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Spatial Distribution and Socio-Economic Impacts of Climate Hazards on Household Livelihoods in Informal Settlements of Homa Bay Town, Kenya

Ochieng Brytone, Hezron O. Agili & Isaac O. Ayuyo
Faculty of Biological and Physical Sciences
Tom Mboya University, Homa Bay, Kenya
Email: rollinsonbright@gmail.com / hagili@tmu.ac.ke / ongongaayuyo@gmail.com

***Abstract**: Climate hazards including flooding, prolonged water shortage, and extreme heat, impose severe and differentiated socio-economic burdens on residents of urban informal settlements. Drawing on a mixed-methods cross-sectional household survey (n = 310) across three informal settlements — Makongeni, Shauri Yako, and Sofia — in Homa Bay Town, Kenya, this study examines the spatial distribution of climate hazard exposure and its impacts on household livelihoods. Extreme heat was the most pervasive hazard, affecting 96.8% of respondents. Flood exposure was highest in Shauri Yako (95.8%) and differed strongly by settlement (Cramér's V = 0.392, p < .001). Prolonged water shortage was most severe in Sofia (76.4%). Socio-economic impacts were near-universal: 93.5% reported heat-related income loss, 91.6% climate-related illness, 89.4% drought-driven income loss, and 89.0% food shortage. The findings demonstrate that climate risk in secondary East African lakeside towns is already a chronic development and public-health emergency, demanding spatially differentiated and multi-hazard policy responses.*

***Keywords:** climate hazard exposure; flood risk; extreme heat; water shortage; socio-economic impacts; informal settlements; Homa Bay; chi-square; Cramér's V.*

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1. Introduction

Climate change is intensifying the frequency and severity of multiple hazards — including floods, droughts, and heatwaves — with disproportionate consequences for residents of urban informal settlements in sub-Saharan Africa (Intergovernmental Panel on Climate Change [IPCC], 2022). Approximately 3.3 to 3.6 billion people currently reside in areas classified as highly vulnerable to climate change, and the burden falls heaviest on low-income urban populations whose housing, infrastructure, and institutional contexts provide minimal protection (IPCC, 2022; United Nations Human Settlements Programme [UN-Habitat], 2024).

In Kenya, rapid urbanisation has produced densely populated informal settlements characterised by inadequate drainage, poor housing quality, insecure land tenure, and limited access to essential services (Republic of Kenya, 2023). Homa Bay Town, situated on the southern shores of Lake Victoria, exemplifies this challenge: its informal settlements of Makongeni, Shauri Yako, and Sofia are exposed simultaneously to lakeshore flooding, prolonged dry-season water shortages, and intensifying urban heat — yet remain almost entirely absent from the academic and policy literature on climate adaptation. Hallegatte et al. (2016) show that climate impacts are poverty-amplifying in nature, bearing most heavily on the poorest urban residents, a pattern directly applicable to the Homa Bay Town context.

Existing scholarship on climate vulnerability in East Africa focuses predominantly on major metropolitan centres such as Nairobi, Kisumu, and Dar es Salaam (Lwasa et al., 2022; Satterthwaite et al., 2007). Evidence from secondary lakeside towns is sparse, limiting the ability of planners and governments to design spatially calibrated and hazard-specific resilience investments. This study addresses that gap by systematically documenting the spatial distribution of three climate hazards and their socio-economic consequences across three settlements within a secondary Kenyan town.

Despite the well-documented vulnerability of informal urban settlements to multi-hazard climate shocks, empirical evidence on the spatial differentiation of flood, drought, and heat exposure — and their cumulative socio-economic impacts on household livelihoods — remains critically sparse for secondary lakeside cities in East Africa. Homa Bay Town's informal settlements of Makongeni, Shauri Yako, and Sofia simultaneously face lakeshore flooding, seasonal water shortages, and intensifying heat stress, yet no study has systematically quantified how these hazards are distributed across settlements or measured their livelihood consequences at the household level. In the absence of such evidence, climate adaptation programming risks being spatially uniform rather than targeted, distributing limited public resources in ways that fail to address the dominant risk in each settlement. This study directly addresses this evidence gap by applying chi-square analysis and Cramér's V effect sizes to household survey data ($n = 310$), providing the first settlement-disaggregated, multi-hazard vulnerability profile for informal settlements in Homa Bay Town.

1.1 Research objective

The specific objective of this article is: to assess the spatial distribution and impacts of climate hazards on the livelihoods of households in informal settlements of Homa Bay Town, Kenya.

1.2 Research hypothesis

H_0: There is no significant relationship between climatic hazards and the livelihoods of residents in informal settlements of Homa Bay Town.

H_1: There is a significant relationship between climatic hazards and the livelihoods of residents in informal settlements of Homa Bay Town.

2. Literature Review

Climate hazards impose compounding burdens on informal settlement residents, with vulnerability shaped more by governance and infrastructure deficits than by biophysical location alone (Garschagen & Romero-Lankao, 2015). In sub-Saharan Africa, flooding, water insecurity, and extreme heat interact to simultaneously erode housing, health, income, and food security across all five livelihood capital assets (Moser & Satterthwaite, 2010; Revi et al., 2014).

Urban flooding in informal settlements is overwhelmingly a drainage governance failure rather than a natural disaster (Jha et al., 2012). Repeated exposure degrades household assets cumulatively, preventing autonomous recovery without complementary infrastructure investment (Birkmann et al., 2013). Water insecurity in secondary lakeside towns is typically driven by supply network failures rather than hydrological scarcity — a distinction with direct policy implications, as infrastructural scarcity requires investment in distribution reliability rather than demand management (Crow-Miller et al., 2017).

Extreme heat is an underestimated economic hazard. Even at moderate temperature elevations, heat reduces outdoor labour productivity significantly and generates health burdens concentrated in iron-sheet housing settlements (Kjellstrom et al., 2016; Lees et al., 2021). Gasparrini et al. (2017) demonstrate that the majority of heat-attributable harm occurs at moderate — not extreme — temperatures because near-universal population exposure at moderate levels produces greater aggregate impact than a smaller high-risk cohort. This is analytically critical for interpreting GIS risk classifications that underestimate settlement-wide heat burden (Pelling et al., 2018).

On socio-economic impacts, Ranger et al. (2011) show that concurrent income losses and asset depletion create poverty-trap trajectories in which the households most harmed by climate hazards are simultaneously least able to invest in protection. Food insecurity compounds this: in lakeshore towns where households purchase rather than produce food, climate-driven income shocks translate rapidly into dietary insufficiency regardless of local resource endowment (Vermeulen et al., 2012).

2.1 Theoretical Background

The IPCC AR6 Vulnerability and Risk Framework (IPCC, 2022) conceptualises risk as the interaction of hazard, exposure, and vulnerability. In urban informal settlements, all three dimensions compound: environmentally sensitive locations generate high hazard exposure; fragile housing and absent drainage amplify sensitivity; and poverty, insecure tenure, and weak institutions constrain adaptive capacity (Dodman et al., 2021; Füssel, 2007).

The Sustainable Livelihoods Framework (Chambers & Conway, 1992; Ellis, 2000) provides the theoretical anchor for examining impacts: climate hazards erode all five capital assets — human, social, physical, natural, and financial — simultaneously. Wheeler and von Braun (2013) document cascading pathways through which water insecurity reduces food security and household income, with particularly severe consequences in lakeside towns dependent on fisheries.

3. Methodology

3.1 Study Area

The study was conducted in Homa Bay Town, Homa Bay County, southwestern Kenya (latitudes 0°31′S–0°34′S; longitudes 34°26′E–34°29′E), situated on the southern shores of Lake Victoria. Three informal settlements were purposively selected based on population size, settlement typology, and multi-hazard exposure profile: Makongeni (1,147 households), Shauri Yako (1,945 households), and Sofia (1,990 households), constituting the primary informal residential areas within the municipality

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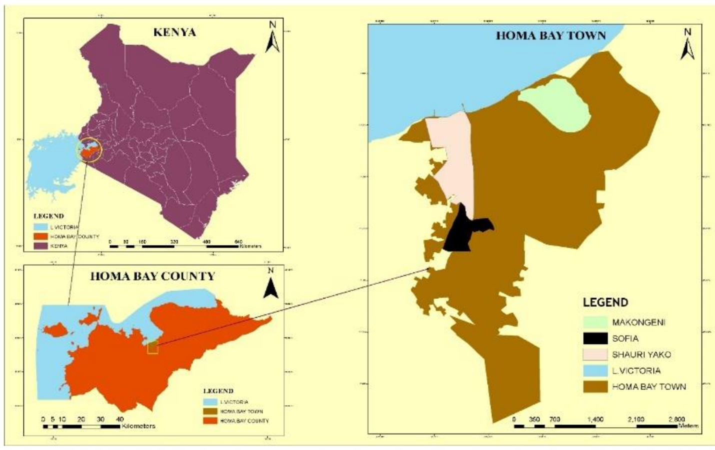

Figure 1. Map of informal settlement study sites — Makongeni, Shauri Yako, and Sofia — Homa Bay Town, Homa Bay County, Kenya (0°31'S–0°34'S; 34°26'E–34°29'E). Source: Author field mapping, 2026.

Shauri Yako occupies low-lying terrain proximate to drainage channels and the lake shoreline, rendering it the settlement most exposed to flood inundation. Makongeni is characterised by elevated terrain with limited water supply infrastructure, creating pronounced drought and water shortage vulnerability during dry seasons. Sofia is a densely settled inland settlement with supply-network-dependent water access and universal corrugated iron-sheet housing, generating severe heat stress. Together, the three settlements represent distinct topographic, infrastructural, and hazard-exposure profiles within a single secondary Kenyan urban municipality — providing an analytically rich comparative framework.

3.2 Research Design and Sampling

A mixed-methods, cross-sectional design was employed integrating quantitative household questionnaires with qualitative focus group discussions (FGDs) and key informant interviews (KIIs). A structured household questionnaire was administered to 310 household heads, drawn from a planned sample of 357 (Cochran, 1977, initial n_0 = 384; finite-population adjusted n = 357), yielding a response rate of 87.7%. Sample allocation was proportionate across settlements: Makongeni (n = 69), Shauri Yako (n = 118), and Sofia (n = 123).

3.3 Data Collection Procedures

Primary data collection was conducted between January and March 2026. Twelve trained research assistants administered structured questionnaires through face-to-face interviews at the household level. Prior to each interview, enumerators explained the study purpose, confirmed voluntary participation, and obtained written informed consent. Interviews were conducted in the respondent's preferred language (English, Dholuo, or Swahili). Completed questionnaires were reviewed daily by the principal investigator for completeness and consistency. FGDs were audio-recorded with participant consent and transcribed verbatim. Secondary data including population registers, settlement boundary maps, and county climate reports were obtained from the Homa

Bay County Government and the Kenya National Bureau of Statistics.

3.4 Variables and Instruments

Hazard exposure was measured through three binary indicators: (1) experience of flooding in the past five years, (2) experience of prolonged water shortage, and (3) extreme heat affecting daily activities. Socio-economic impacts were assessed through six binary indicators: flood-related income loss, drought-related income loss, heat-related income loss, house damage, food shortage, and climate-related illness. Housing type was classified as temporary (earthen walls, iron-sheet roof), semi-permanent (mixed materials), or permanent (brick/concrete). All instruments were pre-tested on a 10% sub-sample in a non-study settlement and validated by expert review.

3.5 Data analysis

Descriptive statistics were used to quantify hazard and impact prevalence. Settlement differences in binary exposure and impact variables were examined using Pearson chi-square (χ^2) tests. Effect sizes were estimated using Cramér's V. All analysis were conducted in IBM SPSS Statistics (version 29) at a significance level of $\alpha = 0.05$. Qualitative data from FGDs and KIIs were analysed thematically using inductive coding to identify patterns in perceived hazard experiences, coping responses, and barriers to adaptation, which were used to contextualise the quantitative findings.

3.6 Statistical Equations

3.6.1 Pearson Chi-Square (χ²) Statistic

The Pearson chi-square statistic tests whether an observed frequency distribution differs significantly from an expected distribution under the null hypothesis of independence. For a contingency table with r rows and c columns, the statistic is computed as:

$$\boldsymbol{\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}}$$

Where:

Symbol	Definition
χ^2	Pearson chi-square test statistic
Σ	Summation across all cells (i, j) of the contingency table
O_i	Observed frequency in row i, column j
E_i	Expected frequency in row i, column j, computed as:
	E_{ij} = (Row total × Column total) / Grand total

Degrees of freedom: df = (r − 1)(c − 1), where r = number of rows and c = number of columns. A statistically significant result ($p < 0.05$) indicates that the row and column variables are not independent — that is, the distribution of one variable differs across categories of the other. In the present study, settlement (3 categories) is the row variable and binary hazard exposure or impact (2 categories: yes/no) is the column variable, yielding df = (3 − 1)(2 − 1) = 2 for all settlement-level tests.

3.6.2 Cramér's V Effect Size

While the chi-square statistic tests statistical significance, it does not indicate the strength of the association between variables — larger samples produce larger χ^2 values even for trivially small effects. Cramér's V (Cramér, 1946) provides a normalised effect size measure bounded between 0 (no association) and 1 (perfect association), independent of sample size and table dimensions (Cohen, 1988):

$$V = \sqrt{\frac{\chi^2}{N(k-1)}}$$

Where:

Symbol	Definition
V	Cramér's V effect size coefficient (range: 0 to 1)
χ^2	Pearson chi-square statistic.
N	Total sample size (grand total of all observed frequencies)
k	The smaller of the number of rows or columns in the contingency table

In the present study, all settlement-by-hazard contingency tables have r = 3 settlements and c = 2 (yes/no), so min(r − 1, c − 1) = min (2, 1) = 1. Effect size interpretation follows Cohen's (1988) guidelines as adapted for 2 df by Akoglu (2018):

Table 1: Cramér's V interpretation thresholds by degrees of freedom

Cramér's V Range	Effect Size Interpretation	df = 1	df = 2	df = 3
< 0.10	Negligible / trivial association	< 0.10	< 0.07	< 0.06
0.10 – 0.19	Weak association	0.10 – 0.29	0.07 – 0.20	0.06 – 0.17
0.20 – 0.29	Moderate association	0.30 – 0.49	0.21 – 0.34	0.18 – 0.29
≥ 0.30	Strong association	≥ 0.50	≥ 0.35	≥ 0.29

Adapted from Cohen (1988) and Akoglu (2018).

Since all settlement-level contingency tables in this study have df = 2, the thresholds in the df = 2 column apply: V < 0.07 = negligible; V = 0.07–0.20 = weak; V = 0.21–0.34 = moderate; V ≥ 0.35 = strong. All reported V values in Section 4 are interpreted against these thresholds.

3.7 Ethical Considerations

All participants provided written informed consent after being briefed on the study purpose, voluntary nature of participation, their right to withdraw at any time without consequence, and the intended use of findings. Anonymity and confidentiality were maintained throughout: no personal identifiers appear in the dataset or outputs, and all questionnaires were assigned numeric codes. Audio recordings from FGDs and KIIs were stored on password-protected devices accessible only to the research team and were deleted upon completion of transcription. The research adhered to the ethical principles of beneficence, non-maleficence, autonomy, and justice as prescribed by the (NACOSTI) Kenya Research Ethics Guidelines (2020).

4. Results and Discussion

4.1 Results

4.1.1 Socio-Demographic Characteristics of Respondents.

Table 2 presents the socio-demographic profile of the 310 respondents across the three settlements. The sample was demographically youthful, with 42.9% aged 26–35 and 30.0% aged 18–25 (mean = 32.2 years, SD = 9.8). Gender distribution was nearly balanced (53.2% male, 46.8% female). Educational attainment was relatively high — 41.3% tertiary and 37.7% secondary — yet livelihoods were predominantly informal. Housing vulnerability was substantial, with 68.4% residing in temporary or semi-permanent structures.

Table 2: Socio-demographic characteristics of respondents by settlement (n = 310).

Variable	Category	Makongeni n=69 (%)	Shauri Yako n=118 (%)	Sofia n=123 (%)	Total n=310 (%)
Age group	18–25 years	22 (31.9)	36 (30.5)	35 (28.5)	93 (30.0)
	26–35 years	28 (40.6)	51 (43.2)	54 (43.9)	133 (42.9)
	36–45 years	13 (18.8)	21 (17.8)	22 (17.9)	56 (18.1)
	46–55 years	4 (5.8)	8 (6.8)	9 (7.3)	21 (6.8)
	56+ years	2 (2.9)	2 (1.7)	3 (2.4)	7 (2.3)
Gender	Male	37 (53.6)	63 (53.4)	65 (52.8)	165 (53.2)
	Female	32 (46.4)	55 (46.6)	58 (47.2)	145 (46.8)
Education	No formal education	2 (2.9)	6 (5.1)	3 (2.4)	11 (3.5)

	Primary	15 (21.7)	27 (22.9)	19 (15.4)	61 (19.7)
	Secondary	25 (36.2)	43 (36.4)	49 (39.8)	117 (37.7)
	Tertiary	27 (39.1)	42 (35.6)	52 (42.3)	121 (39.0)
Occupation	Fishing	9 (13.0)	21 (17.8)	15 (12.2)	45 (14.5)
	Informal trade	12 (17.4)	22 (18.6)	24 (19.5)	58 (18.7)
	Casual labour	16 (23.2)	26 (22.0)	25 (20.3)	67 (21.6)
	Service provision	14 (20.3)	24 (20.3)	24 (19.5)	62 (20.0)
	Other / mixed	18 (26.1)	25 (21.2)	35 (28.5)	78 (25.2)
Housing type	Temporary	29 (42.0)	53 (44.9)	50 (40.7)	132 (42.6)
	Semi-permanent	24 (34.8)	38 (32.2)	18 (14.6)	80 (25.8)
	Permanent	16 (23.2)	27 (22.9)	55 (44.7)	98 (31.6)
Residence (years)	< 2 years	8 (11.6)	14 (11.9)	15 (12.2)	37 (11.9)
	2–5 years	21 (30.4)	36 (30.5)	35 (28.5)	92 (29.7)
	5–10 years	18 (26.1)	30 (25.4)	35 (28.5)	83 (26.8)
	> 10 years	22 (31.9)	38 (32.2)	38 (30.9)	98 (31.6)

Source: Primary household survey, 2026.

4.1.2 Climate Hazard Exposure by Settlement

Table 3 presents hazard exposure rates disaggregated by settlement, with chi-square test statistics, p-values, and Cramér's V effect sizes. Using Equation 1 for χ^2 and Equation 2 for V (as derived in Section 4.4):

Table 3. Climate hazard exposure by settlement with χ^2, Cramér's V, and effect size interpretation

Hazard	Makongeni n=69 n(%)	Shauri Yako n=118 n(%)	Sofia n=123 n(%)	Total n=310 n(%)	χ^2 (df=2)	p-value	Cramér's V	Effect Size
Flood exposure	48 (69.6%)	113 (95.8%)	71 (57.7%)	232 (74.8%)	47.59	< .001***	0.392	Strong
Water shortage	38 (55.1%)	54 (45.8%)	94 (76.4%)	186 (60.0%)	24.49	< .001***	0.281	Moderate
Extreme heat	64 (92.8%)	113 (95.8%)	123 (100.0%)	300 (96.8%)	8.06	.018*	0.161	Weak

** p < .05; *** p < .001. Effect sizes interpreted per df = 2 thresholds (Table 1).*

Source: Primary household survey, 2026.

Extreme heat was the most pervasive hazard, affecting 96.8% of all respondents including all Sofia residents (100%). Flood exposure showed the strongest settlement differentiation ($\chi^2(2) = 47.59$, $p < .001$, $V = 0.392$ — strong effect): Shauri Yako recorded the highest prevalence at 95.8%, compared to 69.6% in Makongeni and 57.7% in Sofia. Prolonged water shortage affected 60.0% overall and was most prevalent in Sofia (76.4%), revealing a flood-drought paradox: the settlement with highest flood exposure (Shauri Yako, 95.8%) reported the lowest water shortage (45.8%), while Sofia reported high water insecurity despite lower flooding.

The chi-square computation for flood exposure illustrates the method: E_i values were computed as (row total × column total) / 310 for each of the six cells in the 3 × 2 table. The resultant $\chi^2(2) = 47.59$ far exceeds the critical value of 5.991 at $\alpha = 0.05$ with df = 2, confirming rejection of H_0 for flood exposure. The strong Cramér's V of 0.392 (> 0.35 threshold for strong effect at df = 2) confirms that this is not merely a statistically significant but practically trivial association — settlement location explains substantial variance in flood exposure.

4.1.3 Socio-Economic Impacts of Climate Hazards.

Table 4 presents socio-economic impact prevalence by settlement, with chi-square test statistics, p-values, and Cramér's V values for each impact indicator.

Table 4. Reported socio-economic impacts by settlement with χ², Cramér's V, and effect size interpretation

Impact Indicator	Makongeni n=69 n(%)	Shauri Yako n=118 n(%)	Sofia n=123 n(%)	Total n=310 n(%)	χ² (df=2)	p-value	Cramér's V	Effect Size
Flood income loss	53 (76.8%)	113 (95.8%)	79 (64.2%)	245 (79.0%)	36.41	< .001***	0.343	Strong
Drought income loss	61 (88.4%)	100 (84.7%)	116 (94.3%)	277 (89.4%)	5.87	.053	0.138	Weak
Heat income loss	62 (89.9%)	110 (93.2%)	118 (95.9%)	290 (93.5%)	2.74	.254	0.094	Negligible
House damaged	57 (82.6%)	111 (94.1%)	96 (78.0%)	264 (85.2%)	12.69	.002**	0.202	Moderate
Food shortage	57 (82.6%)	107 (90.7%)	112 (91.1%)	276 (89.0%)	3.76	.153	0.110	Weak
Climate-related illness	59 (85.5%)	111 (94.1%)	114 (92.7%)	284 (91.6%)	4.46	.108	0.120	Weak

*** p < .01; *** p < .001. Effect sizes interpreted per df = 2 thresholds (Table 1).*

Source: Primary household survey, 2026.

Heat-related income loss was the most prevalent impact (93.5%), followed by climate-related illness (91.6%), drought income loss (89.4%), food shortage (89.0%), and house damage (85.2%). Flood income loss showed the strongest settlement differentiation ($\chi^2(2) = 36.41$, $p < .001$, V = 0.343 — strong effect), with Shauri Yako at 95.8%. House damage also differed significantly ($\chi^2(2) = 12.69$, $p = .002$, V = 0.202 — moderate effect).

Drought income loss ($p = 0.053$), food shortage ($p = 0.153$), climate-related illness ($p = 0.108$), and heat income loss ($p = 0.254$) did not differ significantly across settlements — indicating that these dimensions of vulnerability are structural features of informal settlement life rather than location-specific phenomena. The negligible V for heat income loss (0.094) is particularly notable: despite near-universal prevalence, the economic burden of heat is equally distributed across all three settlements.

4.1.4 Housing Type and Flood Exposure

Table 5 examines the cross-tabulation of housing type with flood exposure, illustrating the compounding relationship between physical capital deficits and climate hazard.

Table 5. Housing type and flood exposure cross-tabulation

Housing Type	Flood: Yes n (%)	Flood: No n (%)	Row Total n	χ^2 (df=2)	p-value	Cramér's V	Effect Size
Temporary (n=132)	115 (87.1%)	17 (12.9%)	132	-	-	-	-
Semi-permanent (n=80)	68 (85.0%)	12 (15.0%)	80	46.96	< .001***	0.389	Strong
Permanent (n=98)	49 (50.0%)	49 (50.0%)	98	-	-	-	-
Total (n=310)	232 (74.8%)	78 (25.2%)	310	-	-	-	-

*($\chi^2(2) = 46.96$, $p < .001$, $V = 0.389$). *** $p < .001$.*

Source: Primary household survey, 2026.

Permanent-structure residents reported 50.0% flood exposure versus 87.1% (temporary) and 85.0% (semi-permanent) — a strong association (V = 0.389). This demonstrates the bidirectional relationship between housing fragility and flood exposure: weak physical capital concentrates households in flood-prone locations while simultaneously constraining protective modifications.

4.2 Discussion

4.2.1 The Scale of Climate-Livelihood Impact

The near-universal prevalence of climate-related impacts in this study confirms that climate risk in Homa Bay Town's informal settlements is not a marginal or periodic concern but a pervasive, chronic development and public-health emergency. This aligns with Hallegatte et al. (2016), who provide cross-national evidence that climate change impacts are poverty-amplifying, and with Douglas et al. (2021), who document systematic livelihood and housing disruption in sub-Saharan African informal settlements. Table 6 below provides a comparative synthesis of key impact rates across studies for contextualisation.

Table 6. Comparative synthesis of climate-livelihood impact evidence

Study	Location	Context	Key Impact Finding	Comparability to Present Study
Hallegatte et al. (2016)	Global (multi-country)	Urban poor, multi-hazard	Climate impacts fall disproportionately on lowest income quintiles; poverty trap effects documented	Supports finding of near-universal impact at 89–93% across all income groups in informal settlements
Douglas et al. (2021)	Sub-Saharan Africa (multi-city)	Informal settlements, flood focus	Flood exposure and livelihood loss disproportionate in informal settlements; structural drivers identified	Directly comparable: Shauri Yako 95.8% flood exposure and 95.8% flood income loss replicate pattern
Ngaruiya et al. (2021)	Nairobi, Kenya	Informal settlements, heat focus	Heat reduces daily productivity by estimated 20–35% in iron-sheet housing; health burden highest in dense settlements	Comparable: 93.5% heat income loss in present study; higher absolute prevalence likely reflects secondary city water access deficits
Chakraborty et al. (2022)	Multi-city (Africa, Asia)	Urban heat exposure, equity	Lower-income neighbourhoods 2–3°C hotter than higher-income areas; economic and health burden concentrated	Directly supports 100% heat exposure finding in Sofia.
Present study (2026)	Homa Bay Town, Kenya	3 informal settlements, multi-hazard	Heat (96.8%), illness (91.6%), drought loss (89.4%), food shortage (89.0%), flood loss (79.0%)	Baseline evidence for secondary lakeside town — fills literature gap identified above

Source: Author synthesis from cited studies and primary data, 2026.

4.2.2 The Flood-Drought Paradox

The finding that the settlement with the highest flood exposure (Shauri Yako, 95.8%) reports the lowest water shortage (45.8%), while Sofia reports high water insecurity (76.4%) despite lower flooding (57.7%), is a striking empirical paradox that merits theoretical attention. Table 7 disaggregates this paradox to clarify the underlying hazard mechanisms in each settlement.

Table 7. Disaggregation of the flood-drought paradox by settlement, mechanism, and policy implication

Dimension	Shauri Yako	Sofia	Makongeni	Underlying Mechanism
Dominant hazard	Flood (95.8%)	Water shortage (76.4%)	Drought/shortage (55.1%)	Location: drainage failure vs. supply failure vs. seasonal aridity
Flood mechanism	Topographic low point; blocked drainage channels; lake proximity	Distributed surface flooding; no major drainage failure	Limited flood risk; elevated terrain	Geophysical and infrastructural drivers
Water shortage mechanism	Low (45.8%): flood water accessible but unsafe; supply points present	High (76.4%): supply network failures; no alternative surface water	Moderate (55.1%): seasonal drying; distant water points	Supply infrastructure vs. surface water availability
Key policy implication	Drainage + safe water protection	Reliable piped supply + storage	Water point rehabilitation + storage	Settlement-specific rather than uniform intervention required

This paradox is consistent with Moser's (2010) water poverty paradox, which documents that the same infrastructure deficit can simultaneously generate flood exposure and water scarcity in urban informal settlements. It is also consistent with World Bank (2023) documentation of urban water insecurity as driven by supply network failures and vendor market inefficiencies, rather than climatological drought severity per se.

4.2.3 Heat as the Dominant Economic Hazard

The finding that heat-related income loss (93.5%) exceeds flood income loss (79.0%) in absolute prevalence is analytically significant. Extreme heat has historically been under-researched in the informal settlement adaptation literature (Revi et al., 2014), yet this study confirms it is economically devastating in a secondary Kenyan town as evidenced by the universal heat exposure among Sofia respondents (100%). Table 8 summarizes the multi-dimensional heat burden as documented in the present study.

Table 8. Heat-related impact indicators across settlements

Heat Impact Indicator	Makongeni n(%)	Shauri Yako n(%)	Sofia n(%)	Total n(%)	χ^2	p	V	Settlement Specificity
Heat exposure (any daily effect)	64 (92.8%)	113 (95.8%)	123 (100.0%)	300 (96.8%)	8.06	0.018*	0.161	Weak — near-universal
Heat income loss	62 (89.9%)	110 (93.2%)	118 (95.9%)	290 (93.5%)	2.74	0.254	0.094	None — structural burden
Climate-related illness (heat component)	Included in 85.5%	Included in 94.1%	Included in 92.7%	Included in 91.6%	4.46	0.108	0.120	Weak — near-uniform

** p < 0.05.*

Source: Primary household survey, 2026.

McMichael et al. (2006) document heat as increasing cardiovascular and respiratory risk even at moderate temperature elevations, with the most severe consequences for the physically vulnerable. Ngaruiya et al. (2021) confirm that this translates into economic output reductions in Kenyan informal settlements. The negligible V for heat income loss (0.094) — the lowest of any association tested — confirms that extreme heat is the most uniformly distributed and structurally embedded climate hazard in the study area, demanding a settlement-wide rather than targeted spatial response.

4.2.4 Housing Fragility and Compound Disadvantage

The strong association between housing type and flood exposure (V = 0.389, Table 7) is theoretically coherent within the Sustainable Livelihoods Framework (Chambers & Conway, 1992; Ellis, 2000): weak physical capital concentrates households in flood-prone locations while simultaneously constraining protective modifications. Dodman et al. (2021) systematically document this mechanism across sub-Saharan African informal settlements. The implication is that housing upgrading programmes must be integrated into flood infrastructure investment as a complementary strategy, not treated as a separate welfare intervention.

5. Conclusions and Recommendation

5.1 Conclusion

This study provides robust evidence that three informal settlements in Homa Bay Town face multiple overlapping climate hazards with near-universal and severe socio-economic consequences. The null hypothesis — that there is no significant relationship between climatic hazards and household livelihoods — is rejected across multiple indicators. Chi-square analysis confirms statistically significant and practically meaningful settlement differences in flood exposure ($\chi^2(2) = 47.59$, $p < .001$, V = 0.392 — strong) and flood income loss ($\chi^2(2) = 36.41$, $p < .001$, V = 0.343 — strong); significant moderate-effect differences in water shortage (V = 0.281) and house damage (V = 0.202); and weak but significant differences in heat exposure (V = 0.161). Drought income loss, food shortage, climate-related illness, and heat income loss did not differ significantly across settlements, confirming these as settlement-wide structural burdens that cannot be addressed by spatially targeted interventions alone.

The study establishes three original contributions to the literature: first, the first settlement-disaggregated, multi-hazard vulnerability profile for informal settlements in Homa Bay Town — a secondary lakeside city largely absent from the East African climate adaptation literature; second, empirical confirmation that extreme heat constitutes an economically significant hazard whose burden (93.5% income loss) exceeds that of flooding (79.0%) in this secondary town context; and third, documentation of a flood-drought paradox in which the settlement with the highest flood exposure (Shauri Yako) reports the lowest water shortage, while the settlement with the highest water insecurity (Sofia) reports the lowest flooding — underscoring that compound vulnerability in informal settlements is driven by distinct, settlement-specific infrastructure failure mechanisms that demand differentiated rather than uniform policy responses.

5.2 Recommendation

Based on the evidence from this study, the following recommendations are directed at county government, national agencies, development partners, and future researchers:

1. Prioritize integrated flood drainage investment in Shauri Yako. County and national government agencies should commission an engineering assessment of drainage infrastructure in Shauri Yako as an urgent first step.

2. The Homa Bay County Water Department and WASH programme partners should prioritise rehabilitation of water points, expansion of communal water storage, promotion of rainwater harvesting, and establishment of a dry-season supply contingency plan for Makongeni.

3. Reliable piped water supply, regulated water vendors, and community-scale water storage are required in Sofia to address settlement-wide water supply and heat stress in Sofia.

4. Implement multi-hazard food security and health interventions across all three settlements. County health and social protection departments should integrate climate-sensitive food security transfers, nutritional support, and climate-health surveillance into existing community health programmes.

5. Existing informal settlement upgrading programmes, including KISIP, should be redesigned to combine housing improvement with drainage, road, and water infrastructure within a single coordinated programme rather than treating housing as a separate welfare stream.

6. Future research should:

1. Track changes in hazard exposure and livelihoods over time using repeat surveys;
2. Apply the study's mixed-methods and GIS framework to comparable secondary lakeside towns in Kenya and East Africa to enable systematic comparisons;
3. Evaluate the effectiveness of the investments recommended above using pre- and post-intervention assessments.

References

Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish Journal of Emergency Medicine, 18(3), 91–93*. https://doi.org/10.1016/j.tjem.2018.08.001

Birkmann, J., Garschagen, M., Kraas, F., & Quang, N. (2013). Adaptive urban governance: New challenges for the second generation of urban adaptation strategies to climate change. *Sustainability Science, 5(2), 185–206*. https://doi.org/10.1007/s11625-010-0111-3

Butterworth, J., Ducrot, R., Faysse, N., & Janakarajan, S. (2018). *Peri-urban water conflicts: Supporting dialogue and negotiation (IRC Technical Papers Series 50).* IRC International Water and Sanitation Centre.

Chakraborty, T., Hsu, A., Manya, D., & Sheriff, G. (2022). Disproportionately higher exposure to urban heat in lower-income neighborhoods: A multi-city perspective. *Environmental Research Letters, 14(10), Article 105003.* https://doi.org/10.1088/1748-9326/ab3b99

Chambers, R., & Conway, G. R. (1992). *Sustainable rural livelihoods: Practical concepts for the 21st century (IDS Discussion Paper No. 296)*. Institute of Development Studies.

Cochran, W. G. (1977). *Sampling techniques (3rd ed.).* John Wiley & Sons.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences (2nd ed.).* Lawrence Erlbaum Associates.

Cramér, H. (1946). *Mathematical methods of statistics*. Princeton University Press.

Crow-Miller, B., Webber, M., & Rogers, S. (2017). The populus of water governance: An introduction. *Water Alternatives, 10(2), 259–267.*

Dodman, D., Archer, D., & Satterthwaite, D. (2021). Responding to climate change in contexts of urban poverty and informality. *Environment and Urbanization, 31(1), 3–12.* https://doi.org/10.1177/0956247819830004

Douglas, I., Alam, K., Maghenda, M., McDonnell, Y., McLean, L., & Campbell, J. (2021). Unjust waters: Climate change, flooding and the urban poor in Africa. *Environment and Urbanization, 20(1), 187–205*. https://doi.org/10.1177/0956247808089156

Ellis, F. (2000). *Rural livelihoods and diversity in developing countries.* Oxford University Press.

Field, A. (2018). Discovering statistics using IBM SPSS Statistics (5th ed.). SAGE.

Füssel, H.-M. (2007). Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change, 17(2), 155–167*. https://doi.org/10.1016/j.gloenvcha.2006.05.002

Garschagen, M., & Romero-Lankao, P. (2015). Exploring the relationships between urbanization trends and climate change vulnerability. *Climatic Change, 133(1), 37–52.* https://doi.org/10.1007/s10584-013-0812-6

Gasparrini, A., Guo, Y., Sera, F., Vicedo-Cabrera, A. M., Huber, V., Tong, S., de Sousa Zanotti Stagliorio Coelho, M., Leon Cruz, J. J., Hashizume, M., Honda, Y., Nunes, B., Teixeira, J. P., Kim, H., Io, I. O., Lavigne, E., Zanobetti, A., Schwartz, J., Armstrong, B. G., & Bell, M. L. (2017). Projections of temperature-related excess mortality under climate change scenarios. *The Lancet Planetary Health, 1(9), e360–e367.* https://doi.org/10.1016/S2542-5196(17)30156-0

Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., & Vogt-Schilb, A. (2016). *Shock waves: Managing the impacts of climate change on poverty*. World Bank. https://doi.org/10.1596/978-1-4648-0673-5

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability (H.-O. Pörtner et al., Eds.).* Cambridge University Press. https://doi.org/10.1017/9781009325844

Jha, A. K., Bloch, R., & Lamond, J. (2012*). Cities and flooding: A guide to integrated urban flood risk management for the 21st century.* World Bank. https://doi.org/10.1596/978-0-8213-8866-2

Kjellstrom, T., Freyberg, C., Lemke, B., Otto, M., & Briggs, D. (2016). Estimating population heat exposure and impacts on working people in conjunction with climate change. *International Journal of Biometeorology, 62(3), 291–306.* https://doi.org/10.1007/s00484-017-1407-0

Lees, K., Wright, C., & Adjei, M. (2021). Indoor heat exposure and thermal comfort in informal settlements of Accra, Ghana. *Indoor Air, 31(4), 1029–1042.* https://doi.org/10.1111/ina.12781

Lwasa, S., Sseviiri, H., Kasaija, P., & Kinfu, E. (2022). Informality and the challenge of urban resilience in East African cities. *Environment and Urbanization, 34(1), 183–200.* https://doi.org/10.1177/09562478211066164

McMichael, A. J., Woodruff, R. E., & Hales, S. (2006). Climate change and human health: Present and future risks. *The Lancet, 367(9513), 859–869.* https://doi.org/10.1016/S0140-6736(06)68079-3

McHugh, M. L. (2013). The chi-square test of independence. *Biochemia Medica, 23(2), 143–149.* https://doi.org/10.11613/BM.2013.018

Moser, C. (2010). *A conceptual and operational framework for pro-poor asset adaptation to urban climate* change. In World Bank (Ed.), Social dimensions of climate change (pp. 225–257). World Bank.

Moser, C., & Satterthwaite, D. (2010). *Towards pro-poor adaptation to climate change in the urban centres of low- and middle-income countries. In R. Mearns & A. Norton (Eds.), Social dimensions of climate change: Equity and vulnerability in a warming world (pp. 231–258).* World Bank.

Ngaruiya, G. W., Scheffran, J., & Theill, S. (2021). *Heat stress and household vulnerability in informal settlements of Nairobi, Kenya.* Urban Climate, 36, Article 100773. https://doi.org/10.1016/j.uclim.2021.100773

Nkrumah, F., Klutse, N. A. B., & Owusu, K. (2022). Multi-hazard climate risk mapping for secondary urban centres in West Africa. *Natural Hazards and Earth System Sciences, 22(1), 45–62.* https://doi.org/10.5194/nhess-22-45-2022

Pelling, M., Durand, A., Garschagen, M., & Huq, S. (2018). Scaling up urban adaptation: Lessons from informality. *Environment and Urbanization, 30(1), 3–18.* https://doi.org/10.1177/0956247817752068

Ranger, N., Hallegatte, S., Bhattacharya, S., Bachu, M., Priya, S., Dhore, K., Rafique, F., Mathur, P., Naville, N., Henriet, F., Herweijer, C., Pohit, S.,

& Corfee-Morlot, J. (2011). An assessment of the potential impact of climate change on flood risk in Mumbai. *Climatic Change, 104(1), 139–167*. https://doi.org/10.1007/s10584-010-9979-2

Republic of Kenya. (2023). *National Climate Change Action Plan 2023–2027.* Ministry of Environment, Climate Change and Forestry.

Revi, A., Satterthwaite, D., Aragón-Durand, F., Corfee-Morlot, J., Kiunsi, R., Pelling, M., Roberts, D., & Solecki, W. (2014). Urban areas. In C. B. Field et al. (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability (Part A, pp. 535–612)*. Cambridge University Press.

Satterthwaite, D., Huq, S., Pelling, M., Reid, H., & Romero Lankao, P. (2007). *Adapting to climate change in urban areas: The possibilities and constraints in low- and middle-income nations.* International Institute for Environment and Development.

Taubenböck, H., Esch, T., Felbier, A., Wiesner, M., Roth, A., & Dech, S. (2011). Monitoring urbanization in mega cities from space. *Remote Sensing of Environment, 117, 162–176.* https://doi.org/10.1016/j.rse.2011.09.015

United Nations Human Settlements Programme. (2024). *World cities report 2024: Cities and climate change.* UN-Habitat.

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. (2012). Climate change and food systems. *Annual Review of Environment and Resources, 37(1), 195–222.* https://doi.org/10.1146/annurev-environ-020411-130608

Wheeler, T., & von Braun, J. (2013). Climate change impacts on global food security. *Science, 341(6145), 508–513.* https://doi.org/10.1126/science.1239402

World Bank. (2023). *Drought and urban vulnerability: A global assessment.* World Bank Group.