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# Adaptation strategies to urban heat

## A case of Kigogo ward in Dar es Salaam

**Tumpale Sakijege**

Senior Lecturer, School of Spatial Planning and Social Sciences (SSPSS), Ardhi University, P. O. Box 35176, Tanzania, Phone: +255713439183, tumpaleg@gmail.com, ORCID: https://orcid.org/

***ABSTRACT***

**Context and background**

Extreme heat is one of the challenges facing urban areas. Though this constitutes a global urban challenge especially large cities in the world, urban studies have barely paid attention to urban heat.

**Goal and Objective:**

This study sought to examine government and community responses and adaptation strategies to extreme heat, using a case of Dar es Salaam city in Tanzania.

**Methodology:**

Kigogo ward in the city of Dar es Salaam was selected as a case study area. Household questionnaire was the main method used for data collection. Through quantitative methods, a total of 100 households in Kigogo ward were surveyed. Collected data were analysed using Stata software.

**Results:**

The findings show that residents adapted to extreme heat drawing on their own knowledge and personal initiatives. Regardless of education level, income status and household size all male and female perceive heat strain. The study also revealed association between independent variables and adaptation strategies, for example results for level of education vis a vis some extreme heat mitigation strategies are as follows: frequent drinking of water ($\chi^2$ (1) = 63.371 p-value = 0.000), planting of trees ($\chi^2$ (1) = 2.559, p-value = 0.110) and water-cooling strategy using ice ($\chi^2$(1) = 5.099, p-value = 0.014). The study concluded that heat and its related impacts have not received due attention in urban policy and city's authorities despite noticeable impacts on residents. The research suggests the city authorities place emphasis on heat information, awareness creation and education to minimize its adverse effects on residents.

**Key words:**

Extreme heat, heat strain, early warning, adaptation strategies, Kigogo

## 1. INTRODUCTION

Climate change has been described as 'the greatest health issue in the world (Su et al., 2022) that put the lives of billions of people at a very high risk (Campbell et al., 2018). Watts et al., (2015) estimated that the effects of climate change will have far-reaching consequences, causing serious health consequences to humans, especially incidence such as urban heat. Teskey et al.,(2015) note that by 2020 and 2040, heat wave will have doubled and quadrupled respectively, such as rising impacts due to rising intensity of temperature occasioned by climate change (Trenberth, 2018). Some scholars (Scovronick et al., 2018) argue that there is a strong connection between all deaths and the increase of high daily temperature. By revealing that extreme heat has led to many deaths (Mortality) and illnesses (morbidity). Whilst others suggest that mortality and morbidity will continue to increase due to rising daily temperatures and the intensity of heat waves globally. These studies shown that heat is a global catastrophe (Asefi-Najafabady et al., 2018) affecting both developing and non-developing countries. Many scholars have reported an increase of heat in the world (Asefi-Najafabady et al., 2018).

Additionally, the next decades, IPCC 2021 predicts that global warming will rise intensely even beyond the global warming level of 1.5$^0$c. A 1.5$^0$c will lead to a significant increase in heat waves as well as prolonging the warm season. Lack of efforts to reduce greenhouse gas emissions can further trigger climate change (IPCC, n.d.). The IPCC report further states that human actions still have an upper hand in determining the future course of climate, especially extreme heat. This study seeks to contribute to evolving debates on urban heat by exploring how urban residents adapt to extreme heat, specifically the techniques used to respond to heat anomalies in their settlements.

Similar to cities across globe, African cities are grappling with the challenges associated with climate change in the urban environment especially adapting and responding to extreme heat (Engelbrecht et al., 2015). The Great Lakes Regions (GLR) of Africa (i.e Burundi, the DRC, Rwanda, Uganda and the United Republic of Tanzania) are the climate change hotspots. In these regions, before 2012, the number of hot days was relatively few compared to the period after 2012. Garland et al.,(2015) have projected that the number of days that health can be negatively affected by heat associated with climate change is estimated to increase in Africa.

Many African countries are the victims of abject poverty and the rate is expected to increase given the COVID 19 outbreak (Bargain and Aminjonov, 2021). This condition implies that the vast majority of people affected by heat in developing countries are unable to adapt with the ongoing extreme heat affecting the continent. Moreover, studies on the heat-related deaths in Africa indicate the potential for further exposure to the elderly and children (Burkart et al., 2014). Extreme heat in cities has become a critical challenge to urban development not only in Tanzania. More than 70% of the land area is unplanned. The city is marked with unplanned settlements and concentration of buildings which prevent cross air. These settlements are developed without proper planning standards. However, the rising proliferation of informal settlements challenges government's efforts towards addressing challenges in the informal settlements. The inhabitants in informal settlements especially in Dar es Salaam live in very vulnerable and unhygienic environments, especially to extreme heat, such as hot humid climate, despite the city's location on the shores of the Indian Ocean (Ndetto and Matzarakis, 2017). Also, housing development in the informal settlements is less sensitive to space, breeds extreme heat due to haphazard buildings structures. The challenge of extreme heat is further compounded in the informal settlements, as such development pay little attention to environment protection and town planning regulations and principles (Rwehumbiza and Sakijege, 2021). However, increasing socio-economic inequalities among residents compel the several low-income earners to dwell in unplanned areas, where extreme heat prevails the most, due to high density. Whilst this represents an urban development challenge, it is unclear how urban residents are coping and adapting to extreme heat in their everyday environments. Related studies in Dar es Salaam report how extreme heat contributes to ill health and loss of lives, especially among residents in the informal settlements (Ndetto and Matzarakis, 2017; Pasquini et al., 2020). Yet, studies barely explore the strategies residents adopt to cope or adapt to urban health. The few attempt such as Pasquini et al.,(2020) examined the heat-health related vulnerability of residents and reveal that increase in temperature exacerbated by climate change is likely to cause significant risk to residents living in vulnerable informal settlements. The study identified some of the coping strategies used by the community in Vingunguti and found that community use the strategy of spending portion of the time during the day and night as well as sleeping outside. However, the research was not quantitative. These raises questions such as, what strategies do residents adopt during extreme heat? What is the government's response to the challenges resulting from extreme heat? However, the overall aim of the study is to assess the how residents in informal settlements adapt to extreme heat, particularly, the strategies they devise cope or adapt to extreme heat. In so doing, this study contributes to urban studies debates by (i) examining the perceptions of residents about urban heat; (ii) the neighbourhoods characteristics that exacerbate vulnerability to urban heat in the informal settlements, (iii), how residents in the informal settlements adapt to urban heat, and thus, discuss the implication for urban policy planning. The paper is organized as follows; section 2; presents a review on early warning systems and adaptation to urban heat, Section 3; presents the study settings and the methods, Section 4, presents the results, Section 5; discuss the implications of the findings for urban policy planning, whilst section 6: presents and the conclusion.

## 2. UNDERSTANDING EARLY WARNING AND ADAPTATION OF URBAN HEAT IN THE INFORMAL SETTLEMENTS OF GLOBAL SOUTH

Early warning system in disaster risk reduction has been defined by UNISDR 2009 as "*The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss*". This definition implies that, access to information about heat by urban residents may augments preparedness and adaptation to heat stress. Jones et al., (2010) describe early warning system as part of the adaptive capacity. By revealing that communities are often more likely to respond to climatic and environmental event if they have the right information about the future threats. Citizens' access to information on the possibility of extreme heat is essential so that they can take appropriate action in a timely manner. But the basic question is, with the information they have, are they capable of taking action? To address this, Jones et al., (2010). In addition, they reveal the role of resources availability in shaping how people cope and adapt to environmental events such as urban heat. Others argue that coping with disasters related events is a dynamic process that can involve the use of a variety of coping strategies. Such may manifest more or less as a reaction to traumatic events that have been occurring in the past and persistence as well (Stephenson and DeLongis, 2020). Although there are many researchers who have written about the adaptation strategies, but not every strategy could be applicable in any environment. This implies that any strategy developed to minimize the vulnerable situation must be appropriate and context specific. Studies furthering the above, reveal how environmental events tend to vary across urban spaces and geographies and requiring more specific interventions (Sakijege and Dakyaga, 2022). The impacts of extreme heat are not the same and many of them are linked to different factors including social, geographical, environmental and biological (Campbell et al., 2018). In the context of urban heat, studies show, deaths are often caused by historical health problems that a particular person suffered from or has been living with. This implies that when assessing perception of community in relation to heat related risk, there is a need to take note of other factors that contribute to worsen the situation. These suggest other that underlying health issues may exacerbate severity of persons with already conditions especially in extreme heat periods, which may result to (e.g. mortality and morbidity). Others add that beyond, the underlying health conditions, living in unsafe environment and living in areas where there is a shortage of greenery, may also act as underlying causes (Loughnan et al., 2010). Such non-biological factors also include building materials that are used to construct houses especially in the informal settlements without or with limited regulations, may increase in heat severity during the day time (Jay et al., 2021). This suggests the need to pay attention to building materials and neighbourhoods characteristics especially in the theorization and understanding of urban heat.

Many countries in the Global South experience compactness of cities and the phenomenon have biggest influence on heat intensity. du Toit et al.,(2021) pointed that large cities in the global south (such as Addis Ababa, Nairobi and Lagos) which have experienced rapid urbanization, have begun to be rapidly affected by the effects of Urban Heat Island. The situation become more severe when combined with heatwaves and cause human casualties. In these cities, area with natural vegetation are outside the urban area. This phenomenon has been linked to unplanned and uncontrolled urbanization. They recommend green spaces to be emphasized in urban areas to bring a cooler climate, moreover, Ngulani and Shackleton,(2020) explained further that the cool effect reaches a distance of up to 2 km from the location of the green space.

## 3. STUDY AREA AND METHODS

The study was conducted in Kigogo informal settlement in Dar es Salaam City in Tanzania between March and April 2022. This settlement represents one of the areas of concern in Dar es Salaam where the heat related risks proliferate and are experienced by residents. Kigogo Ward is located within Kinondoni Municipality in Dar es Salaam. It has a total area of about 1.91 square kilometers. It borders Mzimuni Ward to the North, Dar es Salaam City Council to the East and South and Ubungo Municipality to the Northwest as shown in Figure 1. Kigogo has three sub-wards which are Kigogo Mbuyuni, Kigogo Kati and Mkwajuni. There are 81,068 residents (39,722 males and 41,346 females) and approximately 23,005 households (Ward Statistics). Houses in Kigogo and in other informal settlements in Dar es Salaam are built without considering urban planning standards. Planning aspects related to accessibility, setbacks, space between building, density, orientation are not considered. Moreover, the density of housing in unplanned settlements is very high. This has contributed to an increase in heat. The population living in these areas are predisposed to experience greater thermal discomfort. Moreover, cross air ventilation was therefore not considered during construction, and so are the green areas. Residents in Kigogo reported that the walls of their homes (especially in the eastern side of the buildings) were very hot during the hot season. This information indicates that houses receive sunlight during the day and retain heat for a long time. Comparing the day and night and the impact of heat inside the house, the majority reported that the heat impacts felt are very high at night and had become more severe than it was previously.

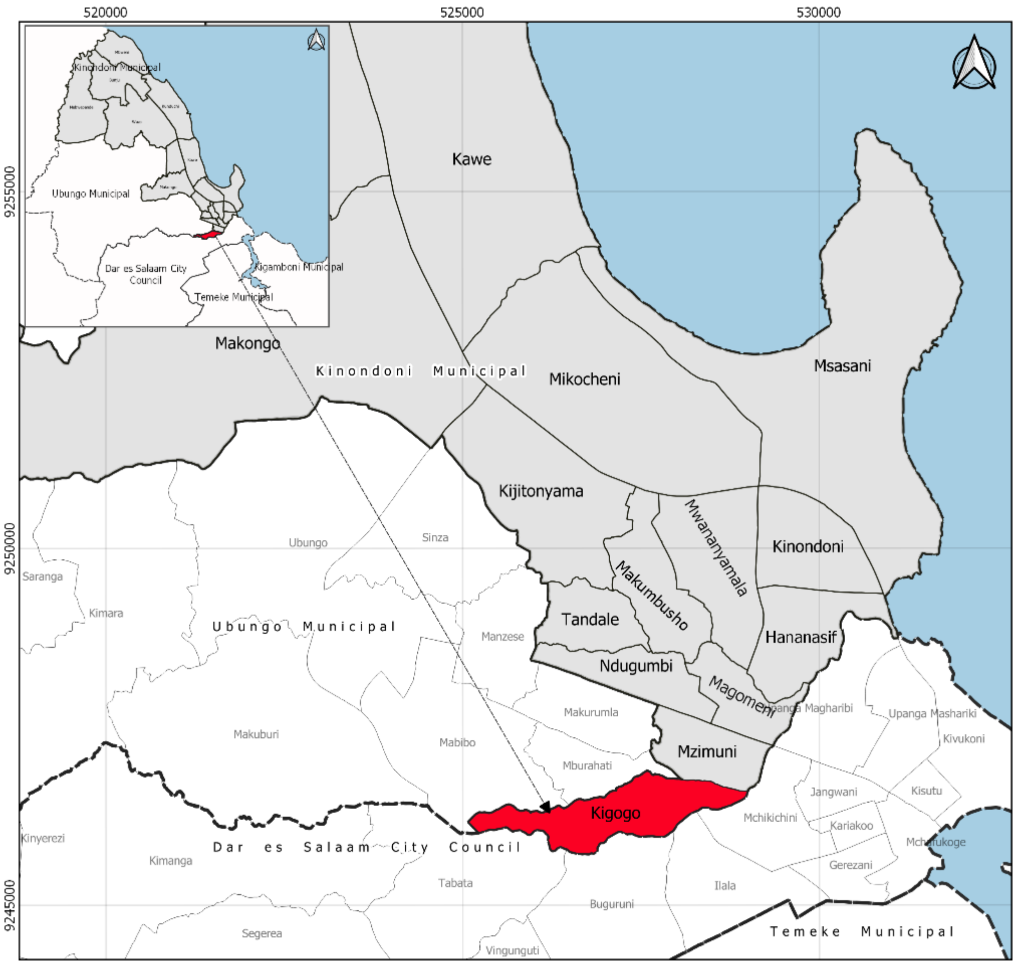


**Figure 1:** Kigogo Ward Location Map

**Source**: Open Street Map

A cross sectional research design was used in the study in the sense that data was collected at a single point in time from a selected sample of the respondents (Creswell and Creswell, 2003). The reason for choosing cross sectional design based on the ability of the design to compare the extent to which at least two groups differ with the dependent variable.

Data were collected between March and April (a period of one to two months after the extreme heat season). The main physical parameter used in understanding how community perceive heat was temperature. The study population included the households living in Kigogo Ward. The households were used as a sampling unit and were interviewed on the matters related to extreme heat, early warning, the adaptation strategies and their adaptive capacity. For survey type prevalence study, sample size can be derived by computing the minimum sample size required for accuracy in estimating proportions by considering precision (d- set at 90%) and percentage picking a choice or response (50% = 0.5). The formular is $n = \frac{4pq}{d^2}$, therefore the required sample size was 100 respondents. 90% confidence level was chosen basing on the fact that the decision to determine an ideal confidence level as well as desired precision is vest with the researcher and of course it is influenced by the nature of the study (Kothari, 2004; Rodríguez et al., 2022). Question that was asked included but not limited to gender; income status; level of education; how do they perceive heat strain during heat season; what are the strategies used to minimize heat (Summarized in Table 1).

**Table 1:** Overview of questions and indicators chosen for assessing heat perception

| Questions | Options |
|---|---|
| Gender | a) Male |
| | b) Female |
| Level of education | a) No schooling |
| | b) Primary education |
| | c) Secondary education |
| | d) College and above |
| Income status> < | a) Unpredictable |
| | b) Less than 100,000 |
| | c) Between 100,000-500,000 |
| | d) Above 500,000 |
| Household size | a) Less than five |
| | b) Above five |
| How do you perceive heat strain during heat season? | a) No heat |
| | b) Moderate |
| | c) Extremely high |
| Do you receive early warning instructions concerning heat? | a) Yes |
| | b) No |
| Strategies used to minimize heat | a) Turn on fan |
| | b) Cooling water by ice |
| | c) Sleeping outside |
| | d) Spending sometime outside and sleep late |
| | e) Cooling water by wind |
| | f) Leaving windows open for ventilation |
| | g) Sleeping on the floor |
| | h) Drink more water |
| | i) Shower more frequently (adapt 9) |
| | j) Air Conditioning |
| | k) Planting trees |
| How do you rate your health status? | a) Very good |
| | b) Good |
| | c) Fair |
| | d) Poor |
| | e) Very poor |

Primary data was used to collect the relevant information for the study. The methods of data collection included observation, household survey, official interview and Focus Group Discussions (FGDs). The tools of data collection were Questionnaires (close ended) for household survey. Quantitative data was processed and analyzed using STATA software (see Table 2 for variable codes used), whereas qualitative data was analyzed through content analysis.

**Table 2:** Variable codes

| Variable Name | Variable codes |
|---|---|
| Level of Education | 0 =No schooling and 1= Educated (Primary education, secondary education and College and above) |
| Health status | 0= Poor and 1 = Good health (Very good, Good and Fair) |
| Gender | 0= Female and 1= Male |
| Household size | 0= less than five 1= above five |
| Heat strain | 0= No heat and 1= Perceive heat strain |
| Turn on Fan | 0=No and 1=yes |
| Cooling water by ice | 0=No and 1=yes |
| Sleeping outside | 0=No and 1=yes |
| spending sometime outside and sleep late | 0=No and 1=yes |
| Cooling water by wind | 0=No and 1=yes |
| Leaving windows open for ventilation | 0=No and 1=yes |
| Sleeping on floor | 0=No and 1=yes |
| Drink more Water | 0=No and 1=yes |
| Shower more frequently | 0=No and 1=yes |
| Air Conditioning | 0=No and 1=yes |
| planting trees | 0=No and 1=yes |

## 4. RESULTS

### 4.1 Perception of Residents in the Informal Settlements About Urban Heat

The study used Mann Whitney U-test to test for significance differences between female and male whereby the dependent variable was perceived heat strain during heat season with three levels which included no heat, moderate and extreme heat. From the analysis made (Table 3), both groups (female and male) had high percentage on extreme heat level compared to no heat and moderate levels. Female group had a mean value of 66 members with its percentage of 97.05% and male group with mean value of 31 members with its percentage of 96.87%. A Mann Whitney U-test showed that this difference was not statistically significant (W= 893.52, p= 0.9733).

Moreover, Mann Whitney U- test was used to test the difference between two groups of household size which were greater or equal to five and less than five household members, to the dependent variable perceived heat strain during heat season. It was found that on both groups, extreme heat level was with high percentage throughout all levels in perceived heat strains. Households below five members had an average of 52 respondents with their percentage of 98.11 while greater or equal to five members had an average of 45 respondents with their percentage of 95.74. The results (Table 1) obtained from U – test (W= 1024.92, p= 0.5019) show that there is no statistically significant difference between two groups (those below five household members and greater or equal to five household members) and levels of perceived heat strains during heat season (no heat, moderate, extreme heat).

Additionally, we used the Kruskal-Wallis's test to test the significant difference between groups with more than two levels such as education level, income and health status. The respondents were asked how they perceived their personal heat strain during the heat season. About more than third quarter of respondents reported perceiving extremely heat strain (n = 96; 96%) or moderate (3; 3%) total participants heat strain (n = 100). Most respondents reported to have been experiencing extremely heat strain (96; 96%). The remaining respondents rated no heat clearly (1; 1%). Using Kruskal-Wallis's test no statistical significance differences were detected based on education level, income and health status to perceived heat strains during the hot season. The results suggest that the three variables (education level, income and health status) had no relationship with community perceptions of heat strain.

Regarding education level it was reported that most were perceiving extremely high heat strain in all different education levels (no schooling, primary education, secondary education and college and above). Statistical analysis in Table 3 shows that there is no statistically significant difference between education levels and perceived heat strain (H=1.374, p=0.7117).

The same applies to income status, whereby, most of the respondents allocated perceiving extremely heat strain during heat season with n=11;100%, n=40;90.91%, n=32;100%, n=12;100% for Unpredictable income, < 100,000, 100,000-500,000 and > 500,000 respectively. Hence from the results (H= 0.452 p= 0.9293) it revealed that there was no statistically significant difference between income status levels and perceived heat strain during hot season.

**Table 3:** Perception on heat strain

| Variable | Perceive heat strain during heat season | | | | |
|---|---|---|---|---|---|
| | No heat<br>n (%) | Moderate<br>n (%) | extremely hot<br>n (%) | Mann-Whitney U-Test (W)<br>Kruskal-Wallis-Test (H) | |
| **Gender** | | | | | |
| Female | 1 (2.95) | 1 (2.95) | 66 (97.05) | W= 893.52 | p= 0.9733 |
| Male | 0 (0) | 1 (3.13) | 31 (96.87) | | |
| **Education Level** | | | | | |
| No schooling | 1 (50) | 0 (0) | 1 (50) | H= 1.374 | p= 0.7117 |
| Primary Education | 0 (0) | 1 (2.38) | 41 (97.62) | | |
| Secondary Education | 0 (0) | 1 (1.96) | 50 (98.04) | | |
| College and above | 0 (0) | 0 (0) | 5 (100) | | |
| **Income Status** | | | | | |
| Unpredictable | 0 (0) | 0 (0) | 11 (100) | H= 0.452 | p= 0.9293 |
| < 100,000 | 1 (2.27) | 3 (6.82) | 40 (90.91) | | |
| 100,000-500,000 | 0 (0) | 0 (0) | 32 (100) | | |
| > 500,000 | 0 (0) | 0 (0) | 13 (100) | | |
| **Health Status** | | | | | |
| very Good | 0 (0) | 0 (0) | 8 (100) | H= 0.380 | p= 0.9443 |
| Good | 0 (0) | 0 (0) | 20 (100) | | |
| Fair | 2 (4.80) | 3 (6.12) | 44 (89.80) | | |
| Poor | 0 (0) | 0 (0) | 23 (100) | | |
| **Household size** | | | | | |
| <5 | 0 (0) | 1 (1.89) | 52 (98.11) | p= 0.5019 | p= 0.5019 |
| >5 | 1 (2.13) | 1 (2.13) | 45 (95.74) | | |

Community members in Kigogo were aware of the rise in temperature in their environment. Most of the respondents reported the prevalence of quite big temperature differences felt at different times of the year. Even though the community members who participated in the study could not determine the exact scale of the temperature, the experiences they revealed enabled an understanding variation of the weather conditions. The study also found that Tanzania meteorological Authority (TMA) provides forecast for different weather elements such as rainfall, temperature, wind and solar. The weather forecast is provided on their website as well as on the news reports. These methods of disseminating weather forecast information were mainly accessible to person with electronic devices (for example television ownership or internet). This implies that whilst information provision, is useful, ownership of electronic gadgets/accessories are pivotal for gaining access to information in the urban environment. This suggest that, the means to disseminating early warning information about extreme heat and associated impacts need to take into account communities' socio-economic statuses. If climate change information leading to extreme heat was to be provided to low-income citizen and if citizens were informed of current and future temperatures it is clear that they would direct more efforts to resolving the problem. One of the methods that is sustainable as reported by Jay et al.,(2021) is improving vegetation cover, a strategy that was mentioned by very few respondents. No respondent reported the existence of guidelines towards minimizing or addressing extreme heat from their local governments. Dissemination of temperature forecast is incompatible with the dissemination of rainfall forecast, whereby, TMA issue the rainfall forecast and indicate the steps to be taken through various levels. Rainfall forecast and the responses to be made are provided from the national level and communicated through various levels up to the level of local governments which are responsible for communicating it to the people, leading to action.

Consequently, households in the study settlements were found to use devise strategies to minimize the adverse effect of heat. Although citizens use a variety of adaptation strategies to cope with extreme heat, the strategies were not sustainable. They lack accurate information on temperature trends and guidance on how to minimize extreme heat. A large number of residents living in informal settlements are forced to live in those areas due to difficulties and inability of accessing plots (including high price) of the planned areas.

In order to gain more insight about the adaptive capacity, the income status of households was assessed and their housing and the environment observed. The study found that, houses in Kigogo were built without considering urban planning standards (limited access), non-heat resistant building materials (e.g., corrugated iron sheet), these signifies lower adaptive capacity in coping with extreme heat. However, the settlement had a committee dealing with disaster issues (WDMC). This committee was made-up of 21 members who were legally recognized. The committee is important because demonstrate some level of awareness among residents about disaster issues, and signifies grassroot at combating local challenges Jones et al.,(2010). Unfortunately, the study realized the role of the committee does not include urban heat disasters. The lack of roles on urban heat related disasters suggest how urban heat has been neglected as an urban development issue even at the local levels.

### 4.2 Neighborhoods Characteristics Exacerbating Vulnerability to Heat in the Informal Settlements

All houses spotted in the area were roofed with corrugated iron sheets. Moreover, the survey revealed that majority of the respondents had no ceiling board or gypsum, a condition that prone and exposes households to high temperature. A greater percentage (more than 90%) of the respondents admitted that they experience higher temperature from October to February and extreme heat between January and February. In addition, neighborhood characteristics such as high housing density, the absence of open spaces, types of building materials used, and the climate were found as some of the neighborhood features to prone residents to vulnerability. Largely, data from satellite image (see Figure 2) reveal overcrowding in terms of housing development and density. The houses have been built too close with extremely limited spaces for air circulation. This condition occasioned extreme heat due to minimal air circulation. The compact nature of their houses was shaped the growth of informal settlement, the unguided ways in which houses were developed (Lategan et al., 2020). Respondents disclosed that high housing density was among the factors contributing to an increase in heat in their settlements. The finding that the concentration of buildings contributes to extreme heat are similar to those reported by Pasquini et al., (2020).

Also, the presence of open spaces contributes significantly to improving the thermal comfort [35]. However, Kigogo ward, as in the case of most informal settlements in Dar es Salaam city, lacks open spaces is linked to lack of thermal comfort. Few vegetation cover and open spaces was also revealed during the households' interviews. These were shaped by informal development, that paid less attention to open spaces and vegetation cover. Lands/plots were largely individually owned and utilized based on residents' development motives than by order land uses. The uncoordinated ways in which land was utilized contributes to the loss of open spaces within the settlements, including rivers prone residents to extreme heat.


**Figure 2:** Part of Kigogo Ward showing concentration of building

Many houses were covered with iron sheets, vulnerable to sun's rises and heat. They reported that rooms, interior of their homes are increasingly being hotter than before. Corrugated iron sheet increased vulnerability of Kigogo communities to the impacts of extreme heat induced hazards. The aspect that building material contributes to making their home vulnerable to extreme heat was reported. Selection of appropriate building materials is one of the most important factors to consider in a hazardous environment, otherwise it contributes to increasing risks e.g. heat problem. Generally, these factors are compounded by the changes in the climate globally. Kigogo, like most parts of Dar es Salaam, is located in tropical climate [18], a report from the Tanzania Meteorological Authority indicates that, many parts of the city of Dar es salaam tend to have higher average temperature. The households' surveys revealed that they were experiencing extreme heat because of the nature of climate they live in as well as the vulnerable environment.

### 4.3 Adaptation Strategies Towards Urban Heat in the Informal Settlements

The survey revealed that residents in the informal settlements draw on varied strategies to adapt to extremely heat in their own ways. These often involved drawing on a combination of factors and practices as depicted in Table 4 and 5.

#### 4.3.1 Drinking more water

Adaptation strategies were shaped by socio-economic characteristics particularly level of education. Some households reported that they adapted to extreme heat often by drinking water frequently at households' levels**.** The analysis revealed that there is association between between the educated households and drinking more water as strategy for minimizing heat as depicted by $\chi^2$ (1) = 63.371 p-value = 0.000.

**Table 4:** Adaptation strategies

| Strategies | n (%) |
|---|---|
| Turn on Fan | 84 (84) |
| Cooling water by ice | 36 (36) |
| Sleeping outside | 25 (25.33) |
| spending sometime outside and sleep late | 49 (49.33) |
| Cooling water by wind | 51 (50.67) |
| Leaving windows open for ventilation | 71 (70.67) |
| Sleeping on floor | 36 (36) |
| Drink more Water | 57 (57.33) |
| Shower more frequently | 33 (33.33) |
| Air Conditioning | 0 (0) |
| planting trees | 24 (24) |

**Table 5:** Strategies used to minimize heat (Chi2-Test, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

| | | **Variables** | | | | | |
|---|---|---|---|---|---|---|---|
| **Adaptation Strategies** | | **Gender** | **Educated** | **Income Status** | **Perception on heat strain** | **Household Size** | **Health Status** |
| Electric fan | Chi2 | $\chi^2(1)$=2.836 | $\chi^2(1)$=2.483 | $\chi^2(3)$=1.252 | $\chi^2(1)$ =0.794 | $\chi^2(1)$=4.037 | $\chi^2(1)$=0.732 |
| | p-Value | 0.092 | 0.478 | 0.263 | 0.373 | 0.045 | 0.392 |
| Cooling water by ice | Chi2 | χ2(1) =5.99 | χ2(1)=0.219 | χ2(3) =0.074 | χ2(1) =2.344 | $\chi^2(1)$=0.514 | $\chi^2(1)$ =11.07 |
| | p-Value | 0.014** | 0.64 | 0.995 | 0.126 | 0.473 | 0.001 |
| Sleeping outside | Chi2 | χ2(1) =0.245 | χ2(1)=0.680 | χ2(3) =1.512 | χ2(1) =0.000 | χ2(1) =0.214 | $\chi^2(1)$ =0.078 |
| | p-Value | 0.621 | 0.409 | 0.668 | 1.000 | 0.644 | 0.780 |
| Delaying in sleep by spending time outside | Chi2 | χ2(1) =0.320 | χ2(1) =0.001 | χ2(3) =5.926 | χ2(1) =0.386 | χ2(1) =1.986 | $\chi^2(3)$ =0.364 |
| | p-Value | 0.571 | 0.977 | 0.115 | 0.534 | 0.159 | 0.546 |
| Water cooling by wind | Chi2 | χ2(1) =0.173 | χ2(1) =50.914 | χ2(3) =3.239 | χ2(1) =3.043 | χ2(1) =0.662 | $\chi^2(3)$ =1.326 |
| | p-Value | 0.677 | 0.000*** | 0.356 | 0.218 | 0.416 | 0.723 |
| Leaving windows and curtains open | Chi2 | χ2(1) =1.136 | χ2(1) =2.928 | χ2(3) =7.743 | χ2(1) =1.297 | χ2(1) =0.534 | $\chi^2(3)$ =1.572 |
| | p-Value | 0.287 | 0.403 | 0.052 | 0.523 | 0.465 | 0.666 |
| Sleeping on the floor | Chi2 | χ2(1) =0.492 | χ2(1) =41.015 | χ2(3) =5.661 | χ2(1) =2.903 | χ2(1) =0.965 | $\chi^2(3)$ =1.179 |
| | p-Value | 0.483 | 0.000*** | 0.129 | 0.234 | 0.326 | 0.758 |
| Drink more water | Chi2 | χ2(1) =0.145 | χ2(1) =63.371 | χ2(3) =3.842 | χ2(1) =1.417 | χ2(1) =0.587 | $\chi^2(3)$ =1.124 |
| | p-Value | 0.704 | 0.000*** | 0.279 | 0.492 | 0.443 | 0.771 |
| Shower more frequently | Chi2 | χ2(1) =2.482 | χ2(3) =16.682 | χ2(3) =4.050 | χ2(1) =0.750 | χ2(1) =0.240 | $\chi^2(3)$ =4.231 |
| | p-Value | 0.115 | 0.001*** | 0.256 | 0.687 | 0.624 | 0.238 |
| Planting trees around houses | Chi2 | χ2(1) =2.559 | χ2(3) =22.805 | χ2(3) =1.888 | χ2(1) =0.987 | χ2(1) =0.038 | $\chi^2(3)$ =0.881 |
| | p-Value | 0.110 | 0.000*** | 0.596 | 0.611 | 0.846 | 0.830 |

### 4.3.2 Planting of trees

Table 3, the analysis by using Chi-Square test obtained that there is association between educated respondents and planting of trees expressed by $\chi^2$ (1) = 0.2805, p-value = 0.000. Another independent variable was gender whereby the analysis revealed that there is no association between male and planting of trees around houses meaning that both female and male do plant trees around houses ($\chi^2$ (1) = 2.559, p-value = 0.110). Same applies to household size, it is obtained that both respondents with lower than five members and greater or equal to five members do plant trees around houses ($\chi^2$ (1) = 0.038, p-value = 0.846.

### 4.3.3 Water-Cooling Strategy by use of Ice

During the hot season, water becomes hot and uncomfortable for bathing. To lessen this affliction, households added ice to cool water taste. One respondent reported that "*my body feels very refreshed when I take cold water for shower*". They believe that, cold water refreshes the body during the extreme hot weather. The analysis also suggests that there is association between male and water-cooling practice during extreme heat period ($\chi^2$(1) = 5.99, p-value = 0.014). this means that regardless of the gender male are observed to cool water by ice compared to female. Cooling water for bathing, can be compared to cold water emulsion as reported by Tipton et al.,(2017). Tipton argues that cold water emulsion can be hazardous and non-hazardous depending on the circumstances and therefore they must be used with caution.

### 4.3.4 Water Cooling by Wind

Households revealed that periods of extreme were periods where water equally too warmed for bathing. Households engaged in the act of placing bathing water at outdoor especially at night to be cooled by wind. Residents equally placed water outdoor and bathe in the following morning. This practice was aimed at minimizing warmness of the water and reducing heat stress. Analysis revealed that there is association between educated respondents and cooling water by wind ($\chi^2$ (1) = 50.91, p-value=0.000. This analysis implies that education shape the ways in which residents adapt to heat in the informal settlements.

### 4.3.5 Sleeping on the Floor

One of the interviewees said that "*you may not understand the suffering we experience during the hot season through my explanation, I wish you could live with us for just a day and be able to experience what I'm saying*" This explanation was given when one respondent was describing how the mattresses were so hot at night, forcing them to move from their beds and sleep on the floor. The respondents confirmed that engaging in this practice makes them feel more comfortable, often lying on the floor because the floor tend to be colder, than sleeping in the mattress. This suggests that to minimize heat stress respondents adapt measures that are too risk for health.

### 4.3.6 Leaving Windows and Curtains Open

In houses with aluminum windows, residents were forced to leave the windows open to allow the wind blow inside and cool their inner spaces. For houses with non-aluminum windows (made of mosquito nets and iron bars), the act of leaving curtains opened constituted the common practice for adapting to extreme heat. Doing this helps to reduce the impact of heat. The majority admitted that the strategy of leaving windows and curtains open was helpful if there was wind blowing.

### 4.3.7 Sleeping Outside the House at Night

"*It is very difficult to sleep at night in hot weather season, we have to sleep outside in our courtyards or on the corridors when we feel that the heat is unbearable inside our houses*". This statement was made by one respondent during the interview, indicating the vulnerable situation during the hot weather season, when people sleep outside their houses in order to enjoy the cool air. Although it is one of the ways to reduce heat, many respondents said it was dangerous because sleeping outside it increases their risk of their properties being stolen by thieves whilst outside.

### 4.3.8 The use of Electric Fan

One method more widely used by the residents in Kigogo to reduce heat was electric fans. The use of electric fans for cooling purposes is considered the main method because many people interviewed confirmed using this method. Depending on the financial capacity, there were families that installed fans in the bedrooms as well as in the living room. There are others who installed fans in the living room and only the parents' room. Others complained of contracting flu especially during the summer. Most respondents associated flu with the use of electric fans in minimizing heat during the hot season as observed by (Aslam et al., 2021). One of the interviewees reported that " I often feel thirsty at night. This condition forces me to wake up and drink water". Feeling thirsty at night may be associated with dehydration caused by the use of electric fans during hot weather.

### 4.3.9 Delayed Sleeping

Of 100 interviewed residents, 49 confirmed to delay sleep in order to minimize the heat impact. They usually sleep between 23:00 and 01:00 hours. This means that their sleeping hours range between 4-6. The purpose of delay sleeping was to get long hours of staying outside the house so that they can get natural air, therefore cool their bodies. "*Due to our compact environment, there are times when one can stay outside and fail to feel the wind blowing. This is usually better than being confined inside for hours*". This revelation justifies the effects of heat in their areas are significant.

## 5. DISCUSSION

Urban heat constitutes a global urban development challenge, that significantly affect the lives especially of residents in the informal settlements, just remained understudied. As showcased in the context of Kigogo, Dar es Salaam, concentration of buildings, absence of vegetation and open spaces, and nature of climate are the leading factors of urban heat related vulnerabilities. These challenges are not only understudied by less accorded attention by urban policy makers and actors. As revealed in the study, whilst the Meteorological departments, provides information to residents about rainfall patterns, information concerning heat are often less provided or neglected. Residents tend to devised their owns of knowing and predicting heat seasons and adapting to such stressors in ways that meet their socio-economic conditions. In the informal settlement with extreme congestion, rising heat waves and less open spaces, households/residents engage in varied practices to protect their health by minimizing the impact of extreme heat. Generally, these practices were not jointly conducted nor community-wide but more driven by individual households. The individualistic ways in which adaptation practices are conducted risk the achievement of a long-term impacts in terms of coping with extreme heat. The non-communal ways in which residents adapt to urban heat can be attributed to the following; (i) the heat problem is considered a temporary problem; as well as (ii) Lack of knowledge about the correct and effective way to reduce the effects of heat. Again, knowledge about extreme heat and what can be done to reduce the challenge is very important. Moreover, no formal mechanism exists at city level disseminating information about extreme heat to local community) as is the case of flood hazard. Communities tend increase their adaptation strategies upon receiving early warning about extreme flood. This suggests to the need for heat and other hazards' information dissemination to local communities. Lack of information and awareness creation has occasioned the adoption of temporary strategies towards minimizing heat (e.g. sleeping on the floor), amidst less priority to sustainable or long-term strategies such as planting trees (Wang and Akbari, 2016). More, other authors (Feitosa et al., 2021) proposed developing public policies geared towards increasing vegetation that are considered significant in controlling urban heat fluxes. Research has shown that, there was no mention on the use of AC as a way of reducing the impact of heat. This can be linked to the limited financial capacity of the local community in Kigogo ward. Although this research did not aim at finding out why people use a particular strategy to adapt with extreme heat, unreported use of AC maybe attributed to the argument that ACs consume a lot of electricity, hence less preferred by the majority of low-income residents besides its' principal cost. Jones et al.,(2010) recommend that the presence of an institution is essential for empowering the local community in disaster response efforts. This study while such an institution (WDMC) may be exist, the focus is usually not all forms of urban disasters. For example, the WDMC was found proactive in flood disaster related issues than heat disaster. The reasons to this practice are two-fold (i) Unlike floods that affect individuals, communities and infrastructure, heat affect individuals and do not create any attention to the community at large, therefore it is neglected. (ii) Heat related risks are intangible and invisible and it cannot be easy to establish who is affected if they do not express their feelings. Moreover, heat-related risk (e.g., illnesses) are not easily detected compared to the effects of floods where one would see (e.g., a house if submerged in flood water, broken bridge etc.). This could be the reason why it is easier to take action to deal with flood than heat disaster.

## 6. CONCLUSIONS

Urban heat stress remains one of the understudied urban phenomena especially in the global South. This research has used Kigogo ward, an informal settlement in the city of Dar es Salaam by exploring how residents adapt to extreme heat. As indicated, this informed by the limited studies especially in the global South that theorize urban heat. Overall, the findings have revealed that there are vulnerable environments that when exposed to heat waves lead to increased indoor heat. More so, features (e.g., presence WDMC) and dissemination of heat early warning are potential factors that may influence the adaptive capacity of residents prone to extreme heat. However, they contribute nothing in heat related issues.

Following the above, this study suggest that Education (specifically disaster related training) is important in building knowledge of residents' prone to disasters in the society. Regardless of the magnitude, visibility or invisibility of disaster associated risks, it is important for our institutions to address and take into consideration every disaster facing the local communities in their areas. This approach may reduce heat impact and the number of heats related deaths that may occur in later years. Moreover, education may assist vulnerable groups to choose sustainable adaptation strategies when dealing with disasters. The study established that Kigogo informal settlements have been built in a way that exacerbate its vulnerability to different disasters (flood, heat, fire etc.). This includes non-existence of open spaces, concentration of buildings and existence of few greenery areas. Given this practice, there is a need to speed up the regularization process, and more importantly to ensure each regularization scheme focuses on improving the availability of open spaces and greenery areas. Eventually, this practice may increase cool and healthier environment and minimize heat related risks.

Citizens should be educated on urban planning principles as well as the best practices to address extreme heat and climate change in general. The knowledge acquired may help in adopting techniques that are sustainable in coping with the impacts of heat and other hazards. Governments have limited capacity to survey and plan developing cities leading to increasing informal settlements. The local community should be encouraged to apply indigenous knowledge in the fight against extreme heat. Co-management in heat related risks should be emphasized. There should be strong cooperation with NGOs, environmentalists, government institutions, environmental institutions, local governments. In terms of advancing research and scholarship on this area, the study recommends future need to explore the health effects of heat and risks and the measures that can be used to abate the adverse outcomes.

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**Tumpale Sakijege**; As a main author, I have prepared the present manuscript

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## 11. KEY TERMS AND DEFINTIOONS

**Adaptation strategies:** A plan of action or efforts taken to minimize impact of heat.

**Early warning:** Entails to disseminate timely warning information to communities on the possible extreme events/ disaster that threatens their lives.

**Heat:** A temperature that is hotter than normal in an area, as climate change heat intensity is increasing.