Effects of climate change on Covid-19 recovery among households in informal settlements of Kakamega Municipality, Kenya

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ABSTRACT

Climate change may increase environmental and socio-economic challenges for households recovering from the COVID-19 pandemic. This study examined the effects of climate change on COVID-19 recovery among households in informal settlements of Kakamega Municipality, Kenya. Guided by Vulnerability and Adaptation Theory, the study adopted a cross-sectional mixed-methods design. The target population comprised households in Masingo, Kambi Somali and Makaburini informal settlements. Of the 384 households targeted, 372 questionnaires were analysed, representing a 96.9% response rate. Systematic sampling was used to select households, while purposive and snowball sampling were used to identify key informants. Data were collected using household questionnaires, 12 key informant interviews, focus group discussions and an observation checklist, alongside Kenya Meteorological Department rainfall and temperature records for 1985–2024. Quantitative data were analysed using descriptive statistics, linear regression, chi-square tests and binary logistic regression, while qualitative data were analysed thematically. Annual rainfall increased by approximately 13.85 mm per year, while mean annual temperature increased by 0.008°C per year. All respondents reported changes in rainfall, with 55.9% describing it as unpredictable, while 99.1% reported increased heat. Economic recovery remained incomplete, with 80.9% reporting partial income recovery and 83.1% experiencing difficulty meeting basic needs. Perceived changes in rainfall were significantly associated with incomplete income recovery (COR = 3.353, $p < 0.001$), whereas flooding and extreme heat were not significantly associated with the selected economic recovery indicators. The study concludes that climate variability is an important consideration in household recovery from COVID-19. It recommends integrating climate-informed livelihood support with improved drainage and basic infrastructure to support vulnerable households in informal settlements.

Keywords: Climate Change; COVID-19 Recovery; Household Livelihoods; Informal Settlements; Kakamega Municipality, Rainfall and Temperature Variability

I. INTRODUCTION

Climate change is an increasing global concern because changing rainfall patterns and rising temperatures affect livelihoods, human health, housing and food security according to Intergovernmental Panel on Climate Change (IPCC, 2021, 2022). Its effects are particularly pronounced in urban areas where rapid population growth, inadequate infrastructure and uneven access to basic services increase exposure to climate-related hazards. Informal settlements are especially vulnerable because many households occupy poorly drained areas, live in inadequate housing and depend on limited and often unreliable sources of income (Cira & Kamunyori, 2016; UN-Habitat, 2022). Flooding, prolonged rainfall and rising temperatures can disrupt economic activities, damage household property, affect sanitation and increase health risks. According to Smit and Wandel (2006), vulnerability depends not only on exposure to environmental changes but also on the sensitivity of households and their capacity to respond and adapt. Consequently, households with limited financial resources and inadequate infrastructure may experience greater difficulties in managing climate-related challenges.

The effects of climate change are particularly important for households whose livelihoods depend on informal employment, small businesses and daily earnings. Such livelihoods are sensitive to weather conditions because unfavourable rainfall and flooding can restrict movement, disrupt trading activities and limit access to workplaces and customers (Douglas et al., 2008; IPCC, 2022). In addition, inadequate drainage and poor sanitation can contribute to water accumulation and unhealthy living conditions, increasing households' exposure to environmental and health risks (Okari, 2019; IPCC, 2022). These challenges may also place additional financial demands on households through property repairs, sanitation and healthcare, further limiting the resources available for other essential needs. In Kakamega, Saalu et al. (2020) examined climate change and its implications for forest-dependent communities, while

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Chelangat and Mulinya (2023) investigated climate change and seasonal agricultural drought in Kakamega South Sub-County. These studies demonstrate the local relevance of climate change and its implications for livelihoods, although they do not specifically address household recovery in urban informal settlements.

The COVID-19 pandemic further exposed the economic and social vulnerability of households living in informal settlements. Restrictions on economic activities, reduced employment and disruptions to household livelihoods affected income, food security and access to essential resources (International Labour Organization [ILO], 2020; Shupler et al., 2021). Shupler et al. (2021) examined household energy and food security in Kenyan informal settlements, while Solymári et al. (2022) documented the livelihood effects of COVID-19 among Kenyan slum dwellers. Tompsett et al. (2021) also examined changes in household income during the pandemic. Collectively, these studies highlight the difficulties households faced in sustaining their livelihoods and meeting basic needs during COVID-19. Importantly, recovery from the pandemic involved more than the restoration of economic activities; it also required households to regain access to essential services, improve their health and resume normal social activities.

Climate change may further complicate household recovery from the pandemic. Households that experienced income losses during COVID-19 may have limited financial capacity to repair flood-damaged homes, improve drainage, access healthcare or sustain their livelihoods during unfavourable weather conditions. Similarly, changing rainfall and temperature conditions may affect household expenditure, working conditions and the availability of essential resources. The IPCC (2022) emphasises that climate-related hazards can intensify existing social and economic vulnerabilities, particularly where adaptive capacity is limited. This suggests that the recovery of vulnerable households should be examined within the wider environmental conditions in which they live, rather than treating the effects of the pandemic and climate change as separate concerns.

Kakamega Municipality provides an important setting for examining this relationship. The 2019 Kenya Population and Housing Census (Kenya National Bureau of Statistics [KNBS], 2019) provides the demographic context for urban planning, while the County Government of Kakamega (2023) identifies climate change as an important development concern. This study focused on Masingo, Kambi Somali and Makaburini informal settlements in Shieywe Ward, where households experience inadequate infrastructure and depend largely on informal livelihoods. These conditions make the settlements relevant for examining how climate-related environmental changes relate to household economic, health and social recovery following the COVID-19 pandemic. Although previous studies have examined climate change and its socio-economic implications in the region, their focus has been different from the present study. For instance, Saalu et al. (2020) examined climate change among forest-dependent communities in Kakamega, while Chelangat and Mulinya (2023) investigated climate change and seasonal agricultural drought in Kakamega South Sub-County. Similarly, Shupler et al. (2021) examined household energy and food security in Kenyan informal settlements, Solymári et al. (2022) investigated the livelihood effects of COVID-19 among Kenyan slum dwellers, and Tompsett et al. (2021) explored household income changes during the pandemic. However, these studies did not specifically examine how climate-related conditions relate to household recovery from COVID-19, particularly in secondary urban centres. This study therefore examined the effects of climate change on COVID-19 recovery among households in informal settlements of Kakamega Municipality, Kenya. It considered rainfall and temperature changes in relation to household economic recovery, health recovery and social well-being, with the aim of generating evidence to inform climate-sensitive livelihood support and urban planning.

1.2 Research Objective

To determine the effects of climate change on COVID-19 recovery among households in informal settlements of Kakamega Municipality, Kenya.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Vulnerability and Adaptation Theory

This study was guided by Vulnerability and Adaptation Theory, which explains how exposure to environmental hazards, household sensitivity and adaptive capacity influence the effects of climate change (Smit & Wandel, 2006). Exposure refers to the extent to which households experience climate-related conditions such as changing rainfall patterns, rising temperatures and flooding. Sensitivity describes how severely these conditions affect household livelihoods, health and living conditions, while adaptive capacity refers to the resources and ability available to households to anticipate, respond to and manage such changes.

The theory is relevant because households recovering from COVID-19 may have limited financial resources, unstable employment and inadequate infrastructure to respond effectively to changing climatic conditions. For instance, households experiencing reduced income may struggle to repair flood-damaged houses, improve drainage or maintain

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their livelihoods during periods of unfavourable weather. Their ability to recover may therefore depend partly on their exposure to climate-related conditions and the resources available to cope with them.

In this study, rainfall and temperature variability represented the independent variables, while economic recovery, health recovery and social well-being represented the dependent variables. The theory provided a framework for examining how climate-related conditions, together with household vulnerability and adaptive capacity, relate to recovery from COVID-19 in informal settlements. It also helped explain why households living in similar climatic conditions may experience different recovery outcomes depending on their socio-economic circumstances and access to support.

2.2 Empirical Review

Previous studies have examined climate change and household livelihoods in Kenya. Saalu et al. (2020) investigated the effects of climate change on forest-dependent communities near Kakamega Forest, while Chelangat and Mulinya (2023) examined climate change and seasonal agricultural drought in Kakamega South Sub-County. These studies demonstrate the relevance of climate variability to local livelihoods. However, their focus on forest-dependent communities and agricultural drought leaves limited evidence on climate change and household recovery in urban informal settlements.

Research on COVID-19 has also established its effects on vulnerable households. Shupler et al. (2021) examined household energy and food security in a Kenyan informal settlement, while Solymári et al. (2022) investigated the livelihood effects of the pandemic among Kenyan slum dwellers. Tompsett et al. (2021) further examined changes in household income during the pandemic. Collectively, these studies demonstrate the economic and social difficulties experienced by informal-settlement households, but they do not directly establish how changing climatic conditions relate to subsequent recovery.

The IPCC (2022) highlights the importance of considering climate hazards alongside existing social and economic vulnerabilities. Similarly, Smit and Wandel (2006) emphasise the role of adaptive capacity in determining how households respond to environmental changes. However, limited empirical evidence integrates these perspectives to examine climate variability and post-COVID-19 recovery in secondary urban centres. This study addresses this contextual and empirical gap by examining rainfall and temperature changes in relation to economic recovery, health recovery and social well-being among households in Masingo, Kambi Somali and Makaburini informal settlements in Kakamega Municipality.

III. METHODOLOGY

3.1 Study Area

The study was conducted in Masingo, Kambi Somali and Makaburini informal settlements in Kakamega Municipality, Kakamega County, western Kenya. The settlements are characterised by high population density, inadequate housing and drainage, limited basic services and dependence on informal economic activities. Kakamega experiences a humid tropical climate, while poorly drained areas within the study settlements increase household exposure to flooding and related environmental challenges. These geographical and socio-economic conditions made the settlements suitable for examining the relationship between climate variability and household recovery following COVID-19.

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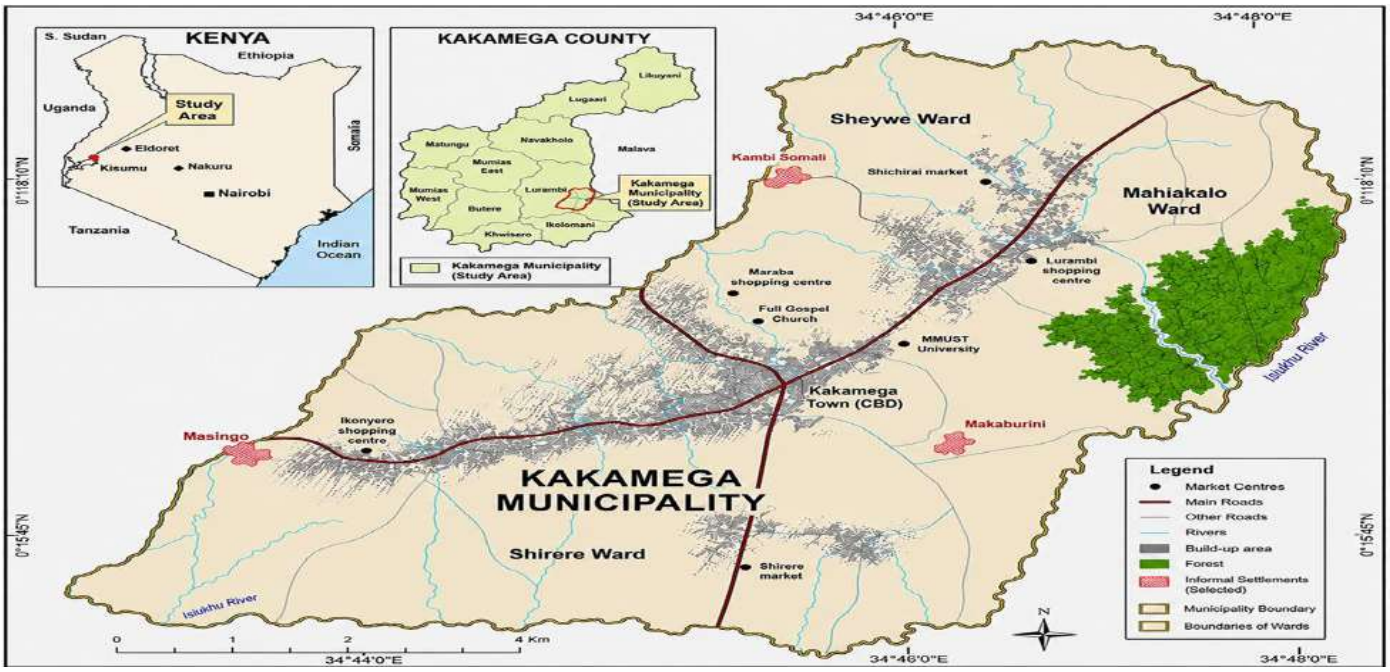


Figure 1

Location of the study area and selected informal settlements in Kakamega Municipality. Source: Researcher, 2026.

3.2 Research Design

The study adopted a convergent cross-sectional mixed-methods design. Quantitative data were collected using structured household questionnaires, while qualitative data were obtained through key informant interviews (KIIs), focus group discussions (FGDs) and field observations. Secondary meteorological records from the Kenya Meteorological Department (KMD) were used to analyse rainfall and temperature trends from 1985 to 2024. The design enabled the study to examine household experiences of climate variability and COVID-19 recovery while using qualitative evidence to provide further explanations of the observed conditions. Quantitative and qualitative findings were compared and integrated during interpretation to strengthen the understanding of climate-related challenges affecting households in the selected informal settlements.

3.3 Target Population

The target population comprised households residing in Masingo, Kambi Somali and Makaburini informal settlements in Kakamega Municipality, Kenya. Household heads or adult household representatives provided information on climate-related experiences and recovery from COVID-19. The qualitative component included key informants from relevant community and institutional groups who provided additional information on climate-related challenges and household recovery.

3.4 Sampling and Sample Size

The three informal settlements were purposively selected because of their informal settlement characteristics and exposure to climate-related challenges. Households were selected systematically within each settlement, while 12 key informants were purposively selected based on their relevant knowledge of climate change, household livelihoods and COVID-19 recovery. The household sample size was determined using Cochran's (1977) formula for estimating a population proportion:

$$n = \frac{Z^2 p(1-p)}{e^2}$$

Where:

n = required initial sample size
Z = standard normal value at the selected confidence level (1.96 for 95%)
P = assumed population proportion (0.5)
e = margin of error (0.05)

Therefore:

$$N = \frac{(1.96)^2(0.5)(1-0.5)}{(0.05)^2}$$

$$=384$$

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The calculated sample was 384 households. Accordingly, 384 households were targeted for the survey. The sample was allocated across the three settlements according to their estimated relative household distribution, informed by preliminary field mapping and consultations with community leaders, as shown in Table 1.

Table 1
Distribution of sampled households by informal settlement

No.	Informal Settlement	Ward	Estimated Share (%)	Calculated Sample	Final Sample
1	Kambi Somali	Shieywe	30	115.2	**115**
2	Makaburini	Mahiakalo	20	76.8	**77**
3	Masingo	Shirere	50	192.0	**192**
Total			**100**	**384.0**	**384**

Of the 384 questionnaires administered, 372 were fully completed and analysed, while 12 incomplete questionnaires were excluded, giving a response rate of 96.9%.

3.4 Data Collection

Data were collected using structured household questionnaires, KIIs, FGDs, field observation and secondary meteorological records. The household questionnaire collected information on household characteristics, perceived changes in rainfall and temperature, flooding, environmental conditions, livelihood disruption, employment and income recovery, health and household well-being. Twelve KIIs and FGDs provided qualitative information on climate-related household experiences, COVID-19 recovery and available institutional and community support. Field observations were undertaken in the three settlements to document visible conditions, particularly drainage, stagnant water, housing and other environmental features relevant to climate-related exposure. Secondary meteorological data covering 1985–2024 were obtained from the Kenya Meteorological Department and used to examine rainfall and temperature trends. These records provided an objective basis for comparison with household perceptions of climate variability.

3.5 Data Analysis

Quantitative data from the 372 completed questionnaires were analysed using SPSS Version 27. Descriptive statistics were used to summarise household, climate and recovery characteristics. Linear regression assessed rainfall and temperature trends for 1985–2024, while chi-square and binary logistic regression examined associations between selected climate conditions and household recovery. Results were reported using percentages, crude odds ratios, 95% confidence intervals and *p*-values, with significance set at $p < 0.05$. Qualitative data from interviews, FGDs and observations were analysed thematically and integrated with the quantitative findings.

3.6 Ethical Considerations

Ethical approval was obtained from the relevant institutional structures at Masinde Muliro University of Science and Technology (MMUST), and research authorization was obtained from the National Commission for Science, Technology and Innovation (NACOSTI) and relevant local authorities before data collection. Informed consent was obtained from all participants, whose participation was voluntary and who were free to withdraw at any time without penalty. Confidentiality and anonymity were maintained by excluding personal identifiers from research records. Data were stored securely and used strictly for academic purposes, while participants' privacy, dignity and welfare were respected throughout the study.

IV. FINDINGS & DISCUSSION

4.1 Response Rate

The study targeted 384 households across Masingo, Kambi Somali and Makaburini informal settlements in Kakamega Municipality. Of the questionnaires administered, 372 were completed and analysed, giving a response rate of 96.9%. The remaining 12 questionnaires were incomplete and were excluded from the analysis. This provided a strong basis for examining household experiences of climate change and recovery following the COVID-19 pandemic.

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Table 2
Household Questionnaire Response Rate

Category	Number
Questionnaires administered	384
Questionnaires completed and analysed	372
Incomplete questionnaires	12
Response rate (%)	96.9

4.2 Climate Change Trends in Kakamega Municipality

4.2.1 Rainfall Variability and Trends

Analysis of Kenya Meteorological Department (KMD) data for 1985–2024 revealed a statistically significant increasing trend in annual rainfall in Kakamega Municipality. Annual rainfall increased by approximately 13.85 mm per year. The regression model was statistically significant, $F(1, 38) = 56.82$, $p < 0.001$, and explained 59.9% of the variation in annual rainfall ($R^2 = 0.599$). The results are presented in Table 2.

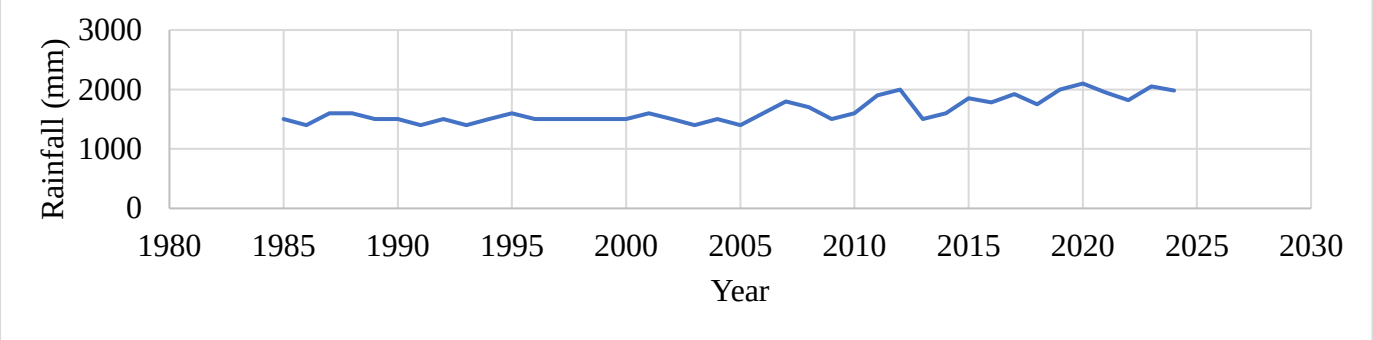


Figure 1
Annual rainfall trend in Kakamega Municipality, 1985–2024Source: Kenya Meteorological Department (KMD) secondary data.

The increasing rainfall trend is consistent with the wider concern about changing precipitation patterns discussed by the Intergovernmental Panel on Climate Change (IPCC, 2022). It also agrees with the regional evidence reported by Saalu et al. (2020), which identified changes in precipitation patterns in the Kakamega region. However, increasing annual rainfall does not necessarily mean that rainfall is evenly distributed throughout the year. Changes in timing and intensity can create uncertainty for households and increase exposure to flooding.

The household survey supported the meteorological findings. All 372 respondents reported changes in rainfall patterns; 55.9% described rainfall as unpredictable, while 44.1% reported increased rainfall. Regarding flooding, 47.3% experienced it sometimes, 36.9% often and 15.8% very often. July and August were each identified by 49.5% of respondents as months when flooding was most common.

Table 3
Household Perceptions of Rainfall Variability and Flooding

Indicator	Percentage (%)
Reported changes in rainfall	100.0
Unpredictable rainfall	55.9
Increased rainfall	44.1
Flooding sometimes	47.3
Flooding often	36.9
Flooding very often	15.8
July identified as a common flooding month	49.5
August identified as a common flooding month	49.5

These findings are important because the study settlements experience inadequate drainage and infrastructure constraints. As discussed by Douglas et al. (2008) and the IPCC (2022), climate-related hazards can have greater consequences in urban settlements where drainage, housing and essential services are inadequate. In Kakamega, flooding may restrict movement, interrupt outdoor work and trading, and make access to workplaces and customers difficult. These disruptions are particularly relevant to households dependent on daily earnings. From the perspective of

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Vulnerability and Adaptation Theory, rainfall exposure interacts with settlement conditions and household resources to influence vulnerability. The findings therefore provide a geographical basis for examining whether climate-related conditions are associated with household recovery following COVID-19.

4.2.2 Temperature Variability and Trends

KMD data for 1985–2024 also showed a statistically significant increasing temperature trend. Mean annual temperature rose from 26.67°C in 1985 to 26.97°C in 2024, representing an estimated increase of approximately 0.008°C per year. The regression model was statistically significant, $F(1, 38) = 3684.25$, $p < 0.001$, with $R^2 = 0.990$.

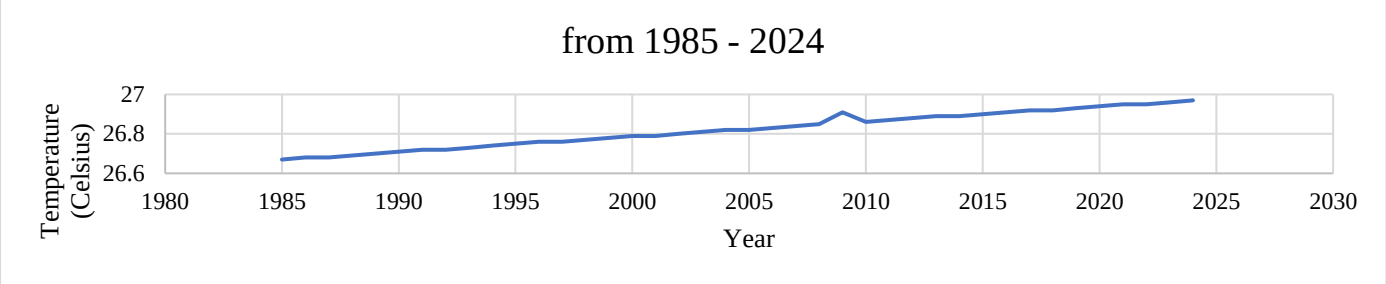


Figure 2

Annual temperature trend in Kakamega Municipality, 1985–2024
Source: Kenya Meteorological Department (KMD) secondary data.

Household perceptions reflected the recorded warming trend. Almost all respondents (99.1%) reported increased heat. Extreme heat was experienced sometimes by 52.7%, often by 34.2% and very often by 12.2%. December was identified as the hottest month by 52.7%, followed by January at 46.4%.

The agreement between the meteorological record and household perceptions suggests that rising temperatures were both measurable and locally experienced. The IPCC (2022) identifies low-income urban populations as particularly vulnerable to extreme heat because of inadequate housing, limited infrastructure and restricted access to essential services. In the study settlements, heat may affect households whose livelihoods involve casual labour, street vending, small-scale trading and other activities requiring outdoor work. It may also increase demand for water and affect comfort within poorly ventilated housing. These findings establish the local context for assessing how climate conditions relate to household economic, health and social recovery.

4.3 Effects of Climate Change on Covid-19 Recovery among Households

4.3.1 Effects of Climate Change on Household Economic Recovery

The findings indicate that household economic recovery following the COVID-19 pandemic remained incomplete. Of the 372 households surveyed, 80.9% reported partial income recovery, while 19.1% reported no recovery. No respondent reported full income recovery. Employment conditions further illustrated the economic difficulties facing households: 50.8% were unemployed, 40.3% depended on casual work and 8.9% were self-employed. In addition, 83.1% reported difficulty meeting basic household needs, while 16.9% could not meet them at all. These findings demonstrate that the effects of the pandemic continued to influence household livelihoods and living conditions.

Table 4

Indicators of Household COVID-19 Recovery

Indicator	Category	Percentage (%)
Income recovery	Partial recovery	80.9
Income recovery	No recovery	19.1
Employment status	Unemployed	50.8
Employment status	Casual work	40.3
Employment status	Self-employed	8.9
Meeting basic needs	With difficulty	83.1
Meeting basic needs	Not at all	16.9

These findings reflect the economic vulnerability of households in the study settlements. All surveyed households reported monthly incomes below KSh 5,000, while many depended on informal activities that offered limited income security. Such livelihoods can be disrupted by illness, movement restrictions, reduced customer demand and environmental hazards. The findings are consistent with Tompsett et al. (2021), who documented substantial income

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reductions among households in Kibera during the COVID-19 period, and Shupler et al. (2021), who reported income decline and food insecurity in a Nairobi informal settlement.

The present study extends this evidence to Kakamega Municipality by examining household economic recovery alongside climate-related pressures. The fact that 80.9% of households reported only partial income recovery, while most continued to struggle to meet basic needs, indicates that some improvement in income did not necessarily restore household economic security. In informal settlements where residents depend on casual employment and small businesses, rainfall-related disruptions may interfere with outdoor work, transport and access to customers. Increased heat may also create difficulties for residents engaged in physically demanding activities. These conditions may add to the challenges experienced by households already operating with limited financial resources.

The relationship between climate change and economic recovery was further examined using binary logistic regression and chi-square tests. The results presented in Table 6 show a statistically significant association between perceived changes in rainfall and incomplete income recovery (COR = 3.353, $p < 0.001$). This indicates that the rainfall-change variable was associated with incomplete household income recovery in the fitted model. The relationship is relevant to the livelihoods of households that depend on daily earnings and informal economic activities, which may be affected by changes in rainfall conditions. However, the precise direction and magnitude of the association should be interpreted according to the outcome coding and reference category used in the original statistical analysis.

The comparison between increased and unpredictable rainfall was not statistically significant (COR = 1.051; 95% CI: 0.561–1.972; $p = 0.876$). Similarly, flooding frequency was not significantly associated with income recovery ($\chi^2 = 0.854$, $p = 0.653$), the ability to meet basic needs ($\chi^2 = 0.282$, $p = 0.869$) or food availability ($\chi^2 = 0.134$, $p = 0.935$). Extreme heat frequency was also not significantly associated with income recovery ($\chi^2 = 4.102$, $p = 0.251$), the ability to meet basic needs ($\chi^2 = 3.020$, $p = 0.389$) or food availability ($\chi^2 = 0.477$, $p = 0.924$).

Table 5

Association Between Climate-Related Conditions and Economic Recovery

Climate indicator	Recovery indicator	Test result	p-value	Interpretation
Perceived change in rainfall	Incomplete income recovery	COR = 3.353	<0.001	Statistically significant
More rainfall versus unpredictable rainfall	Incomplete income recovery	COR = 1.051; 95% CI: 0.561–1.972	0.876	Not significant
Flooding frequency	Income recovery	$\chi^2 = 0.854$; df = 2	0.653	Not significant
Flooding frequency	Ability to meet basic needs	$\chi^2 = 0.282$; df = 2	0.869	Not significant
Flooding frequency	Food availability	$\chi^2 = 0.134$; df = 2	0.935	Not significant
Extreme heat frequency	Income recovery	$\chi^2 = 4.102$; df = 3	0.251	Not significant
Extreme heat frequency	Ability to meet basic needs	$\chi^2 = 3.020$; df = 3	0.389	Not significant
Extreme heat frequency	Food availability	$\chi^2 = 0.477$; df = 3	0.924	Not significant

The non-significant findings for flooding and extreme heat do not establish that these conditions had no relevance to household economic recovery. Rather, they indicate that the statistical tests did not identify significant relationships with the selected economic indicators. The widespread economic difficulties reported by households, including low monthly incomes and unstable employment, may have contributed to incomplete recovery across the settlements. This demonstrates that household economic recovery was influenced by broader livelihood conditions as well as environmental circumstances.

From the perspective of Vulnerability and Adaptation Theory, these findings illustrate how household exposure to environmental conditions interacts with sensitivity and the capacity to respond (Smit & Wandel, 2006). Households with limited financial resources and insecure employment may have fewer options for managing interruptions to their livelihoods. The findings demonstrate that economic recovery remained incomplete and that perceived changes in rainfall were significantly associated with incomplete income recovery

4.3.2 Effects of Climate Change on Household Health Recovery

The findings indicate that households continued to experience environmental conditions with potential implications for health recovery following the COVID-19 pandemic. All respondents (100%) reported stagnant water around their homes during rainy periods, and all reported the presence of mosquitoes. In addition, 99.1% reported increased heat. Drainage conditions were also inadequate, with 36.9% of respondents reporting poor drainage, 23.9% faulty drainage, 19.8% clogged drainage and 19.4% blocked drainage. These findings demonstrate widespread exposure to environmental conditions that may affect the quality of household living environments.

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Table 6

Climate-Related Environmental Conditions

Environmental condition	Percentage (%)
Stagnant water during rainy periods	100.0
Mosquito presence	100.0
Poor drainage	36.9
Faulty drainage	23.9
Clogged drainage	19.8
Blocked drainage	19.4
Increased heat	99.1

The presence of stagnant water and mosquitoes across all surveyed households, together with inadequate drainage, points to continuing environmental health concerns in the study settlements. During rainy periods, inadequate drainage may contribute to water accumulation around homes and along access routes. Such conditions may interfere with daily activities and make it difficult to maintain clean and safe residential surroundings. The findings are consistent with Douglas et al. (2008), who highlighted the vulnerability of poor urban communities to flooding and inadequate infrastructure. The IPCC (2022) also identifies climate-related environmental conditions as important considerations for human health and well-being.

The findings further showed that 57.5% of respondents rated their health status as poor, 30.9% as fair and 11.6% as good. In addition, 12.6% reported experiencing long-term illness after COVID-19. These results indicate that some households continued to experience health difficulties during the recovery period. Increased heat may also create additional challenges for residents engaged in outdoor and physically demanding activities, while inadequate drainage and water accumulation raise concerns about the quality of the immediate residential environment.

The statistical analysis of drainage conditions and reported health status is presented in Table 7. Clogged drainage, compared with blocked drainage, was statistically associated with reported health status (COR = 0.340; 95% CI: 0.128–0.906; p = 0.031). However, the association between faulty drainage and blocked drainage was not statistically significant (COR = 0.497; 95% CI: 0.207–1.192; p = 0.117). Similarly, poor drainage compared with blocked drainage was not statistically significant (COR = 1.083; 95% CI: 0.510–2.300; p = 0.835).

Table 7

Association Between Drainage Conditions and Reported Health Status

Environmental condition	Comparison	COR (95% CI)	p-value
Clogged drainage	Clogged versus blocked drainage	0.340 (0.128–0.906)	0.031
Faulty drainage	Faulty versus blocked drainage	0.497 (0.207–1.192)	0.117
Poor drainage	Poor versus blocked drainage	1.083 (0.510–2.300)	0.835

The findings are relevant to the living conditions reported by households and are consistent with concerns about inadequate sanitation, drainage and environmental services in informal settlements. Okari (2019), in a study of Kaburini Slum in Kakamega Town, also examined the public health implications of housing, water and sanitation conditions. The present findings similarly highlight the importance of environmental conditions when examining household health and recovery in informal settlements.

From the perspective of Vulnerability and Adaptation Theory, inadequate drainage and exposure to environmental conditions may increase household sensitivity to climate-related risks, particularly where residents have limited resources to improve their living environments (Smit & Wandel, 2006). Nevertheless, the findings should be interpreted as associations and reported environmental conditions rather than evidence that drainage problems, stagnant water or mosquitoes directly caused the health conditions reported by respondents.

In general, the findings demonstrate that household health recovery took place within an environment characterised by inadequate drainage, widespread stagnant water and increased heat. These conditions highlight the importance of improving drainage and environmental services as part of efforts to support household health and recovery.

4.3.3 Effects of Climate Change on Household Social Well-being

Social well-being was examined in relation to households' ability to meet basic needs and resume social and daily activities during the post-COVID-19 recovery period. The findings presented in Table 4 show that 83.1% of households experienced difficulty meeting their basic needs, while 16.9% reported being unable to meet them at all. These results indicate that the effects of the pandemic extended beyond income loss to the ability of households to

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maintain their everyday living conditions. Limited household income and unstable employment may have constrained access to essential needs and affected the restoration of normal household activities.

The environmental conditions reported in the study also provide an important context for understanding social well-being. All respondents reported stagnant water around their homes during rainy periods, while 99.1% reported increased heat. In settlements characterised by inadequate drainage, water accumulation may interfere with movement, access to services and routine household activities. Increased temperatures may also affect comfort and participation in outdoor activities. Douglas et al. (2008) highlighted the vulnerability of poor urban communities to flooding and inadequate infrastructure, while the IPCC (2022) recognises that climate-related hazards can affect human well-being, particularly among populations with limited capacity to respond.

The relationship between extreme heat and the recovery of social activities was examined using binary logistic regression. As shown in Table 8, the frequency of extreme heat was not significantly associated with the resumption of social and daily activities. Compared with respondents who experienced extreme heat very often, those reporting heat sometimes had a COR of 1.288 (95% CI: 0.489–3.390; p = 0.608), while those reporting heat often had a COR of 1.696 (95% CI: 0.595–4.835; p = 0.323). Both results were statistically insignificant.

Table 8

Association Between Extreme Heat and Social Activity Recovery

Extreme heat frequency	Comparison	COR (95% CI)	p-value
Sometimes	Sometimes versus very often	1.288 (0.489–3.390)	0.608
Often	Often versus very often	1.696 (0.595–4.835)	0.323

The non-significant results indicate that the reported frequency of extreme heat did not statistically distinguish households according to social activity recovery in this analysis. However, this does not mean that increased heat was unimportant to household life. Since 99.1% of respondents reported increased heat, exposure was widespread across the study population. Social recovery may also depend on other circumstances, including household income, health conditions, employment and available social support.

The findings highlight the relationship between environmental conditions and the wider circumstances that shape social well-being. The difficulty experienced by most households in meeting basic needs suggests that recovery involved more than restoring income alone. It also involved the ability to maintain everyday household activities and living conditions. In line with Vulnerability and Adaptation Theory, household recovery is shaped by the interaction between environmental exposure, sensitivity and the capacity to respond (Smit & Wandel, 2006).

Overall, the findings indicate that households in the three informal settlements continued to experience challenges affecting economic recovery, health and social well-being. Although some statistical associations were significant, others were not. The findings therefore demonstrate the importance of considering climate-related environmental conditions alongside household economic and social circumstances when examining post-COVID-19 recovery.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The study concludes that climate change is an important consideration in understanding household recovery from the COVID-19 pandemic in the informal settlements of Kakamega Municipality. The observed increases in rainfall and temperature, alongside frequent flooding, poor drainage and stagnant water, highlight the environmental challenges within which households continue to pursue economic, health and social recovery. The findings indicate that recovery has remained incomplete, particularly in the economic dimension, where 80.9% of households reported only partial income recovery, while 19.1% had not recovered their income. The significant association between perceived rainfall changes and incomplete income recovery further suggests that changing rainfall conditions may compound the livelihood difficulties experienced by already economically vulnerable households.

The study also establishes that household health recovery takes place within an environment characterised by inadequate drainage, stagnant water and widespread mosquito exposure. These conditions point to the importance of the local physical environment in shaping household health and well-being after the pandemic. Although not all the statistical relationships examined were significant, the findings demonstrate that climate-related environmental conditions should not be overlooked when assessing recovery in informal settlements. From the perspective of Vulnerability and Adaptation Theory, the findings underscore how exposure to changing climatic conditions, combined with limited household resources and inadequate infrastructure, can constrain the capacity of households to recover.

The study therefore concludes that post-COVID-19 recovery in informal settlements should be understood as a process shaped not only by the effects of the pandemic but also by prevailing climatic, environmental and socio-economic conditions. Sustainable household recovery therefore requires attention to climate-sensitive livelihoods,

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improved drainage and environmental sanitation, and accessible health and social support. Integrating climate change considerations into local recovery planning is essential to addressing the interconnected challenges facing households in Kakamega Municipality.

5.2 Recommendations

The Kakamega County Government should strengthen climate-informed interventions in Masingo, Kambi Somali and Makaburini by prioritising the improvement and regular maintenance of drainage infrastructure, proper solid-waste management and environmental sanitation. Particular attention should be given to clearing blocked drainage channels, improving water flow in flood-prone areas and promoting appropriate waste disposal to minimise water accumulation and unhealthy environmental conditions. The County Government should also strengthen early-warning and public awareness systems to enable households to prepare for periods of heavy rainfall, flooding and extreme heat. These interventions should be supported by community-based environmental monitoring and regular public sensitisation on flood preparedness, sanitation and the prevention of mosquito breeding.

In view of the high proportion of households that had not fully recovered their income following the COVID-19 pandemic, the County Government, in collaboration with relevant national government agencies, development partners and community organisations, should expand livelihood support programmes targeting economically vulnerable households. Such programmes could include access to small-business recovery support, vocational training, affordable credit and initiatives that promote alternative sources of income. This would help households reduce their dependence on climate-sensitive livelihood activities and improve their ability to manage future economic disruptions. Furthermore, the County Government should strengthen access to affordable primary healthcare, environmental health services and community health education, particularly in areas affected by stagnant water, poor drainage and increased mosquito exposure.

Finally, climate change considerations should be integrated into local urban planning and household recovery programmes to ensure that infrastructure development, public health interventions and livelihood support address the interconnected environmental, economic and social challenges experienced in informal settlements. Collaboration between the County Government, public health departments, community leaders and residents is essential in identifying priority needs and ensuring that interventions respond to the specific conditions of the three settlements. These measures would contribute to improved living conditions, reduced climate-related disruptions and more sustainable household recovery from future socio-economic shocks.

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