly Income	Educational Status
(1) Concern during EH					
• Exhaustion	0.0413*	0.0143*	NS	NS	NS
• Interruption of essential services	NS	NS	NS	NS	0.0006***
• Disruption of daily activities	NS	NS	NS	0.0122*	NS
(2) Ability to undertake daily activities during EH	<0.0003***	0.0034**	<0.0001***	<0.0001***	NS
(3) Loss due to EH	0.0001***	0.0278*	0.0001***	0.0113*	NS NS

EH = Extreme Heat; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; NS=Not significant.
Source: Field Survey, 2022.

The ability to undertake daily activities during extreme heat is strongly influenced by a range of demographic factors, including age ($p < 0.0003$), marital status ($p = 0.0034$), generation group ($p < 0.0001$), and household income ($p < 0.0001$), indicating that these variables play a vital role in coping with extreme heat. Furthermore, losses due to extreme heat are significantly associated with age ($p = 0.0001$), marital status ($p = 0.0278$), generation group ($p = 0.0001$), and household income ($p = 0.0113$), suggesting that certain demographic groups, particularly older, married individuals from lower-income households, are more vulnerable to financial and personal losses during extreme heat events.

3.4. Extreme heat governance

3.4.1. How does extreme heat governance vary across neighbourhoods

Across all neighbourhoods, several key themes emerged regarding responses to extreme heat governance (Table 4). A significant proportion of residents reported making personal investments to prevent heat risks, with Dansoman having the highest percentage (56.9 %) compared to Osu (50.8 %) and Ashaley Botwe (40.0 %). Despite this, awareness of government-led extreme heat prevention strategies was low in all neighbourhoods, with less than 1.4 % of respondents acknowledging any such efforts. Engagement in decision-making related to extreme heat was also consistently low, with fewer than 5 % of respondents across the three communities actively participating. Moreover, most residents in all areas were unwilling to relocate due to extreme heat, especially in Osu (76.3 %). Lastly, a large majority perceived the accountability of disaster risk management institutions as low, with over 60 % expressing dissatisfaction with how these institutions manage extreme heat risks.

The only significant difference between neighbourhoods was found in the receipt of local government notifications about extreme heat ($p = 0.021$). Ashaley Botwe had a noticeably lower proportion of residents receiving notifications (73.3 %) compared to Dansoman (86.3 %) and Osu (88.1 %).

Table 4
Extreme Heat Governance Across Neighbourhoods.

Question	Neighbourhood	Frequency (%)	X^2	P-value
Personal investments to prevent risks of extreme heat	Dansoman	56.9		
	Osu	50.8	2.154	0.707
	Ashaley Botwe	40.0		
Receiving local government notifications about extreme heat	Dansoman	86.3		
	Osu	88.1	7.705	0.021*
	Ashaley Botwe	73.3		
Has the local/national government put in place prevention strategies	Dansoman	1.4		
	Osu	0.0	1.112	0.892
	Ashaley Botwe	0.0		
Active engagement in decision-making related to extreme heat	Dansoman	4.1		
	Osu	5.1	7.247	0.123
	Ashaley Botwe	3.3		
Willingness to relocate due to extreme heat	Dansoman	65.8		
	Osu	76.3	1.112	0.892
	Ashaley Botwe	61.7		
Accountability of disaster risk management institutions	Dansoman (Low)	69.9		
	Osu (Low)	61.0		
	Ashaley Botwe (Low)	61.7		
	Dansoman (High)	0.0	7.247	0.123
	Osu (High)	1.7		
	Ashaley Botwe (High)	1.7		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; x^2 = Mean.
Source: Field Survey, 2022.

3.4.2. How do socio-demographic factors influence extreme heat governance

The findings (Table 5) show that age, marital status, and generation group are key factors influencing household behaviours related to extreme heat governance. Older individuals are more likely to invest in heat prevention, provide reasons for not investing, and engage in decision-making. Marital status significantly affects investment decisions, with married households more likely to take preventive measures. Generation group also plays a role, with specific generational attitudes influencing both investment and non-investment behaviours.

As one resident noted, *"Nowadays, air-conditioning is no longer a luxury. The heat is so intense that the fans are no longer working effectively. I have had to install air-conditioners in the rooms in this house. My electricity bills have gone up, but I have no choice*". This reflects the pressure felt by households, especially older individuals, to make investments in response to increasing intense heat.

4. Discussions

4.1. Residents demographic factors, awareness, and experiences of extreme heat

The socio-demographic characteristics of residents across the sampled neighbourhoods reflect broader trends observed in the Greater Accra Region (GAR) and Ghana. According to the 2021 Population and Housing Census (GSS, 2021), individuals aged 30–50 years form a significant part of the economically active population. This is mirrored in the study, where this age group represents 49.2 % of respondents. The younger 18–30 age group is more prevalent in Ashaley Botwe, likely due to the area's appeal to younger migrants seeking affordable living, employment opportunities, and land, a trend consistent with national migration patterns. Monthly household income levels vary significantly between the neighbourhoods. Ashaley Botwe has a higher proportion of respondents earning GHS 1000 or less, indicating potential economic vulnerabilities, while Dansoman shows a higher percentage of respondents in the upper-income bracket (GHS 2001 and above). This income disparity reflects the socio-economic diversity within the Greater Accra Metropolitan Area (GAMA) and highlights the financial strain households face, particularly with rising energy costs due to increased use of cooling systems during extreme heat (Avordeh et al., 2021). As one resident remarked, *"Nowadays, air-conditioning is no longer a luxury. The heat is so intense that the fans are no longer working effectively. I have had to install air-conditioners in the rooms in this house. My electricity bills have gone up, but I have no choice."* This shows the economic pressures exacerbated by extreme heat.

Our analysis revealed a strong correlation between the perception and experience of extreme heat, indicating that both subjective and objective factors influence how individuals experience environmental stressors like heat. Perception of heat is shaped by various factors, including individual sensitivity to temperature changes, previous exposure, and access to coping mechanisms such as air conditioning or shaded areas. For instance, residents in communities with limited infrastructure or green spaces may perceive heat as more intense and disruptive, even if actual temperature levels remain consistent across neighbourhoods.

In Osu, the findings align with studies on urban heat islands, where densely built environments and limited green spaces amplify heat stress (Adomako et al., 2021; Athukorala and Murayama, 2020; Gyimah et al., 2023). Similar patterns are evident in Lagos, Nigeria, where compact urban structures exacerbate thermal stress (Adegun and Ayoola, 2022), and in Nairobi, Kenya, where limited greenery heighten urban heat effects (Odhengo et al., 2024). Similarly, in Ashaley Botwe, perceptions of heat are influenced by rapid, unplanned urban development, intensifying localized heat effects (Poku-Boansi, 2021). Comparable patterns are observed in Pretoria, South Africa, where peri-urban areas face heightened heat stress due to unregulated development (Muyambo et al., 2023).

On the other hand, the experience of heat is not solely defined by daily maximum temperatures but also by factors such as the duration of exposure, night-time cooling capacity, and the availability of heat adaptation strategies (Coffel et al., 2018; Maggiotto et al., 2021). Residents in neighbourhoods with poorly ventilated living spaces or inadequate cooling mechanisms often report more acute experiences of heat stress. This explains why individuals in neighbourhoods with fewer resources or substandard infrastructure, such as Ashaley Botwe, might report higher levels of heat stress, despite facing similar temperatures to other areas. In contrast, Dansoman's relatively better infrastructure and green spaces may mitigate heat perceptions, as supported by studies (Gyimah et al., 2023; Sarfo et al., 2018) suggesting that areas with more vegetation tend to report lower perceptions of heat impacts. These findings are consistent with global research showing that built environments and socio-economic factors shape both the perception and experience of extreme heat (Santamouris, 2020; Sha and Cheng, 2024).

Our findings show that the perception of extreme heat is nearly universal, with 98.3 % of Osu respondents reporting experiencing it, along with similarly high rates in Dansoman and Ashaley Botwe. While this perception may not directly correlate with measurable increases in air temperature, it is often shaped by environmental factors such as the urban heat island effect, infrastructure, and personal conditions like access to cooling. This is consistent with Maggiotto et al. (2021), who highlight the growing impact of heatwaves in urban areas, exacerbated by urbanisation and climate change. Similar trends have been observed in Accra and other West

Table 5
Influence of Socio-demographic Factors on Extreme Heat Governance.

EH Governance	Age	Marital Status	Generation Group
• Household Investment in Extreme Heat Prevention	0.0284*	0.0008**	0.0039**
• Why Household Hasn't Invested in Extreme Heat Prevention	0.0035**	–	0.0037**
• Engagement in Decision-Making Related to Disaster Risk Management	0.0305*	NS	NS

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; NS=Not significant.
Source: Field Survey, 2022.

African cities including Lagos and Dakar, where rapid urban growth and inadequate green spaces intensify the effects of extreme heat (Adomako et al., 2021; Bassett et al., 2020; Brousse et al., 2019; Wilby et al., 2021).

A more pessimistic view was observed among Osu households, contrasted with relative optimism in Ashaley Botwe, suggesting varying local impacts of heat mitigation and adaptation strategies. The optimism in Ashaley Botwe may be influenced by personal resilience, prior experience with extreme heat, or access to cooling. Several studies support our findings on differing heat perceptions. For instance, Stone et al. (2010) in New York and Wilhelmi and Hayden (2010) in Phoenix found that access to cooling systems and prior heat experience shaped optimism, like Ashaley Botwe. Jay et al. (2021) highlights the critical importance of localized responses such as air conditioning for managing heat impacts whilst discussing the benefit and negative effects. Additionally, the distinct neighbourhood perceptions point to the need for targeted urban planning interventions that consider each community's unique environmental, demographic, and socio-economic contexts.

The findings reveal clear socio-demographic differences shaping how residents perceive and experience extreme heat. In Dansoman, older residents and higher-income households are better equipped to cope with extreme heat, reflecting a lower perceived vulnerability. This aligns with studies like Zahran et al. (2006), which suggest that older generations with higher income tend to have more resources, such as air conditioning and better housing infrastructure, to mitigate heat effects. The combination of age and financial stability provides these residents with greater resilience against prolonged heat exposure. In Ashaley Botwe, the younger population—mainly Millennials—shows a higher awareness of climate risks. This aligns with findings by Gray et al. (2019), which indicate that younger individuals tend to be more informed and concerned about climate change issues compared to older generations. However, economic constraints limit their ability to invest in effective heat mitigation strategies, such as air conditioning or proper insulation. This economic vulnerability, coupled with rapid urban development, contributes to longer heat exposure and greater concerns over worsening heat conditions, as seen in other studies of urbanizing areas (Poku-Boansi, 2021). In Osu, the older population reflects a heightened concern about extreme heat, as older individuals are more susceptible to heat-related health issues, aligning with findings from Santamouris (2020) on urban heat island effects. However, despite their awareness, residents face structural challenges like dense urbanisation and limited green spaces, which amplify heat risks. The role of education is particularly evident here, as residents with higher educational attainment exhibit greater awareness of heat risks, consistent with Xu et al. (2017), which links higher education to increased environmental risk perception. Nevertheless, despite this awareness, Osu's urban environment limits adaptation options, leaving residents vulnerable to extreme heat.

4.2. Extreme heat impact and vulnerabilities

Our analysis of the differential impacts of and responses to extreme heat contributes to the expanding discourse on urban heat islands and climate adaptation strategies in the Global South. The observed variances in health concerns, physiological impacts, perceived risks, adaptive capacities, and household losses underline the urgent need for context-specific mitigation and adaptation strategies to combat rising urban temperatures — a challenge that is increasingly recognised in global climate change research (Harlan and Ruddell, 2011; Sachindra et al., 2016). The heightened concern for health impacts from extreme heat in Dansoman, compared to Osu and Ashaley Botwe is consistent with studies (Codjoe et al., 2020; Ebi and Loladze, 2019; Jacobson et al., 2019) that highlight how urban areas face increased health vulnerabilities due to factors such as urban density, inadequate infrastructure, and socioeconomic disparities. The physiological impacts of extreme heat, notably excessive sweating and extreme thirst reflect findings from Basu and Samet (2002) and Ebi et al. (2021), who document the direct effects of high temperatures on human health. These variations across the studied neighbourhoods highlight the interplay between environmental conditions and urban infrastructure in influencing health outcomes (Buttazzoni et al., 2022). A respondent's reference to night-time temperatures in this study highlights a critical component of the urban heat island (UHI) effect, where persistently elevated nocturnal temperatures significantly impact health risks and disrupt thermal comfort. Higher night-time temperatures reduce the ability of residents to recover from daytime heat, increasing the risk of heat-related illnesses (Founda and Santamouris, 2017; Jin et al., 2023; Middel and Krayenhoff, 2019).

The perception of extreme heat as a high risk in Osu, more so than in Dansoman and Ashaley Botwe, may be influenced by factors such as urban density. Osu is recognised as GAMA's primary commercial and entertainment hub in Ghana, with its popularity contributing to higher population densities than Dansoman and Ashaley Botwe. Although there are no long-term temperature measurements for Osu, the perception of extreme heat by residents can be influenced by various factors beyond actual climate changes. Individuals who have lived in the area for many years may experience changes in their perception of heat due to physiological adaptations, such as acclimatization or changes in heat sensitivity with age. Research by Middel and Krayenhoff (2019) suggests that prolonged exposure to heat can lead to adjustments in how individuals perceive temperature, highlighting the complex interplay between objective environmental conditions and subjective human experiences. This confirms Klinenberg's (2015) findings on the social determinants of heatwave vulnerability. The significant difference in the capacity to maintain livelihood activities across the suburbs supports research by Wilhelmi and Hayden (2010) and more recently by Gough et al. (2019), who emphasize the impact of extreme heat on economic productivity and the necessity for adaptive strategies to mitigate these effects. The variability in household losses due to extreme heat, with Osu and Dansoman experiencing higher incidences than Ashaley Botwe, can be contextualized within the broader literature on the socioeconomic impacts and disruptions to public utilities caused by climate change (Hallegatte, 2016; Kayaga et al., 2021). This highlights extreme heat's tangible socio-economic and health effects on urban households, suggesting a need for targeted support and intervention strategies.

Several studies report that specific demographic groups, such as older people and those with lower income levels, are more vulnerable to the impacts of extreme heat (Astone and Vaalavuo, 2023; Fastl et al., 2024; Voelkel et al., 2018). This vulnerability may be due to physiological, economic, and social factors. Our findings support the observation that older age groups and lower-income households report greater exhaustion and disruption during EH events. This may be attributed to physiological factors, as older individuals are more vulnerable to heat stress due to reduced thermoregulation capacity and pre-existing health conditions, while lower-income households may lack access to adequate cooling mechanisms or resources to mitigate heat impacts (Amankwaa and Ampomah, 2024; Guzman-Echavarria et al., 2023; Meade et al., 2020). Additionally, married individuals, particularly those with dependents, may face compounded pressures during extreme heat events. Family responsibilities, such as caring for children, supporting elderly relatives, and managing household needs, can increase the physical and emotional strain associated with these conditions. The observed significant correlation between marital status and reported exhaustion or disruption (Table 4) underscores the additional caregiving and household management demands faced by married individuals, particularly in larger or multigenerational households.

4.3. *Extreme heat governance and practical implications*

The findings reveal a significant gap between the management of extreme heat events and the needs of urban populations in GAMA. This gap is particularly concerning given the rapid pace of urbanisation in cities like Accra, where climate resilience is essential for sustainable development, particularly in line with Sustainable Development Goal 11 (SDG 11), which advocates for sustainable cities and communities. As seen in other rapidly growing urban centres in the Global South, such as Nairobi and Lagos, unplanned urbanisation has been linked to increased vulnerability to climate risks, including extreme heat (De Sherbinin et al., 2012; He et al., 2019). In Osu and Ashaley Botwe, high population density and limited green spaces have exacerbated the urban heat island effect, intensifying the impact of heatwaves (Piracha and Chaudhary, 2022). The growing built environment in these neighbourhoods has outpaced the provision of green infrastructure, leading to increased heat exposure, a challenge similarly observed in Accra (Adomako et al., 2021).

The results highlight the critical need for heat-resilient infrastructure in GAMA. In Dansoman, where there is comparatively more green space, residents reported fewer impacts of extreme heat than those in Osu and Ashaley Botwe. This finding supports literature emphasizing the integration of green infrastructure, improved building codes, and enhanced urban forestry as crucial strategies for reducing extreme heat impacts (Dicker et al., 2021; Pauleit et al., 2021). Studies from South Africa, such as Adeyemi et al. (2015, 2022), underscore the strong correlation between impervious surface areas, vegetation loss, and elevated mean surface temperatures. These observations parallel the relatively better-preserved green spaces in Dansoman, which mitigate heat stress compared to Osu and Ashaley Botwe. Similarly, studies like Mutua (2022) in Mombasa emphasize the planning implications of the urban heat island effect, particularly for economically vulnerable populations. For example, the implementation of urban greening initiatives such as tree planting and urban gardens could significantly alleviate heat stress in areas like Osu and Ashaley Botwe. This approach aligns with successful practices in cities such as Singapore and Melbourne, where urban greening programmes have effectively reduced heat stress and improved urban resilience (Thorn et al., 2021). Local governments must prioritize investments in climate-resilient infrastructure to protect vulnerable populations, especially in economically challenged neighbourhoods such as Ashaley Botwe, where limited household resources exacerbate the risk of heat-related health issues (Ngo et al., 2020).

Community engagement is also vital for climate adaptation. Studies emphasize that local participation can enhance the effectiveness of adaptation strategies and community-led governance (Amankwaa et al., 2024; Bockstael et al., 2016; Wolff, 2021). In Osu, for instance, residents noted the lack of local government engagement and community-driven solutions, with 95 % indicating that they had not been involved in decision-making related to disaster management. This gap is especially problematic given that early warning systems and public education campaigns have proven effective in other settings, such as Bangladesh, where community-based approaches to disaster preparedness have greatly reduced the impacts of extreme weather events (Rawlani and Sovacool, 2011). This suggests that involving communities in GAMA in decision-making processes would significantly enhance their resilience to extreme heat. In the context of flooding, Amankwaa et al. (2024) have emphasized the need to recognize community agency in managing flood risks and compensating for insufficient government support through solidarity and self-help.

The perceived lack of accountability among disaster risk management institutions, as indicated by survey respondents, further illustrates the disconnect between policy and community needs. Only 1 % of respondents rated disaster management institutions as highly accountable. This finding reflects a global pattern where disconnects between policy frameworks and practical implementation often undermine effective climate governance, as highlighted by Aryal et al. (2021). The National Disaster Management Organisation (NADMO) could play a more active role by establishing clear accountability structures and improving communication with residents. In Ashaley Botwe, for example, respondents reported limited access to heat risk information, with over 30 % stating they were unaware of any local government strategies. This lack of engagement limits community preparedness, highlighting the importance of clear and consistent communication channels between government agencies and residents (Khan and Roberts, 2013). NADMO could lead efforts by regularly disseminating information on heat risks and response strategies, ensuring that communities are well-informed and prepared.

Additionally, investments in extreme heat prevention are essential for reducing vulnerability and enhancing resilience. The study shows that demographic factors such as age, marital status, and generation group significantly influence investments in adaptive measures. For instance, older residents in Dansoman were more likely to invest in cooling systems, while younger households in Ashaley Botwe, facing economic constraints, lacked the resources to do so. This reinforces the need for inclusive strategies that account for varying capacities to adapt, as observed in studies across other African cities (Ngo et al., 2020).

The findings also carry significant practical implications for disaster risk reduction in GAMA. Residents in all three neighbourhoods expressed dissatisfaction with government efforts to manage extreme heat. This dissatisfaction may stem from a lack of communication about existing policies, limited resources, or a disconnect between government strategies and local priorities. For instance, the need for more green spaces and better infrastructure was a recurrent theme in Osu and Ashaley Botwe, where residents reported feeling particularly vulnerable due to limited shade and rising energy costs associated with cooling their homes.

To address these challenges, local governments should prioritize public awareness and community engagement. In Dansoman, where higher-income households are more likely to invest in cooling systems, targeted educational campaigns for lower-income households in Osu and Ashaley Botwe could help close the awareness gap and promote affordable adaptation strategies. Additionally, older adults may have different risk perceptions and adaptive capacities, making it essential to design resilience-building activities that engage all age groups. Addressing financial barriers is equally important. Subsidizing energy-efficient air conditioning and support for heat-proofing measures in lower-income neighbourhoods would alleviate some of the economic strain caused by extreme heat. These initiatives align with sustainable development goals, including poverty reduction (SDG 1), good health and well-being (SDG 3), and sustainable cities and communities (SDG 11). Enhancing urban resilience in GAMA requires both physical and socio-economic measures, such as establishing cooling centers, promoting urban greening, and implementing early warning systems. In parallel, social programs aimed at reducing the health and economic impacts of extreme heat are essential.

In conclusion, addressing governance gaps in extreme heat management in GAMA requires a holistic approach that integrates community participation, infrastructure investment, and enhanced accountability. Tailored interventions are vital for building long-term climate resilience and ensuring that residents are adequately prepared to cope with the intensifying effects of extreme heat.

5. Conclusion

This study reveals significant variability in awareness and experiences of extreme heat among urban households in the GAMA. The findings indicate that perceptions and adaptive capacities differ greatly across communities, with socio-economic status, access to resources, and local environmental conditions playing crucial roles. For instance, residents of Osu and Dansoman reported varying levels of heat awareness and different strategies for coping, reflecting disparities in access to cooling infrastructure and green spaces. The diverse responses from neighbourhoods like Osu, Dansoman, and Ashaley Botwe highlight the complex nature of extreme heat challenges in rapidly urbanizing areas, highlighting the need for targeted, context-specific strategies to effectively address these challenges.

The results also point to critical gaps in governance and community engagement. There is a noticeable lack of effective communication between local governments and residents regarding extreme heat mitigation efforts. Many participants were unaware of any governmental actions being taken to address extreme heat, suggesting a disconnect that hinders community resilience. Moreover, the study found that local inhabitants often rely on informal and personal networks for information and support, rather than formal governmental channels. This underscores the need for governments to better integrate local insights into policy frameworks and develop more inclusive, participatory approaches to climate adaptation. Strengthening these connections can lead to more effective and equitable strategies for managing extreme heat in GAMA and similar metropolises facing rapid urbanisation and climate change impacts.

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CRediT authorship contribution statement

Yaw Agyeman Boafo: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ebenezer Forkuo Amankwaa:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Catalina Spataru:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization. **Priscila Carvalho:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Data curation, Conceptualization.

Declaration of competing interest

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Appendix A. Supplementary data

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Data availability

Data will be made available on request.

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