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**UNIVERSITY OF GHANA  
COLLEGE OF HUMANITIES**

**SOCIO-SPATIAL PATTERNS OF FLOOD OCCURRENCE AND ADAPTATION IN  
THE TAMALE METROPOLITAN AREA (TaMA), GHANA**

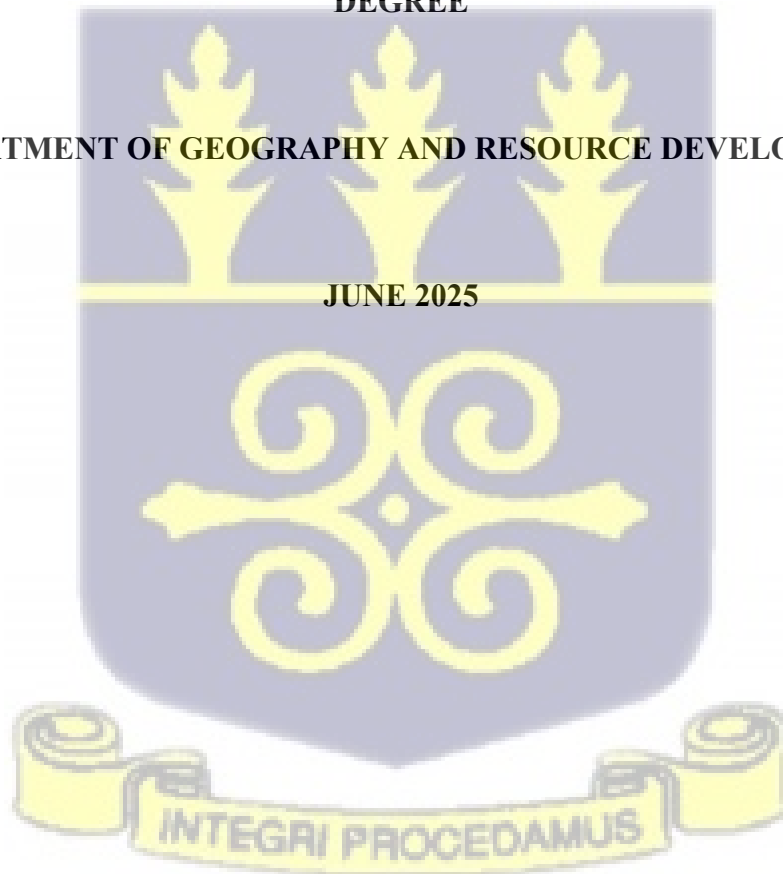
**BY**

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON, IN  
PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF  
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DEGREE**

**DEPARTMENT OF GEOGRAPHY AND RESOURCE DEVELOPMENT**

**JUNE 2025**



**DECLARATION**

**DECLARATION**

I certify that this thesis is original and the result of my personal study. Aside from acknowledged references to existing literature, the thesis has not been submitted, in part or in whole, for any degree at this or any other institution.

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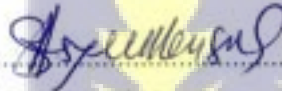


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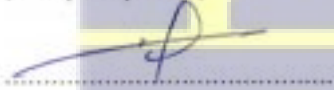
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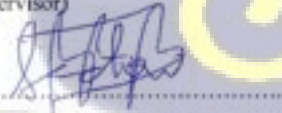
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## ABSTRACT

This study examines the socio-spatial patterns of flood occurrence and adaptation in the Tamale Metropolitan Area (TaMA) Ghana, focusing on differences among Kalariga (high-income), Nalung (medium-income), and Koblimahagu (low-income). Guided by Urban Political Ecology and Urban Resilience Theory, the research explores how income, spatial location, and governance shape flood exposure, institutional support, and community adaptation. Using a cross-sectional, exploratory sequential mixed-methods design, the study integrates geospatial analysis, a household survey of 281 respondents, and qualitative interviews and focus group discussions. The findings show that flooding is frequent across TaMA but disproportionately affects low-income communities due to rapid urbanisation, inadequate drainage, and weak enforcement of land-use regulations. Institutional adaptation is unevenly distributed, with high-income areas receiving more timely support, while fragmented coordination and overlapping mandates limit effective flood management. Communities demonstrate varied coping practices: high-income households employ preventive structural measures, whereas low-income groups rely on reactive, low-cost strategies that do little to reduce long-term vulnerability. The study recommends strengthening drainage, green infrastructure, and waste management through community–city partnerships; enhancing coordination and data sharing via an open Flood Information Hub; and empowering women and youth groups as key actors in preparedness and awareness. It further proposes the establishment of university-led Flood and Waste Innovation Labs to support low-cost technological solutions and evidence-based policy. Empirically, the research deepens understanding of how socioeconomic, climatic, and human drivers interact to shape spatial vulnerability. Theoretically, it demonstrates the value of integrating social and spatial analysis for equitable, resilience-oriented urban flood governance aligned with SDG 11 and SDG 13.

## DEDICATION

To my beloved husband, Felix Mumuni Mahama, who has been a constant pillar of strength and support throughout this journey. Words cannot fully convey my gratitude for his sacrifices, patience, and unwavering belief in me. His encouragement and love have been instrumental in bringing this work to fruition, and I am eternally thankful.

This work is also dedicated to the communities in which this research was conducted. I have formed a deep and lasting connection to these communities, and it is my sincere hope that this research contributes meaningfully to efforts aimed at reducing their vulnerability to flood risk. May this work serve as a step toward greater resilience, equity, and transformation.



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May God richly bless each one of you. This achievement is as much yours as it is mine.

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## LIST OF ABBREVIATIONS

**AI** – Artificial Intelligence

**BBC** – British Broadcasting Corporation

**CB-FRM** – Community-Based Flood Risk Management

**CBO** – Community-Based Organization

**COVID-19** – Coronavirus Disease 2019

**CRED** – Centre for Research on the Epidemiology of Disasters

**CSO** – Civil Society Organization

**DEM** – Digital Elevation Model

**EPA** – Environmental Protection Agency

**EWS** – Early Warning System

**FAO** – Food and Agriculture Organization (of the United Nations)

**FEMA** – Federal Emergency Management Agency

**FEWS** – Flood Early Warning System

**FGDs** – Focus Group Discussions

**FSD** – Forestry Services Division

**GCF** – Green Climate Fund

**GIS** – Geographic Information Systems

**GLOF** – Glacial Lake Outburst Flood

**GMet** – Ghana Meteorological Agency

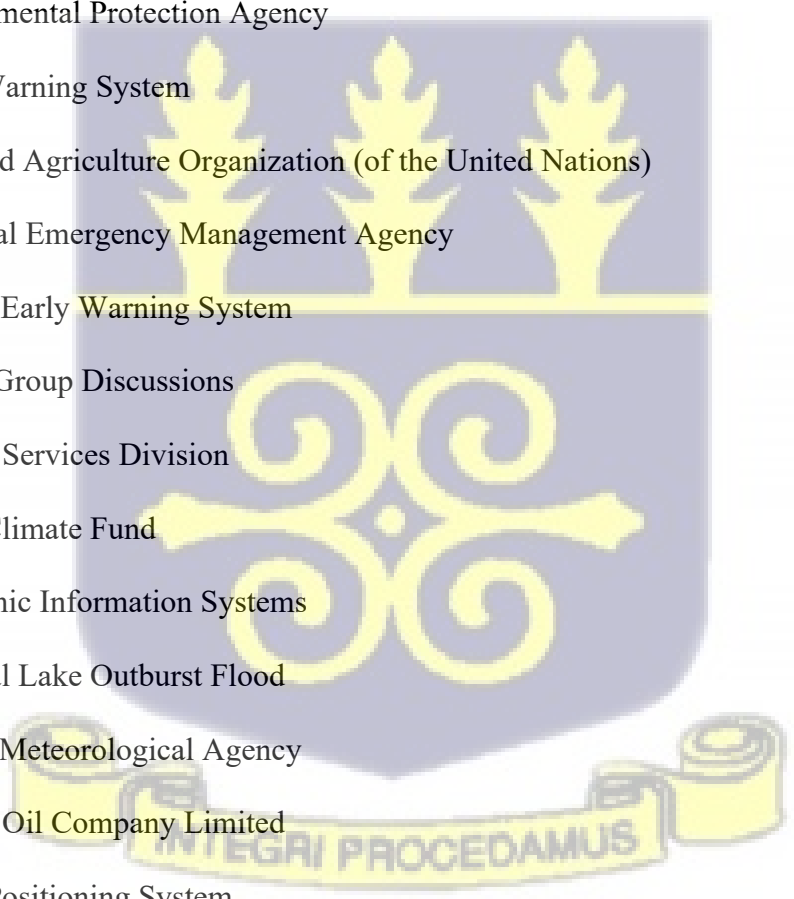
**GOIL** – Ghana Oil Company Limited

**GPS** – Global Positioning System

**GSS** – Ghana Statistical Service

**GTMA** – Greater Tamale Metropolitan Area

**GWCL** – Ghana Water Company Limited



**HSD** – Hydrological Services Division

**IBM** – International Business Machines

**IFRC** – International Federation of Red Cross and Red Crescent Societies

**IPCC** – Intergovernmental Panel on Climate Change

**KII** – Key Informant Interview

**LULC** – Land Use and Land Cover

**MOSE** – *Modulo Sperimentale Elettromeccanico* (Venice flood barrier system)

**NADMO** – National Disaster Management Organization

**NDA** – Northern Development Authority

**NEMA** – National Emergency Management Agency (Nigeria)

**NFIP** – National Flood Insurance Program

**NGO** – Non-Governmental Organization

**NOAA** – National Oceanic and Atmospheric Administration

**NSSL** – National Severe Storms Laboratory

**NYC** – New York City

**ORR** – Office of Recovery and Resiliency

**PHC** – Population and Housing Census

**RCC** – Regional Coordinating Council

**SDGs** – Sustainable Development Goals

**SMS** – Short Message Service

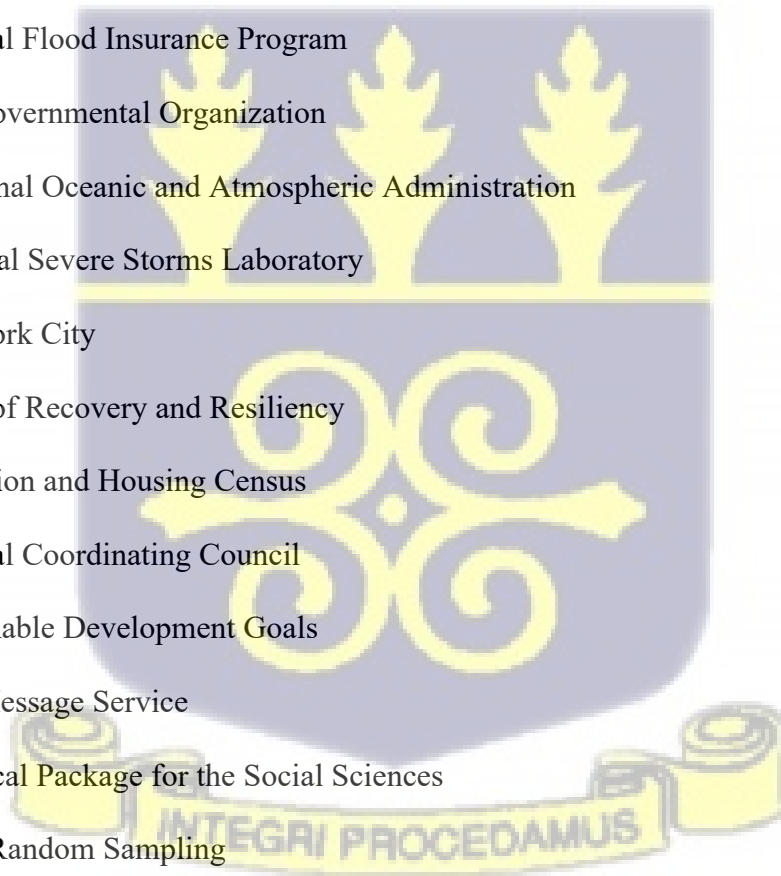
**SPSS** – Statistical Package for the Social Sciences

**SRS** – Simple Random Sampling

**TAMA** – Tamale Metropolitan Area

**TaMA** – Tamale Metropolitan Assembly

**U.S.** – United States



**UGI** – Urban Green Infrastructure

**UNDRR** – United Nations Office for Disaster Risk Reduction

**UNISDR** – United Nations International Strategy for Disaster Reduction

**USA** – United States of America

**USDOT** – United States Department of Transportation

**VFDM** – Volta Flood and Drought Management

**WASH** – Water, Sanitation, and Hygiene

**WMO** – World Meteorological Organization

**WSUD** – Water Sensitive Urban Design



## CHAPTER 1

### INTRODUCTION

#### 1.1 Background of the Study

As a result of changing climatic conditions, flooding, the most common and destructive natural disaster in the world, is predicted to become more severe, extensive, and frequent (Mirza, 2011; Orderud et al., 2022; Parvin et al., 2016; UNDRR & CRED, 2020). In metropolitan regions where population increases, rapid land use changes, and poor planning are common, floods have caused significant social, economic, and infrastructure damage worldwide (Asumadu-Sarkodie et al., 2015; Darabi et al., 2019; Jamali et al., 2018). With 83% of all disasters worldwide linked to extreme weather, climate and weather-related disasters have increased by roughly 35% in the last ten years, impacting 1.7 billion people and killing over 410,000 people (IFRC, 2021). Over 2,000 significant flood-related disasters have occurred in Africa in the past 30 years, making it especially vulnerable (Zeufack et al., 2021). The scale of recent flood disasters in West Africa is evident in the 2022 floods in Nigeria, which resulted in more than 600 deaths and the displacement of 1.4 million people (Maclean, 2022; Maishman, 2022). Likewise, Ivory Coast experienced its deadliest flooding event in June 2022, killing 15 people and affecting almost 12,000 individuals (Davies, 2022a, 2023). These are noteworthy occurrences in Africa. With increased urbanisation and little ability for adaptation, these occurrences underscore the growing challenges developing countries confront in addressing climate hazards, especially for low-income urban dwellers. Flooding is a recurrent hazard in Ghana, driven by the interaction of extreme rainfall, inadequate infrastructure, and longstanding urban governance challenges. The 2015 Accra floods exemplify these dynamics: heavy rainfall overwhelmed the city's poorly maintained drainage network and interacted with

unregulated urban growth. The situation escalated when a fuel station explosion during the floods killed over 150 people, revealing severe gaps in emergency preparedness and risk management (BBC News, 2015; Boakye-Yiadom, 2015). Similarly, in October 2022, intense rainfall led to the spillage of the Weija dam, inundating communities in the Greater Accra Region. Nearly 1,000 homes were submerged and more than 1,500 residents displaced, highlighting the vulnerability of critical water management systems to hydrological stress (Davies, 2022b). These events underscore how flood disasters in Ghana stem not only from natural processes but from structural deficiencies in planning, infrastructure, and urban governance. Flood risk is particularly acute for urban poor populations residing in informal settlements, which are often located in flood-prone areas such as wetlands, low-lying zones, and drainage corridors. Limited access to infrastructure, insecure land tenure, and exclusion from formal planning processes compound their vulnerability (Bangalore et al., 2017; Douglas et al., 2008; Greenpeace Africa, 2022; Kufour Owusu-Ansah et al., 2019). Consequently, flooding in these communities triggers cascading impacts, including loss of shelter, disruption of livelihoods, constrained mobility, and heightened health risks (Aliyu et al., 2023; Fraser et al., 2017; McGranahan et al., 2007).

Tamale faces recurrent pluvial and flash flooding, with impacts unevenly distributed across socio-economic and spatial lines. Low-income neighborhoods often situated in low-lying areas with inadequate drainage bear the greatest risk, reflecting entrenched urban inequalities (Ampofo et al., 2024b, 2025). Rapid urban expansion, encroachment on waterways, and poor enforcement of land-use regulations have intensified flood frequency and exposure, a trend observed across other Ghanaian cities such as Accra and Kumasi (Oteng-Ababio et al., 2024; Sarfo et al., 2024). Recent studies highlight that vulnerable groups lack resources and

institutional support for recovery, while formal responses remain largely reactive, prioritizing emergency relief over proactive planning and long-term adaptation (Agyei-Mensah et al., 2024; Almoradie et al., 2020). Emerging research advocates for hybrid governance and co-production approaches integrating state institutions, traditional authorities, and community actors to strengthen resilience and legitimacy in flood risk management (Agyei-Mensah et al., 2024). These challenges underscore the urgency of anticipatory, inclusive, and well-coordinated flood governance aligned with SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities), and SDG 13 (Climate Action). As socio-spatial inequalities, climate-driven hazards, and weak urban governance intersect to shape resilience outcomes (Asibey et al., 2023), the need for governance approaches that acknowledge and address these structural disparities becomes even more apparent. Consequently, these conditions not only heighten the vulnerability of certain groups but also raise critical questions about equity and justice in flood risk governance and disaster resilience.

## 1.2 Problem Statement

With significant occurrences documented in 2013, 2015, 2017, 2020, and 2021, flooding has increased in frequency in the Tamale Metropolitan Area (TaMA) (Bugri, 2020; MyJoyOnline, 2013, 2015; Osei, 2021). Particularly in vulnerable neighbourhoods like Koblimahagu, Nalung, and Kalariga, these occurrences have negatively impacted livelihoods, caused extensive displacement, and devastated infrastructure. Flooding in Tamale continues to occur and recurs frequently, reflecting both the cumulative effects of inadequate drainage infrastructure, inefficient land use planning, and a lack of institutional coordination, as well as more general hydrological changes linked to climatic variability. The population of the Tamale Metropolitan Area was 374,744 according to the 2021 Population & Housing Census. It is now estimated at

784,420 as at 2025. The population has grown **over** fifteen-fold since 1960, showing a rapid urbanization trend. The sharp increase between 2010 and 2025 reflects Tamale's transformation into a major northern urban hub, driven by migration, service-sector expansion, and city boundary growth. This trend has significant implications for urban planning, flood management, and infrastructure demand. Although flooding has become increasingly frequent in TaMA, existing studies have paid limited attention to the patterns of flood occurrence and their effects on different socio-economic groups. Vulnerability is not homogeneous; rather, it is influenced by socioeconomic disparities, inadequate participatory planning, uneven land use regulation enforcement, and poor governance. Due to their frequent relocation to high-risk locations and lack of access to early warning systems, robust infrastructure, and funding, low-income communities are disproportionately impacted.

While numerous studies in Ghana have mapped flood-prone areas or assessed physical dimensions of vulnerability often relying on GIS, hydrological modelling, and hazard zonation (Dekongmen et al., 2021; Kwang & Matthew Osei, 2017; Nkonu et al., 2023; Owusu et al., 2024; Twumasi & Asomani-Boateng, 2002; Yankson et al., 2017) far fewer have explicitly analysed how social and spatial inequalities shape differential exposure to flood hazards and access to adaptation measures. A small but important body of work, however, demonstrates this gap. For example, Amoako & Inkoom (2018) show how informal urbanisation, tenure insecurity, and infrastructural neglect concentrate flood vulnerability among low-income households in Accra; Aboagye & Owusu-sekyere (2020) illustrates how socio-demographic characteristics influence coping capacity; and Owusu-Ansah et al. (2019) highlight how access to institutional support and social networks shapes differentiated vulnerability in communities around the Weija Dam.

Research in Northern Ghana has largely focused on hydrological modelling and rural vulnerabilities, particularly in the Volta Basin (Armah et al., 2010; Smits et al., 2024; Yeboah et al., 2024), rather than on urban inequality or governance. In contrast, urban flood studies are more prominent in Ghana's major cities particularly southern coastal and forest-zone cities such as Accra and Cape Coast, as well as Kumasi in the middle belt and typically attribute urban flooding to unchecked spatial growth, drainage encroachment, and inadequate infrastructure (Abeka et al., 2020; Amoako & Boamah, 2014; Amoako & Frimpong Boamah, 2020; Kufour Owusu-Ansah et al., 2019; Poku-Boansi et al., 2020). Despite Tamale's rapid urbanisation and its status as northern Ghana's largest and fastest-growing urban centre, comparable studies on the dynamics of urban flooding remain limited. Where Tamale is examined, the focus tends to be on specific aspects of flood management, such as government responses to disaster events and institutional coordination challenges (Agyei-Mensah et al., 2024), water quality impacts following flood episodes (Cobbina et al., 2021), or access to social services and urban infrastructure (Hafiz, 2014). Studies by Amankwaa & Gough (2023) and Ampofo et al. (Ampofo et al. 2024a, 2024b, 2024c, 2025) provide valuable insights into climate-related mobility, livelihoods, and adaptation, yet they do not analyse how flood vulnerability varies geographically among different socio-economic groups or how structural inequalities shape adaptive capacity.

In the Tamale Metropolitan Area, empirical evidence from recent municipal flood assessments and community reports indicates that income levels, housing characteristics, and neighbourhood location influence both the frequency and severity of flooding and the types of support or adaptation strategies available. Current flood adaptation policies tend to be top-

down, with limited incorporation of local knowledge and community practices (Oladokun et al., 2023). As a result, some communities rely on informal or self-organised strategies in the absence of adequate institutional support. This study addresses the urgent need for an interdisciplinary and spatially informed investigation into urban flood vulnerability in Tamale by examining flood risk and adaptation from a socio-spatial perspective that considers power, inequality, and resilience. It specifically explores how socioeconomic factors, geography, and government actions interact to influence flood vulnerability, impacts, and adaptation in three socio-economically diverse neighbourhoods Kalariga (higher-income), Nalung (middle-income), and Koblimahagu (lower-income). The study employs a mixed-methods approach to map flood event distribution, evaluate community-based adaptation strategies, and assess institutional coordination in flood response. The goal is to generate policy-relevant, context-specific insights that support resilient, equitable, and spatially targeted flood adaptation strategies for Tamale's diverse urban population.

### 1.3 Research Objectives

The main objective of this study is to understand the socio-spatial patterns of flood occurrence and adaptation in TaMA, focusing on how it affects different socio-economic groups in flood-prone communities. By exploring these spatial dynamics, the study aims to discern the correlation between flood vulnerability and the socioeconomic status of affected individuals. Specifically, the research aims to achieve the following objectives;

1. To assess the socio-spatial patterns of flood occurrence in TaMA, and how geographic and human factors influence their distribution.
2. To evaluate institutional flood adaptation strategies in TaMA and their effectiveness in addressing socio-spatial inequities.

3. To examine community-based adaptation strategies and the challenges that hinder equitable flood resilience in TaMA.

#### 1.4 Research Questions

The main research question is how do socio-spatial patterns of flood occurrence and adaptation vary across socio economically diverse neighbourhoods in the Tamale Metropolitan Area, and how do these variations influence community vulnerability and resilience? Specifically the research answers the following questions;

1. How do socio-spatial patterns of flood occurrence manifest across communities in TaMA, and how do geographic and human factors shape their distribution?
2. What institutional flood adaptation strategies have been implemented in TaMA?
3. To what extent have these institutional strategies addressed socio-spatial inequities in flood risk?
4. What community-based adaptation strategies are used by communities to cope with flooding in TaMA?
5. What challenges hinder the adoption, implementation, or sustainability of equitable community-based flood adaptation strategies?

#### 1.5 Research Hypotheses

This study is built on the established understanding that flood risk in urban African contexts is shaped not only by biophysical conditions but also by deeply embedded socio-spatial inequalities. Prior research grounded in Urban Political Ecology (UPE) demonstrates that unequal planning systems, infrastructural disparities, and political marginalisation disproportionately expose lower-income communities to environmental hazards (Alpermann

et al., 2024; Douglas et al., 2008; Swyngedouw & Heynen, 2003). Similarly, Urban Resilience Theory (URT) highlights how adaptive capacity and institutional responsiveness vary across socio-economic groups, leading to differentiated resilience outcomes (Friend & Moench, 2013; Meerow & Stults, 2016; Ziervogel et al., 2017). These theoretical assertions provide the empirical and conceptual foundation upon which the present hypotheses are formulated. Drawing on these established claims, this study assumes that patterns of flood exposure, access to institutional support, and reliance on community-based adaptation in Tamale are not random, but systematically associated with socio-economic characteristics and spatial differentiation across neighbourhoods. Based on the theoretical underpinnings and the research problem described earlier, three hypotheses are formulated to guide the empirical testing.

**Hypothesis 1: Socio-economic status and frequency of flood occurrence**

These hypotheses are based on UPE's assertion that inequality in land-use planning and infrastructure generates spatially uneven environmental risks (Douglas et al., 2008; Swyngedouw & Heynen, 2003).

*Null Hypothesis ( $H_{01}$ ):*

*$H_{01}$ : There is no significant relationship between community socio-economic status and the frequency of flood occurrence in the Tamale Metropolitan Area.*

*Alternative Hypothesis ( $H_1$ ):*

*$H_{12}$ : There is a significant relationship between community socio-economic status and the frequency of flood occurrence in the Tamale Metropolitan Area.*

The basis of this hypothesis is that socio-economic status (SES) measured through indicators such as income, education, occupation, and housing quality is widely used in environmental vulnerability studies (Amoako & Inkoom, 2018). UPE suggests that low-income groups are more likely to reside in low-lying or under-serviced areas due to exclusion from formal planning and secure tenure, resulting in higher flood impacts.

## **Hypothesis 2: Socio-economic characteristics and institutional flood adaptation support**

These hypotheses draw from UPE's critique of uneven state intervention and "resilience gentrification" (Anguelovski et al., 2016; Gould & Lewis, 2021) and URT's focus on governance and institutional responsiveness (Ziervogel et al., 2017).

*Null Hypothesis (H<sub>02</sub>):*

*H<sub>02</sub>: "There is no significant relationship in the level of institutional flood adaptation support across communities with different socio-economic characteristics."*

*Alternative Hypothesis (H<sub>12</sub>):*

*H<sub>12</sub>: "There is significant relationship in the level of institutional flood adaptation support across communities with different socio-economic characteristics."*

The basis of this hypothesis stems from the fact that research in Ghana shows that agencies such as NADMO and local government bodies tend to distribute support unevenly, often favouring wealthier or more visible neighbourhoods over marginalised ones (Manful & Opoku-Ankomah, 2021).

## **Hypothesis 3: Socio-economic status and adoption of community-based adaptation**

These hypotheses are grounded in UPE's view that autonomous, community-driven adaptation emerges from institutional neglect (Chaffin et al., 2016; Swyngedouw & Heynen, 2003), and URT's notion of *everyday resilience* (Friend & Moench, 2013; Sharpe, 2018)

*Null Hypothesis (H<sub>03</sub>):*

*H<sub>03</sub>: "There is no significant relationship in the level of adoption of community-based flood adaptation strategies across communities with different socio-economic characteristics"*

*Alternative Hypothesis (H<sub>13</sub>):*

*H<sub>13</sub>: "There is significant relationship in the level of adoption of community-based flood adaptation strategies across communities with different socio-economic characteristics"*

This hypothesis is based on the assertion that empirical evidence from Ghana demonstrates that communities with limited institutional support develop their own informal adaptation

systems, including sandbagging, communal labour, informal drainage clearing, and reliance on social networks (Amoako, 2018; Ziervogel et al., 2017).

### **1.6 Significance of the Study**

This study would significantly enhance the understanding of the spatial patterns of flood occurrence and adaptation in the Tamale Metropolitan Area. The research provides critical insights into the geographic distribution of flood risks by mapping and analysing flood-prone areas, which is vital for effective disaster preparedness, response, and long-term Adaptation. Local authorities and planners can reduce the frequency and impact of flood disasters on individuals and property by prioritising actions in high-risk neighbourhoods and identifying spatial clusters of vulnerability. Furthermore, by emphasising the spatial relationship between land use, inadequate drainage, and flood exposure, the study aids in guiding infrastructure development and urban planning. The sustainable urban growth of Tamale relies on the development of climate-sensitive infrastructure, efficient drainage systems, and resilient land-use patterns, all of which can be informed by this research. Additionally, the study enhances the understanding of how various populations in the metropolitan area cope with and adapt to the impacts of frequent flooding. By documenting local adaptation strategies, such as household-level adjustments, traditional knowledge, and community-based responses, the study promotes the exchange and replication of effective coping mechanisms in similarly affected areas. These findings can strengthen community resilience, enabling residents to anticipate, withstand, and recover from flood risks more effectively. This study provides significant empirical support for the formulation and implementation of national and local policies within a broader framework. When combined with socioeconomic and environmental data, knowledge of the geographical dimensions of flood vulnerability facilitates the creation

of targeted, evidence-based strategies. In Ghanaian and other flood-prone urban regions, such policies can promote adaptive behaviours and support sustainable development. Furthermore, the study's findings assist in climate adaptation planning as climate change continues to increase the frequency and intensity of extreme weather events. They emphasise the need for both structural and non-structural measures to address local vulnerabilities. Moreover, by highlighting community involvement in adaptation, the study promotes the development of collaborative and inclusive flood adaptation plans that engage local government officials, emergency services, NGOs, and residents. This study adds to the growing body of academic work in the fields of urban planning, environmental studies, geography, and disaster risk management. Serving as a reference point for further research and application, it offers a geographically grounded analysis of flood occurrence and response, showcasing strategies in an urban African context. This work supports the creation of a more flood-resilient Tamale and furthers the broader goals of sustainable and climate-resilient urban development by exploring the relationship between space, vulnerability, and adaptation.

### **1.7 Limitations of the Study**

This study acknowledges several limitations that frame the interpretation of its findings. First, the socioeconomic data derived from household surveys may be subject to reporting bias, as respondents could unintentionally misrepresent their experiences, preparedness levels, and exposure, thereby affecting data validity (Abass et al., 2022; Christiana et al., 2021). Second, the analysis was constrained by limited access to high-resolution biophysical datasets particularly detailed topographic, hydrological, and land-use information which restricted the precision of spatial vulnerability mapping (Aboagye, 2012; Yiran et al., 2024). Third, the study's temporal scope captured only a specific period, limiting the ability to account for long-

term flood patterns, evolving adaptive behaviors, and gradual shifts in vulnerability, a challenge noted in similar Ghanaian flood studies (Agyepong et al., 2024; Naah et al., 2025). Fourth, the research did not incorporate future scenarios such as projected climate change impacts, urban expansion, and population growth, which are critical for anticipating future flood risk landscapes (Abass, 2022; Gaisie & Cobbinah, 2023; Owusu & Obour, 2020). Finally, financial and human resource constraints influenced the scale of fieldwork, sample size, and the extent of spatial analysis and validation activities, a limitation widely reported in vulnerability assessments in sub-Saharan Africa (Dekongmen et al., 2021b; Sarfo et al., 2024). Despite these constraints, the study offers valuable insights into current socio-spatial flood dynamics and provides a foundation for future research to address these gaps.

### **1.8 Thesis Structure/Organisation of the Study**

This thesis is organised into seven chapters. Chapter 1 is the Introduction, providing the background and context of the study while emphasising the significance of understanding flood patterns and vulnerabilities, as well as management and adaptation in urban areas. The research objectives and questions are clearly outlined, justifying the importance of the study, setting the scope, and discussing the limitations of the research. The chapter concludes with a preview of the subsequent chapters. Chapter 2 reviews existing literature related to flood occurrences, vulnerabilities and adaptation. It critically examines previous studies and policies, laying a foundation for the current research by highlighting gaps in knowledge and suggesting the theoretical and conceptual framework for the study. Chapter 3 details the research methodology, providing comprehensive information about the research design, data collection methods, and analysis techniques. It outlines the rationale for selecting specific methodologies,

ethical considerations, and the importance of ensuring transparency in the employed research methods.

Chapter 4 examines the socio-spatial patterns of flood occurrence in Tamale, focusing on the analysis of these patterns and exploring both natural/geographical and human/anthropogenic factors contributing to flood vulnerability. It integrates spatial analysis to identify vulnerable areas within the city, offering a thorough understanding of how floods impact different communities in Tamale. Chapter 5 introduces institutional flood adaptation strategies and the challenges associated with them, particularly from the perspective of key experts in government and climate change. It explains the development of flood adaptation practices in Tamale. It discusses existing engineering structural solutions alongside non-structural measures such as policies, land-use planning, and flood forecasting and warning systems. Furthermore, it assesses the effectiveness of these measures in mitigating flood risks and impacts, while also exploring the challenges and limitations encountered in implementing these strategies. In other words, it focuses on planned adaptations, which are usually executed by the government. Focusing on adaptive and coping strategies, Chapter 6 identifies and analyses existing practices in Tamale, particularly citizen-led, community-based, autonomous adaptation in the three selected communities of Kalariga, Nalung, and Koblimahagu, considering their socioeconomic status and how it affects flood adaptation and resilience. It reveals why communities adopt or do not adopt certain adaptive practices. The concluding chapter, Chapter 7, summarises the study's key findings and implications, discussing the contributions made to the field of study and suggesting directions for future research. Practical recommendations are provided for policymakers, practitioners, and communities based on the research outcomes, concluding the research with actionable insights.

## CHAPTER 2

### LITERATURE REVIEW, THEORETICAL AND CONCEPTUAL FRAMEWORK

#### 2.1 Introduction

Urban flood occurrences, vulnerabilities and adaptation constitute pivotal areas of research, providing essential insights for disaster management and urban development strategies. While extensive studies have elucidated these phenomena in global contexts, there exists a notable gap in understanding the unique challenges faced by cities such as Tamale in northern Ghana. Despite sporadic yet impactful flood research in Tamale, there remains a dearth of comprehensive studies addressing the intricate dynamics of flooding (Amankwaa & Gough, 2023; Hafiz, 2014; S. M. Kayaga et al., 2020). This chapter embarks on the exploration of literature to bridge this knowledge gap. It examines the nuanced dimensions of urban floods, scrutinising natural and anthropogenic drivers of flood occurrence and vulnerability and adaptive capacities. It also constructs the theoretical and conceptual framework essential for the current study. By establishing a solid foundation in this chapter, the ensuing chapters will conduct a detailed analysis of flood occurrences, vulnerabilities and flood adaptation strategies specific to Tamale. This comprehensive review not only informs the current study but also enriches the broader discourse on urban flood adaptation. It contributes to the growing body of knowledge applicable to regions confronting similar challenges.

#### 2.2 Flooding

Flooding is a natural occurrence that has the propensity to alter the routine lifestyle of populations through its damaging effects, such as washed-out houses, landed properties, goods,

and assets (Asumadu-Sarkodie et al., 2015, 53). According to the National Oceanic and Atmospheric Administration's (NOAA) National Severe Storms Laboratory (NSSL), "Flooding is an overflowing of water onto land that is normally dry. Floods can occur during heavy rainfall, when ocean waves come ashore, when snow melts rapidly, or when dams or levees break. Damaging flooding may happen with only a few inches of water, or it may cover a house to the rooftop. Floods can occur within minutes or over an extended period and may last from days to weeks or longer. Floods are the most widespread of all weather-related natural disasters" (NOAA National Severe Storms Laboratory, 2022, p. 1). Also, flooding is an abnormally swirling body of water above sea level resulting from melting snow, tidal waves, extreme rainfall, or runoff from paved places (Ani et al., 2020, p. 32; European Environmental Agency, 2022). Also, flooding is mostly a short-term situation of partial or complete accumulation of water on a parcel of dry land or area due to overflow of inland or tidal waters (Ani et al., 2020; World Health Organisation, 2019). In Africa, floods are driven by extreme rainfall and related factors rather than snowmelt or coastal storm surges. Heavy rains overwhelm rivers and drainage systems, causing them to inundate homes and roads. In Africa's tropical climate, intense seasonal downpours, combined with the effects of climate change, have increased flood frequency and severity (Asumadu-Sarkodie et al., 2015; Taylor et al., 2022). For example, Ghana's major rainy season and recent climate trends have led to more frequent and intense floods in recent decades (Asumadu-Sarkodie et al., 2015; Ayazi & Elsheikh, 2019).

### 2.3 Drivers of Flooding

Drivers are factors that alter the state of the flooding system, and in this study they are explained using the source–pathway–receptor (SPR) model. It is important to emphasise that the SPR

model is used solely as an explanatory tool within the literature review to illustrate how physical and environmental flood processes occur. It is not the conceptual framework guiding the overall study. Instead, it provides a structured way of understanding the natural and physical mechanisms that generate flooding before shifting to the socio-political and resilience-oriented conceptual discussions later in the chapter. In the SPR model, flood risk seldom results from a single factor; rather, it emerges from interactions among multiple drivers. For example, socio-economic drivers influence patterns and rates of urbanisation, which in turn modify surface runoff and increase pluvial flood risk. Similarly, storm surges interacting with rising sea levels can intensify coastal water levels and alter the frequency of extreme flooding events. These relationships are illustrated conceptually in Figure 2.1, which provides an overview of how natural sources, pathways, and receptors interact in shaping flood events.

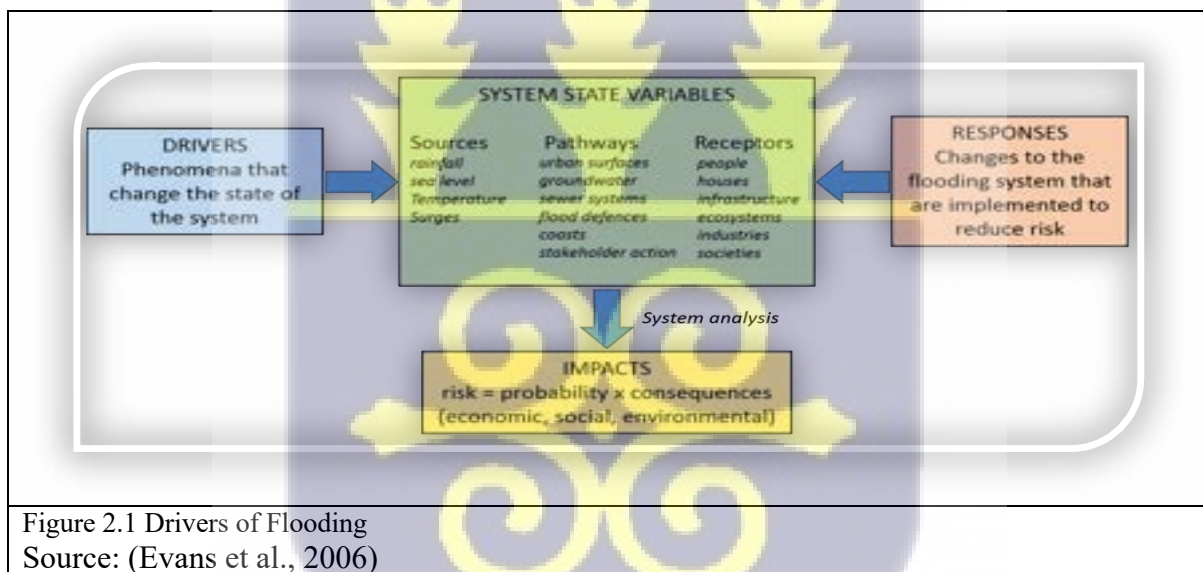


Figure 2.1 Drivers of Flooding  
Source: (Evans et al., 2006)

The concept of “responses” refers to actions taken to mitigate or reduce flood risk. However, the line between drivers and responses can blur, as poorly designed responses may inadvertently function as drivers, while well-managed drivers may be transformed into effective responses (Evans et al., 2006, p. 2; O’Donnell & Thorne, 2020, p. 2). Drivers of flooding are generally categorised into natural (geographic) and anthropogenic (human-

induced) factors. Natural drivers arise from meteo-hydrological and biophysical processes (Berghuijs et al., 2019), including intense precipitation, extreme temperatures, high antecedent soil moisture, snowmelt, and complex ocean–atmospheric circulations (Bowen & Pallister, 2000, p. 32; Hossain et al., 2021; Molner, 2022; Uhe et al., 2021). Anthropogenic drivers, in contrast, stem from human activities that modify the environment in ways that influence flooding. These include the construction of water-storage and control structures (such as dams), extensive urbanisation, and deforestation (Bowen & Pallister, 2000, p. 32). Together, these activities can alter land elevation, surface permeability, and runoff pathways (Balch et al., 2020, p. 6; Noone, 2013). In combination, natural and human drivers determine the hydraulic forces acting on a given landscape, producing different flood types depending on the location and interaction of these processes (Jian, 2014). The drivers discussed here therefore provide the physical context for the types of flooding examined later in the chapter, before the study shifts into the socio-political and resilience dimensions captured in the theoretical and conceptual frameworks.

## 2.4 Types of Flooding

Different types of floods exist, and therefore, the nature and extent of damage also varies as well. Understanding the varieties of flooding could go a long way to help prepare and mitigate the effects of flooding on communities prone to flooding. Many authors have classified flooding severally. However, Jha et al. (2012, pp. 55–64) categorised floods into riverine (fluvial), pluvial (overland), coastal and groundwater (failure of artificial water systems). They further observed that when flooding is categorised based on its origin, speed, and force, then it can either be flash floods, urban floods, semi-permanent floods, or slow-rise floods”. Wright (2007) opines that floods are generally grouped into riverine, urban drainage, ground failures,

fluctuating lake levels, coastal , and erosion flooding. Also, Newground (2022) observes that flooding is categorised into river, groundwater, surface water, coastal, sewer, reservoir and canal flooding.

It is noted that, as some flooding categories are the same for all the authors, some have been named differently but carry the same explanation. For instance, all three authors agree on river, coastal and groundwater flooding. But Newground (2022) goes further to describe some other types based on the function of the object used, such as canal flooding, while Wright (2007) describes some types of flooding based on the characteristics of the object, such as fluctuating lake levels. So, one can say that the major disparity lies in the choice of words used to describe one type of flooding from the other, but they present similar information. Since this research dwells on flooding in cities and urban areas, an in-depth analysis of urban flooding is presented in the following section.

#### **2.4.1 Urban Flooding and Its Drivers**

Urban flooding happens when very heavy rainfall overwhelms the urban drainage system, and excess water cannot be absorbed. Additionally, urban flooding occurs when soil absorption, surface runoff, or drainage cannot effectively disperse intense rainfall, often caused by slow-moving thunderstorms (Hafiz, 2014; B. Kusi-Appiah, 2016). Moreover, urban floods can also result from excess water from rain or snowmelt that cannot sink into the ground due to the ground's exceeded carrying capacity. This causes the water to flow over land through urban areas before reaching drainage systems or watercourses (Jha et al., 2012). The main causes of urban flooding are generally surface runoff and inadequate drainage within an area. Urban floods can stem from various factors, often arising from a complex combination of causes. The

urban environment is subject to the same natural forces as the natural environment, but the presence of urban settlements worsens the problem. Cities can be flooded by rivers, coastal floods, pluvial and groundwater floods, and failures of artificial systems (Jha et al., 2012). The drainage system's failure to remove sewage water, especially during heavy rain, significantly contributes to urban flooding when combined with surface water flow into floodplains. Floodwaters then occupy natural or constructed depressions or meander through the terrain, creating a surface flow network, usually called the “major system,” while the “minor system” refers to an underground sewer network (Maksimović et al., 2009). The main structures that rainfall uses to cause floods in urban areas include roads, footpaths, natural ground depressions, and small watercourses.

These structures can transmit flood water across long expanses creating floods in far-off areas from where the drainage system capacity was exceeded. Surface runoff at neighbouring locations not linked to the sewer network adds up to the flood flow. Even though urban surface pathways largely follow buildings and streets, water also runs across gardens and other open spaces (Maksimović et al., 2009). The straightening and lining of channels; the construction of streets, curbs, and stormwater inlets, sewers and other underground conduits; culverts; and other means of controlling runoff, result in improved hydraulic efficiency of the local drainage network. In other words, the time required for surface runoff to reach a stream channel is reduced. Unless the drainage network is specifically designed to counteract this increase in the rate of runoff from the watershed, the result is likely to be an increase in flood peaks. Thus, flooding will happen more quickly and usually to greater depths than before urban development occurred. Around 20-25 per cent of all economic losses resulting from flooding occur in areas not designated as being in a “floodplain,” but because of urban drainage (Wright, 2007).

#### 2.4.2 Flash Flooding and Its Drivers

Flash flooding has emerged as a significant concern in hydrological and climate-related disaster literature, particularly due to its destructive nature and increasing frequency under changing climatic and urbanisation patterns. Globally, flash floods are defined as rapid, life-threatening inundations that occur within a few minutes to several hours following extreme rainfall events, dam or levee failure, or the sudden release of water from obstructions such as ice or debris jams (Stern, 2019). The United States National Weather Service underscores that flash flooding is particularly hazardous due to its swift onset, often leaving limited time for warnings, evacuations, or protective measures. While these broad definitions provide a helpful framework, their application to the African context, particularly in Ghana, necessitates adjustment. In most Sub-Saharan African settings, flash floods are not caused by snowmelt, ice jams, or tidal surges, as observed in temperate or coastal environments (Jha et al., 2012; Wright, 2007). Instead, the phenomenon is primarily driven by high-intensity, short-duration rainfall events, poor urban drainage systems, unregulated development in flood-prone zones, and dam-related water releases. For instance, in urban Ghana, cities such as Accra, Kumasi, and Tamale frequently experience flash floods due to the combination of intense rainfall and the obstruction or absence of drainage infrastructure, particularly in informal settlements (Amoako & Inkoom, 2018; Mensah & Ahadzie, 2020). These floods result in rapid accumulation of water on roads, within low-lying residential areas, and around stormwater outlets, often within hours of heavy rain. In addition to urban-related causes, dam operations contribute significantly to flash flooding in Ghana. The deliberate spillage from reservoirs such as the Weija and Akosombo dams during peak rainfall periods often leads to abrupt inundation of downstream communities. These spillage events are exacerbated by the intense runoff from rainstorms, leading to widespread displacement, infrastructure destruction, and livelihood losses (Asare & Tuffour,

2024). A notable case is the October 2023 Akosombo Dam spillage, which displaced over 35,000 people in communities along the Volta River, including Mepe and Battor (Dadson, 2023).

Topographical and land use factors further heighten the risk of flash floods. In areas with steep terrain and limited vegetative cover, whether from deforestation or degradation, runoff tends to accumulate quickly, often causing debris-laden flows that damage infrastructure and homes. Deforestation in upstream zones of Ghana and other parts of West Africa has markedly reduced the soil's capacity to absorb water, leading to increased overland flow and flash flooding (Taylor et al., 2022). Similar effects have been documented in East African countries such as Kenya and Madagascar, where hilly topography and poor drainage systems compound the severity of flash flood events (Ramiamanana & Teller, 2021). Climate change is widely recognised as a compounding factor in the growing incidence of flash flooding. Warmer temperatures are associated with more intense and frequent precipitation events in West Africa, particularly in the Guinea Savannah and transitional zones of Ghana (Central Intelligence Agency, 2021). These changing precipitation patterns increase the likelihood of short-duration, high-volume rainstorms capable of overwhelming both natural and artificial drainage systems. The effects are especially pronounced in urban centres where impermeable surfaces such as roads and rooftops dominate, leading to surface water accumulation and increased runoff velocity (Mensah & Ahadzie, 2020).

Anthropogenic factors, particularly poor land use planning, inadequate enforcement of building regulations, and limited investment in stormwater infrastructure, have exacerbated the frequency and severity of flash flooding across Ghana. Informal settlements often encroach on

riverbanks and natural floodplains without protective infrastructure or adequate space for water dispersal (Amoako & Inkoom, 2018). Consequently, the occurrence of flash flooding in Ghana and similar African contexts must be understood as both a natural hazard and a product of socio-political and infrastructural neglect. Overall, flash floods in Ghana and much of Sub-Saharan Africa are primarily driven by intense rainfall, weak drainage infrastructure, dam-induced flows, and poor spatial planning. Unlike in colder or coastal regions where snowmelt and ice jams contribute significantly, the African context demands a focus on rainfall variability, land degradation, and urban exposure. As climate change intensifies, the need for early warning systems, enforcement of zoning laws, and investments in resilient infrastructure becomes increasingly urgent.

## **2.5 Elements of Flood Risk**

### **2.5.1 Hazards**

The term "hazard" is commonly used to refer to natural risks such as earthquakes, wind, and floods. However, hazards can occur in every facet of human existence. Some of these may develop naturally, while others may arise from human activity. Recognising this, the IPCC defined a hazard as "the potential occurrence of a natural or human-caused physical event that may result in loss of life, injury, or other health effects, as well as damage to and loss of property, infrastructure, livelihoods, service provision, and environmental resources" (Lavell et al., 2012, p. 44) Hazards turn into disasters when physical phenomena inflict harm to people and property. A disaster, according to the United Nations International Strategy for Disaster Reduction (UNISDR), is "a major disruption of society's functioning, resulting in widespread human, material, or environmental losses that exceed the afflicted society's ability to manage on its resources" (UNISDR, 2009, p. 9). That is, a catastrophe is the result of a hazard, assessed

in human terms (lives lost, people impacted, economic losses, environmental losses) and mediated by the features of the social and environmental systems exposed to and affected by the hazard (UNISDR, 2009).

When a danger turns into a disaster, the affected people either become destitute and recover slowly, or they can manage and recover quickly; a combination of the two is also possible. Disasters, according to this method of thinking, are socially produced occurrences, that is, they are the result of the effect of hazards on individuals whose susceptibility has been established by social, economic, political, and other mediating contexts (Blaikie et al., 2014). As a result, some researchers believe that vulnerability is a considerably more important predictor of catastrophic risk than the presence of hazards itself (Ward & Shively, 2012). As a result, disasters produced by hazards are impacted not only by the magnitude and frequency of the hazard occurrence but also by the susceptibility of the afflicted civilisation and its natural environment (Cardona et al., 2012; Shaw, Islam, et al., 2013). In this light, Helmer and Hilhorst (2006) feel that the key insight that disaster studies may provide to climate-related research is that "vulnerability is crucial to determining the character of catastrophes" (Helmer & Hilhorst, 2006, p. 2).

### **2.5.2 Exposure**

The term "exposure" refers to the presence (location) of people, livelihoods, environmental services and resources, infrastructure, or economic, social, or cultural assets in areas that might be negatively affected by physical occurrences and hence vulnerable to possible future injury, loss, or damage (IPCC, 2023c). If the elements are not positioned in hazardous places, they will not be exposed. However, as the population grows, there will be more diversified demands

for land, and the steady decline in the supply of safer locations means that humans and human endeavour will invariably be positioned in potentially dangerous areas (IPCC, 2023a). Exposure will thus be determined by where populations choose or are compelled to reside, as well as how they develop their settlements, communities, and livelihoods (Brooks et al., 2005). According to recent studies, exposure is the type and intensity of environmental or sociopolitical stress that a system endures, and its features include the threat's size, frequency, duration, and geographic scope (Burton et al., 1978). Accordingly, certain risks are more severe than others, and some occur more frequently, more quickly, or continue longer than others (Adger, 2006). It also demonstrates how the hazard's different impact zones rely on these traits and other environmental aspects of the place where it manifests. Consequently, it may be inferred that exposure partially encompasses the geographical and temporal components of vulnerability, making it dynamic in both time and location (Folke, 2006).

### **2.5.3 Vulnerability and Suceptibility**

The concept of vulnerability is often used to describe the inability to withstand the impacts of a challenging environment. However, its scientific application varies depending on the field and the specific focus of the research (Birkmann et al., 2016). Traditionally, the concept of vulnerability originated in geography and natural hazards research (Birkmann, 2007; O'Brien et al., 2007), but it has since expanded to encompass a wide range of contexts within the social sciences (e.g., Cutter et al., 2003; Pelling, 2010). In the context of natural hazards, vulnerability is often defined as the characteristics of individuals or groups that affect their ability to anticipate, cope with, resist, and recover from the impacts of natural hazards (Birkmann et al., 2013). This definition highlights the social dimensions of vulnerability, emphasising how age, class, ethnicity, gender, and physical or mental disabilities can affect a group's susceptibility to

hazards. However, vulnerability can vary significantly across different groups, depending on the nature of the threat and the socio-cultural environment. This definition, with its focus on the social consequences of natural hazards, is often considered more socially oriented (see also Bassett & Fogelman, 2013; Ford et al., 2011) for more perspectives on vulnerability.

Climate change research has made significant contributions to the understanding of vulnerability, framing it as an integrated measure of the likelihood and impact of hazards (Jurgilevich et al., 2017). The Intergovernmental Panel on Climate Change (IPCC) has been at the forefront of this research, defining vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes." Vulnerability, according to the IPCC, is determined by the extent and rate of climate variability to which a system is exposed, along with its sensitivity and adaptive capacity (IPCC, 2023b). This definition incorporates both physical causes and their effects while also considering the social context, which includes notions of sensitivity and adaptive capacity (IPCC, 2023a). Essentially, vulnerability reflects the residual impact of climate change after adaptation measures have been implemented (Lissner et al., 2012). It is context-dependent and varies by spatial scale, influenced by factors such as wealth, social equity, food security, health, education, infrastructure, and technology (O'Brien et al., 2007). Although definitions of vulnerability vary, they are commonly grouped into two main categories: biophysical vulnerability and social vulnerability (Bakkensen et al., 2017). This distinction is essential for reducing ambiguity and enhancing the consistency of how vulnerability is understood and applied in research and practice (Fekete et al., 2014). However, the boundary between these two categories is often not clear-cut. The susceptibility of societies to hazards is shaped not only by the physical characteristics of the hazard itself but also by the

social, economic, and political contexts in which communities exist (Bohle et al., 1994). Consequently, the impacts of environmental disasters on social stability can vary significantly depending on the interplay between natural events and societal factors.

Biophysical vulnerability is generally assessed using indicators such as economic losses, human fatalities, production disruptions, and environmental degradation (Schneiderbauer et al., 2006). This form of vulnerability aligns with traditional risk analysis frameworks, which emphasise the likelihood of hazard occurrence and its potential consequences, often quantified through the damage inflicted on exposed systems (Gallopín, 2006). It is particularly relevant in evaluating ecosystem vulnerability, as it accounts for the spatial location of affected systems and the resources available for managing associated risks (Füssel & Klein, 2006). In contrast, social vulnerability emphasises the role of socioeconomic and demographic factors in shaping a community's capacity to respond to and recover from hazards (Cutter et al., 2016). Although multiple definitions of vulnerability exist in the literature, this study adopts the definition proposed by the Intergovernmental Panel on Climate Change (IPCC, 2023b). The IPCC's framework is especially suitable for spatial analysis, as it provides a robust quantitative structure that can be integrated into Geographic Information Systems (GIS). Notably, it combines biophysical and social dimensions of vulnerability, offering a comprehensive and multidimensional lens for analysis. Accordingly, the following sections will explore the core components of vulnerability: exposure, sensitivity, and adaptive capacity.

## 2.6 Degree of Impact

The degree of impact refers to the magnitude and severity of the consequences a hazard imposes on an exposed system. In climate-change and disaster-risk scholarship, impacts arise

from the interaction among exposure to a hazard, system sensitivity, and adaptive capacity (Birkmann, 2007; IPCC, 2001; Turner et al., 2003). These components jointly determine how strongly a climatic or hydrological event affects households, infrastructure, livelihoods, and ecosystems. A system characterised by high sensitivity, frequent exposure, and constrained adaptive capacity will experience disproportionately severe impacts compared with a system that is less sensitive or more capable of coping. Understanding the interaction among these components provides a robust foundation for analysing flood impacts within the study area.

### 2.6.1 Sensitivity

Sensitivity refers to the extent to which a system is affected when exposed to a hazard. The IPCC (2014) defines sensitivity as “the extent to which a system is affected, either adversely or beneficially, by climate variability or change.” In the context of flooding, sensitivity captures how the characteristics of households, buildings, infrastructure, ecosystems, and social systems influence the severity of damage or disruption experienced. It is shaped by inherent physical, ecological, socioeconomic, and infrastructural attributes (Glick et al., 2011). Consequently, systems exposed to the same hazard may experience divergent outcomes. For example, households living in poorly constructed or mud-built structures are more prone to structural failure during flooding than those in reinforced concrete buildings. Likewise, livelihood systems that depend heavily on environmental stability, such as rain-fed agriculture, are typically more sensitive to hydrological disturbances than more diversified livelihood systems. Sensitivity is dynamic, shifting across space and time as systems evolve or deteriorate (Simelton et al., 2012). As such, higher levels of sensitivity are strongly associated with more severe impacts from identical flood events.

### 2.6.2 Flood Occurrence

Flood occurrence represents the manifestation of a flooding event at a particular location. It is driven by a combination of meteorological and hydrological processes including intense rainfall, storm surges, river overflow, dam failures, and rising groundwater and is often exacerbated by human activities such as unplanned urbanisation, deforestation, and inadequate drainage systems (Glago, 2021; Rentschler et al., 2022). Meteorological forces (e.g., heavy precipitation, cyclonic activity) interact with hydrological conditions (e.g., saturated soils, topography, river-channel capacity) to produce flooding. Anthropogenic pressures, including altered land use, encroachment on waterways, and poor drainage infrastructure, further modify surface-runoff patterns, increasing flood frequency and severity. The frequency, magnitude, and duration of flood occurrence strongly influence the degree of impact. As Cutter et al. (2009) note, repeated or high-magnitude exposure intensifies impacts even in moderately resilient systems, whereas infrequent or lower-magnitude events may be absorbed with comparatively less disruption.

### 2.6.3 Adaptive Capacity and Resilience

Adaptive capacity is the ability of a system to adjust to hazards, moderate potential damage, exploit opportunities, or cope with adverse consequences (IPPC, 2001; Millennium Ecosystems Assessment, 2005). It is shaped by environmental, social, cultural, political, and economic factors that influence preparedness, response, and recovery (Gitz & Meybeck, 2012). Adaptive capacity operates along both short- and long-term dimensions. Short-term capacity includes immediate coping strategies such as temporary relocation, access to relief, the use of savings, or reliance on social networks (Birkmann et al., 2013). Long-term adaptive capacity encompasses structural measures such as livelihood diversification, improved infrastructure,

land-use planning, and governance reforms that gradually reduce vulnerability (Maguire, 2020; Singh et al., 2023).

Resilience closely related to adaptive capacity refers to the ability of a system to absorb disturbances while maintaining essential functions (Holling, 1973; Manyena, 2006). It includes both innate resilience (i.e., existing system attributes that buffer impacts) and adaptive resilience (i.e., learning and reorganisation following disturbance) (Zhou et al., 2010). Systems with higher resilience experience reduced impacts from equivalent hazards. Increasingly, global and national policy frameworks prioritise resilience and adaptive-capacity enhancement. Across Africa, governments and regional bodies are investing in resilience-building initiatives.

For example, the African Union's Climate Change and Resilient Development Strategy (2022–2032) provides a continent-wide framework for strengthening adaptation, early-warning systems, and climate-resilient development ((African Union, 2022). The Africa Adaptation Acceleration Programme (AAAP), led by the African Development Bank and the Global Center on Adaptation, aims to mobilise US\$25 billion to support climate-resilient infrastructure, agriculture, and urban systems (African Development Bank & Global Center on Adaptation, 2021). At national levels, Ghana's *National Adaptation Plan (2023)* prioritises flood-risk management, resilient infrastructure, and community-level adaptation (Environmental Protection Agency of Ghana, 2023), while Nigeria's Lagos Flood Management and Resilience Project focuses on urban drainage, coastal protection, and community preparedness (Insurance Development Forum et al., 2025; Orimoogunje & Aniramu, 2025). These initiatives highlight the centrality of sustained investment in adaptive capacity and resilience in reducing the degree of impact associated with climatic and flood hazards.

## 2.7 Adaptation

Vulnerability to climatic hazards arises from the interaction among exposure to harmful events, sensitivity to those events, and the capacity or resilience of a system to cope, adapt, or recover (Smit & Wandel, 2006a). Adaptation, by contrast, refers to the adjustments made by human or natural systems to moderate harm or exploit beneficial climatic opportunities. The IPCC (2014) defines adaptation as “the process of adjustment to actual or expected climate and its effects,” distinguishing between adaptation in human systems, which focuses largely on reducing adverse impacts, and adaptation in natural systems, which may be facilitated through human intervention (Hill, 2025). Adaptation strategies fall broadly into two categories: incremental adaptation, which maintains the core structure and functions of a system, and transformational adaptation, which involves fundamental changes when incremental measures prove insufficient. Both forms aim to reduce sensitivity and enhance system capacity to withstand climate-induced impacts.

Multiple perspectives highlight the behavioural, structural, and institutional dimensions of adaptation (Aitsi-Selmi, Murray, et al., 2016; Lei et al., 2014; McLaughlin, 2011). These perspectives position adaptation as the practical means through which societies minimise susceptibility to climate risks. Recent scholarship underscores the importance of well-designed adaptation interventions to avoid profound social and ecological losses (Abbass et al., 2022; Ng, 2024). Effective adaptation planning requires an appreciation of how climatic hazards and vulnerabilities vary across space and time. Emerging literature also emphasises the role of innovative technologies, resilient infrastructure, and nature-based solutions in addressing climate impacts (Puig et al., 2025; Shyamala et al., 2025). Advances in plant genetics, for instance, illustrate how biological adaptation can enhance climate-resilient agricultural systems (Wu et al., 2025). Collectively, these insights reinforce the understanding that effective

adaptation, when integrated into planning and policy processes, is essential for reducing vulnerability and strengthening resilience in the face of climate-related hazards.

## 2.8 Institutional Structures for Urban Flood Adaptation

Urban flooding is a growing global challenge, with climate change and rapid urbanisation exacerbating the frequency and intensity of flood events. Institutional structures at various levels, global, national, state, and local, play critical roles in mitigating and managing flood risks. These structures encompass formal government bodies, non-governmental organisations (NGOs), private sector actors, and community-based organisations. The effectiveness of flood adaptation strategies often hinges on the coordination and collaboration among these entities. Globally, institutions such as the United Nations Office for Disaster Risk Reduction (UNDRR) and the World Meteorological Organisation (WMO) provide frameworks and guidelines to support flood adaptation (Perera et al., 2019; United Nations, 2021). The Sendai Framework for Disaster Risk Reduction 2015–2030 emphasises risk assessment, capacity building, and community engagement as pillars for effective flood adaptation. These global frameworks guide countries in adopting integrated approaches to flood risk reduction, including nature-based solutions and resilient urban planning, in Tamale are limited. By publishing findings on Tamale, the study complements work like Parnell & Pieterse (2016) and Pieterse & Parnell (2014).

In many cases, international NGOs and development partners, including the International Federation of Red Cross and Red Crescent Societies (IFRC), play pivotal roles in supporting local flood response and recovery efforts, particularly in resource-constrained settings (IFRC, 2024). In Africa, urban flooding is compounded by rapid urbanisation, inadequate infrastructure, and weak institutional capacities. National-level institutions in countries such as

Nigeria, Kenya, and Ghana are tasked with coordinating flood risk management through disaster management agencies and water resources authorities. For instance, Nigeria's National Emergency Management Agency (NEMA) oversees flood response and works with state governments to implement adaptation measures. However, resource limitations and governance gaps often hinder the effectiveness of these agencies (Adelekan, 2016, pp. 257–260). Similarly, Kenya's Water Resources Authority collaborates with local governments to manage flood-prone areas, integrating water resource management with urban planning (Kiptum et al., 2023).

Ghana faces similar challenges, where the National Disaster Management Organisation (NADMO) leads the national flood adaptation agenda. NADMO's mandate includes coordinating disaster preparedness, response, and recovery efforts. However, the effectiveness of NADMO is often limited by inadequate funding and weak enforcement of urban planning regulations, particularly in rapidly urbanising areas (Mensah-Bonsu, 2022). The agency's activities are further constrained by fragmented governance structures, with overlaps between local government authorities and traditional leadership in managing land use and urban development. In the urban context, cities like Accra and Kumasi have implemented localised flood adaptation initiatives. For example, Accra has adopted nature-based solutions, such as restoring wetlands and implementing the “Odaw River Basin Management Plan,” to address recurring flood risks (Debele et al., 2023). These efforts are complemented by community-based organisations and NGOs, which support vulnerable populations in informal settlements. However, the reliance on donor-funded projects and the limited institutional capacity of municipal assemblies remain challenges for sustained flood adaptation in Ghana.

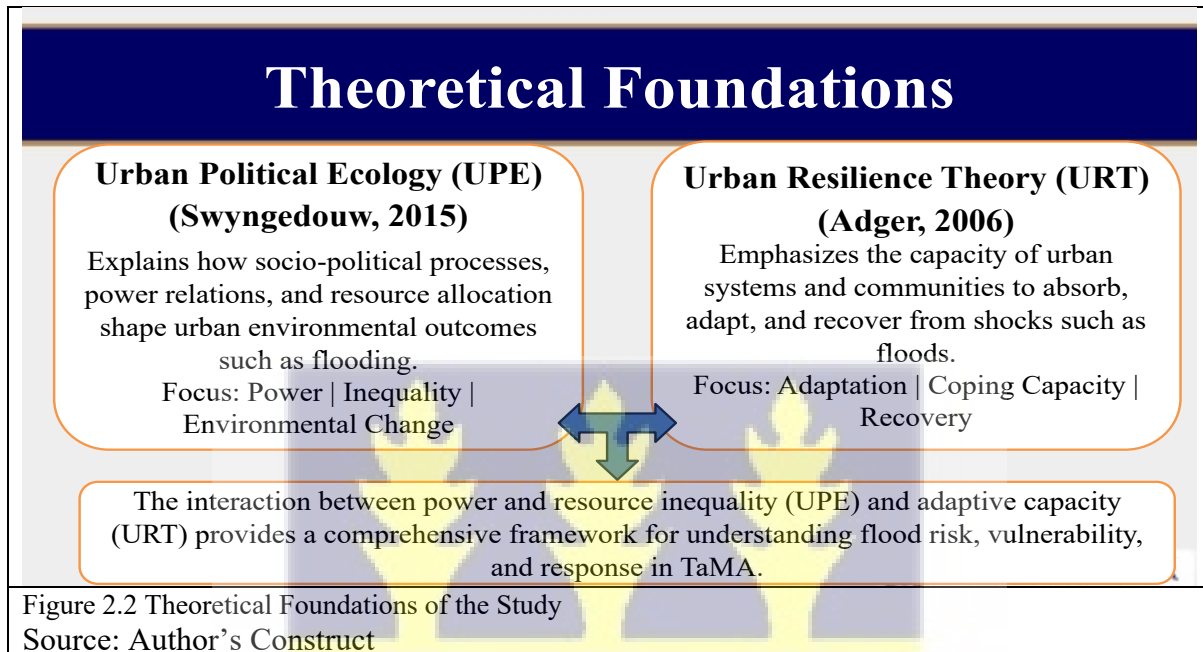
In Tamale, the interplay between state and non-state actors explains the complexity of urban flood governance. The Tamale Metropolitan Assembly (TaMA) is responsible for enforcing urban planning regulations, maintaining drainage systems, and implementing flood Adaptation measures. However, the rapid urbanisation of Tamale has outpaced the development of infrastructure, leading to blocked drainage systems and encroachments on flood-prone areas. The coexistence of formal state governance and traditional leadership structures exacerbates these issues. Chiefs and other traditional authorities hold considerable influence over land allocation and community mobilisation, yet their roles are often informal and not fully integrated into official governance frameworks (Agyei-Mensah et al., 2024).

Non-state actors, including NGOs and community groups, play an essential role in flood adaptation in Tamale. Organisations such as the Northern Development Initiative have facilitated community-driven flood adaptation strategies, including early warning systems and flood-resilient housing designs. These efforts are particularly critical in low-income areas where state interventions are minimal. In contrast, higher-income areas often rely on private resources to implement individual flood protection measures, highlighting socioeconomic disparities in flood resilience (Odersky & Löffler, 2024).

Urban flood adaptation requires a multilevel governance approach that integrates global frameworks with local realities. In Tamale, addressing the challenges of urban flooding necessitates enhanced collaboration between state and traditional institutions, the inclusion of non-state actors, and targeted interventions to reduce vulnerabilities in low-income communities. By leveraging these synergies, Tamale can develop a more resilient and adaptive framework for managing flood risks.

## 2.9 Theoretical Foundations of the Study

This study is grounded in a combined theoretical framework that integrates Urban Political Ecology (UPE) and Urban Resilience Theory (URT) to explain the socio-spatial patterns of flood occurrence and adaptation in the Tamale Metropolitan Area (TaMA). Figure 2.2 illustrates the theory used in the research.



Drawing first on UPE, the framework highlights how socio-political processes, power relations, and unequal resource allocation shape environmental outcomes such as urban flooding (Lawhon et al., 2014; Swyngedouw, 2015). From this perspective, floods are not simply natural events but are produced through historical and contemporary decisions on land use, infrastructure provision, drainage maintenance, and urban planning. In many African cities, including TaMA, structural inequalities in governance and service delivery compel low-income and politically marginalised residents to occupy environmentally risky areas such as low-lying floodplains, wetlands, and poorly drained informal settlements (Chiu, 2020; Yiran, 2014). UPE therefore helps explain why certain neighbourhoods experience recurring floods, who is most exposed, and how institutional priorities and power asymmetries contribute to

persistent patterns of vulnerability. Complementing this structural analysis, Urban Resilience Theory (URT) provides insight into the capacity of households, communities, and urban systems to absorb, adapt to, and recover from flood events (Adger, 2003; Brooks et al., 2005; Lobo et al., 2023; Meerow et al., 2016; Meerow & Stults, 2016; Waters & Adger, 2017). URT extends the concept of resilience beyond physical infrastructure, emphasising social, economic, institutional, and behavioural dimensions. Factors such as livelihood stability, access to resources, local knowledge, social networks, and institutional support play a critical role in shaping the ability of households to prepare for and respond to flood hazards. Evidence from African contexts, including community-led adaptation efforts in Tuti Island, Sudan, demonstrates how participatory approaches such as the Taya early warning system and Nafeer social mobilization enhance adaptive capacity and strengthen resilience to flooding (Abubakar & Aina, 2019; Sen & Osman, 2022; Tambal et al., 2024). Applying URT to TaMA therefore helps explain how different socioeconomic groups mobilise various forms of capital and support systems to cope with flood impacts and recover from disruptions.

Bringing UPE and URT together produces a holistic and multidimensional lens for understanding flood risk in TaMA. UPE illuminates the structural and political drivers of exposure and unequal vulnerability, while URT reveals the differentiated adaptive capacities shaped by income, education, livelihoods, and social support systems. This integration allows the study to recognise the socio-political foundations of flood risk, the neighbourhood-level variations in resilience, and the ways in which historical marginalisation and limited political influence constrain opportunities for effective adaptation. Through this combined perspective, the framework captures both the structural determinants and the agency-based mechanisms that shape flood vulnerability and adaptive behaviour. It therefore provides

a comprehensive theoretical basis for analysing the complex interactions between governance, inequality, resilience, and socio-spatial flood patterns in TaMA.

## 2.10 Conceptual Framework

The conceptual framework for this study integrates Urban Political Ecology (UPE) and Urban Resilience Theory (URT) to explain the socio-spatial patterns of flood occurrence and adaptation in the Tamale Metropolitan Area (TaMA) Drivers (Figure 2.3).

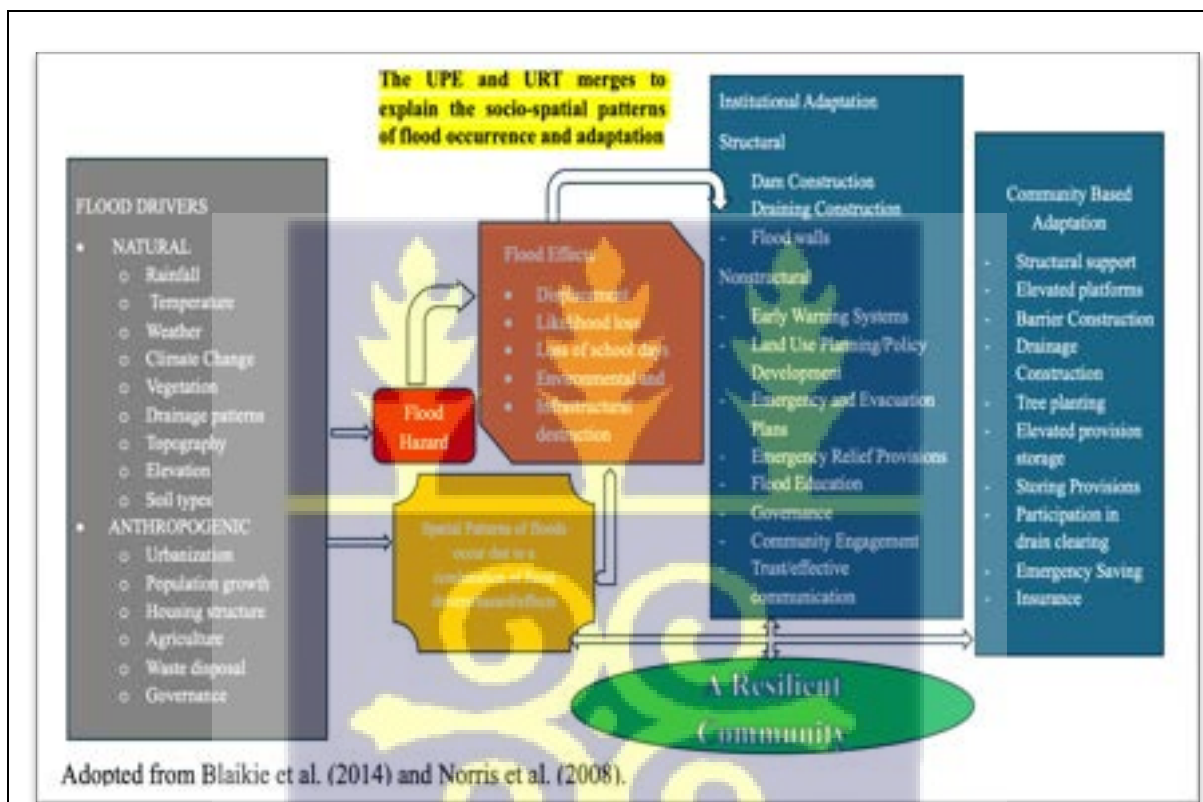


Figure 2.3 Conceptual Framework of the Study  
Author's Construct

These theories work together to capture both the structural forces that create uneven exposure to hazards and the adaptive capacities that enable households and institutions to respond to flooding. UPE provides insight into how governance arrangements, political power relations, and resource allocation shape environmental risks and uneven flood exposure across urban space (Blaikie et al., 2014; Lawhon et al., 2014; Swyngedouw, 2015). URT complements this

by emphasising the ability of urban systems and communities to absorb, adapt to, and recover from disturbances through institutional and community-based strategies (Adger, 2006; Norris et al., 2008). At the foundation of the framework are flood drivers, which have been grouped into two simplified categories: Natural Drivers and Anthropogenic.

Natural Drivers include meteorological and hydrological conditions such as rainfall intensity, temperature patterns, drainage characteristics, topography, and soil types. Anthropogenic Drivers include land-use change, urbanisation, population growth, building practices, waste disposal, governance processes, and inadequate infrastructure. These drivers interact to generate flood hazards which is the actual occurrence of inundation events. UPE helps explain why these hazards disproportionately affect certain neighbourhoods, particularly low-income or politically marginalised areas where governance failures, inadequate services, or informal settlements intensify exposure. Flood hazards produce a range of flood effects, including displacement, livelihood losses, school disruptions, and environmental or infrastructural damage. These effects reveal different dimensions of vulnerability such as physical, social, economic, and institutional mirroring established vulnerability and risk models such as Blaikie et al.'s Pressure-and-Release (PAR) model and Cutter's hazards-of-place framework.

The framework then identifies two main forms of adaptation that shape the capacity to cope with and recover from flooding. Institutional adaptation, which includes structural measures such as drainage construction, embankments, and flood walls. Non-structural measures such as land-use planning, early warning systems, community engagement, governance reforms, and emergency preparedness. Community-Based Adaptation, which includes locally driven actions such as elevated platforms, temporary barriers, drainage clearing, tree planting, emergency

savings, storing provisions, and participation in local decision-making. URT provides the conceptual foundation for understanding how these adaptation pathways strengthen community resilience. Institutional interventions support system-wide preparedness, while community initiatives foster social capital, knowledge, and local ownership of risk reduction.

The final component of the framework is community resilience, which emerges when institutional and community adaptation act together to moderate exposure, reduce sensitivity, and enhance the ability to withstand and recover from flood disturbances (Norris et al., 2008).

A resilient community is therefore one where environmental risks are addressed through equitable governance, robust infrastructure, proactive planning, and strong social networks.

The framework thus integrates theoretical insight with practical adaptation mechanisms to analyse and interpret flood occurrence and adaptation behaviour in TaMA.



## CHAPTER 3

### STUDY AREA AND METHODOLOGY

#### 3.1 Introduction

Chapter three provides a comprehensive overview of the study area and elucidates the methodologies employed for data collection. Situated within the Northern Region of Ghana, the study area is specifically delineated to encompass the Tamale Metropolitan Area. Within this urban context, the research narrows its focus to three (3) selected communities, chosen strategically to facilitate an in-depth investigation into the dynamics of flood occurrences and adaptation strategies. The methodological approaches adopted encompass a detailed exposition of the study design, sample methodology, data sources, and analytical procedures utilised to gather and analyse pertinent information.

#### 3.2 Study Area

This section explains the geographical and natural elements, as well as the anthropogenic and human factors, that characterise Tamale as a region susceptible to flood inundations. It explains the nature of the study areas to flooding, based on their natural and human-induced features. Natural elements refer to the features and components of an area that are not directly created.

##### 3.2.1 Geographical/Natural Elements of Tamale

###### 3.2.1.1 Location and Size

The research is located within the Tamale Metropolitan Area (Figure 3.1), a prominent urban centre in northern Ghana (Fuseini et al., 2017). Geospatially, Tamale is situated between latitudes 9.16° and 9.34° North and longitudes 00.36° and 00.57° West. Geographically,

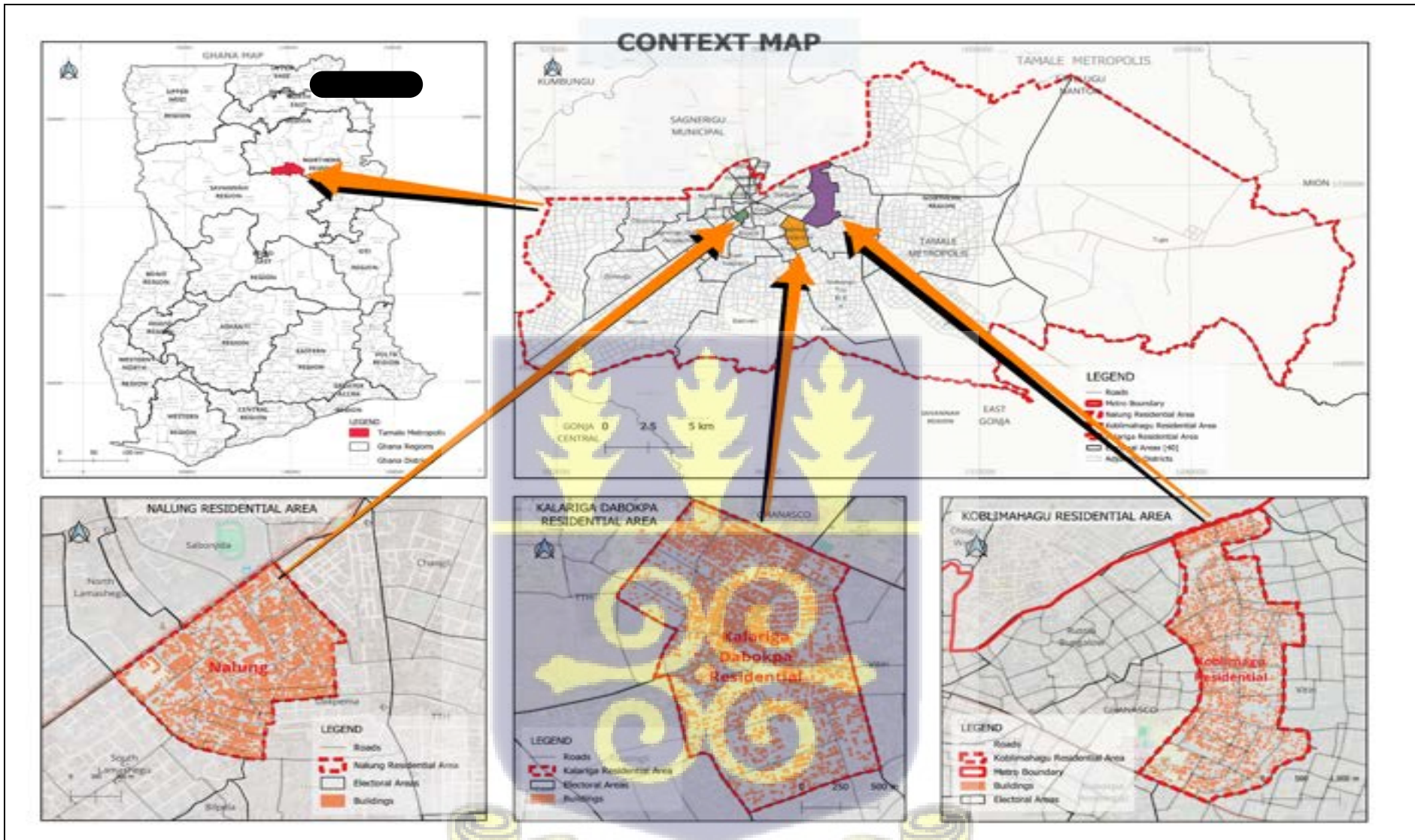


Figure 3.1 Study Area showing Nalung, Kalariga and Koblimahagu

Author's Construct, 2025.

Tamale is centrally located within the Northern Region of Ghana at an average elevation of approximately 180 metres above sea level (Ghana Statistical Service [GSS], 2021). The metropolis covers an estimated land area of 440.4 km<sup>2</sup> and serves as a major administrative and commercial hub in northern Ghana (Ghana Statistical Service [GSS], 2021b; Songsore, 2017). Administratively, Tamale is bordered to the west and north by the Sagnarigu Municipality, to the east by the Mion District, to the south by the East Gonja District, and to the southwest by the Central Gonja District. The creation of the Sagnarigu Municipality in 2012 resulted in the re-demarcation of the former Tamale metropolitan area, leaving the current Tamale Metropolis with the South Sub-Metro, Central Sub-Metro and the Central Annexe (Ministry of Local Government & Development, 2012). Tamale's strategic location positions it as an important economic corridor, linking southern Ghana to the Sahel region. Its centrality enhances its market potential, enabling it to serve as a key transit, trading, and service centre for agricultural produce and livestock from surrounding districts and neighbouring countries such as Burkina Faso, Mali, Niger, and Togo (Issahaku & Neysmith, 2017; Yaro, 2013). The metropolis contains 116 communities, of which 41 (35%) are urban, 15 (13%) are peri-urban, and 60 (52%) are rural (Ghana Statistical Service [GSS], 2021), reflecting its diverse settlement pattern and varying levels of infrastructure and service access.

The rural parts of the Tamale Metropolis constitute the primary zones for agricultural activities and serve as the food basket for the city, supplying cereals, vegetables, and livestock to urban markets (Issahaku & Maharjan, 2014; Metropolitan Planning Coordinating Unit, 2021). Despite their economic importance, these rural communities continue to face significant deficits in basic social and economic infrastructure, including all-weather roads, school facilities, health centres, markets, and recreational spaces (Ghana Statistical Service [GSS], 2021). These infrastructural deficiencies limit mobility, restrict access to essential services, and heighten vulnerability to climatic hazards. The geographic location and physical layout of the

Tamale Metropolitan Area also influence its exposure and vulnerability to flooding. Tamale lies within the Guinea Savannah ecological zone, characterised by a unimodal rainy season with intense, short-duration rainfall events that often trigger localised flooding (Abdul-Rahaman & Issahaku, 2020; Nyantakyi-Frimpong & Bezner-Kerr, 2015). Its expansive land area which includes densely built urban zones and low-lying rural settlements creates differential exposure patterns. Urban areas often experience flash floods due to limited drainage capacity, whereas rural areas are highly susceptible to flood-related crop losses, soil erosion, and livelihood disruptions (Diao et al., 2007; Yaro, 2013). These dynamics complicate flood adaptation efforts, as rural communities depend heavily on rain-fed agriculture and often lack the infrastructure and institutional support needed to recover from flood events.

### **3.2.1.2 Climatic Conditions**

Tamale's unique climatic patterns (Figure 3.2) are characterised by significant temperature variations, uneven rainfall distribution, and seasonal shifts, making it an ideal location for studying socio-spatial patterns of flood occurrence and adaptation. These climate factors contribute directly to the risk and impact of flooding within the metropolis, underscoring the city's suitability for this research.

#### **3.2.1.2.1 Temperature and Seasonal Variation**

Tamale, located in Ghana's Guinea Savannah ecological zone, experiences significant seasonal temperature changes that impact hydrological and environmental processes. These changes influence soil moisture dynamics, vegetation cover, and runoff generation, which are essential for understanding flood occurrence patterns in the area. The warmest month in Tamale is usually March, with average daily temperatures around 32.0 °C and maximums often surpassing 38.3 °C (Ghana Statistical Service [GSS], 2022; MPCU, 2021). Conversely, August, during the height of the rainy season, has the lowest average temperature of about

25.4 °C. These temperature changes correspond with important shifts in soil moisture content, vegetation cover, and rainfall intensity. It's crucial to recognize that high ambient temperatures alone do not significantly change the intrinsic hydraulic properties of soil, such as permeability or porosity. Literature on soil physics indicates that temperature variations only slightly affect water movement through soils by mildly decreasing water viscosity, which can increase saturated hydraulic conductivity by around 2% per °C (Constantz, 1982; Jury & Horton, 2004). However, these impacts are minimal compared to the effects of soil texture, organic matter, structure, and previous moisture conditions (Hillel, 1998; Montgomery et al., 2016). The indirect impact of high temperatures is on soil moisture status. Extended heat during the dry season, particularly from January to April, causes soil desiccation and the degradation of organic matter on the surface. This may lead to surface crusting or the formation of water-repellent (hydrophobic) layers due to the buildup of waxy organic compounds. Research in tropical and semi-arid regions, including Brazil and parts of West Africa, shows that during dry seasons, hydrophobic soils substantially hinder initial infiltration, often resulting in increased surface runoff when the first rains occur (Doerr et al., 2000; Mataix-Solera & Doerr, 2004). Furthermore, dry and crusted soils are susceptible to slaking when the first intense raindrops fall. This weakens soil structure, resulting in surface seals or crusts that diminish infiltration capacity (Valentina & Bressonb, 1992). Under these circumstances, early rains at the start of the wet season are more likely to cause rapid surface runoff and flash flooding, especially in areas with poor vegetation cover or compacted soils. Research in similar Sahelian and savannah environments has documented comparable soil moisture and infiltration dynamics, particularly during the early rainy season when soils exhibit high hydrophobicity following prolonged dry periods (Casenave & Valentin, 1989; Montgomery et al., 2016).

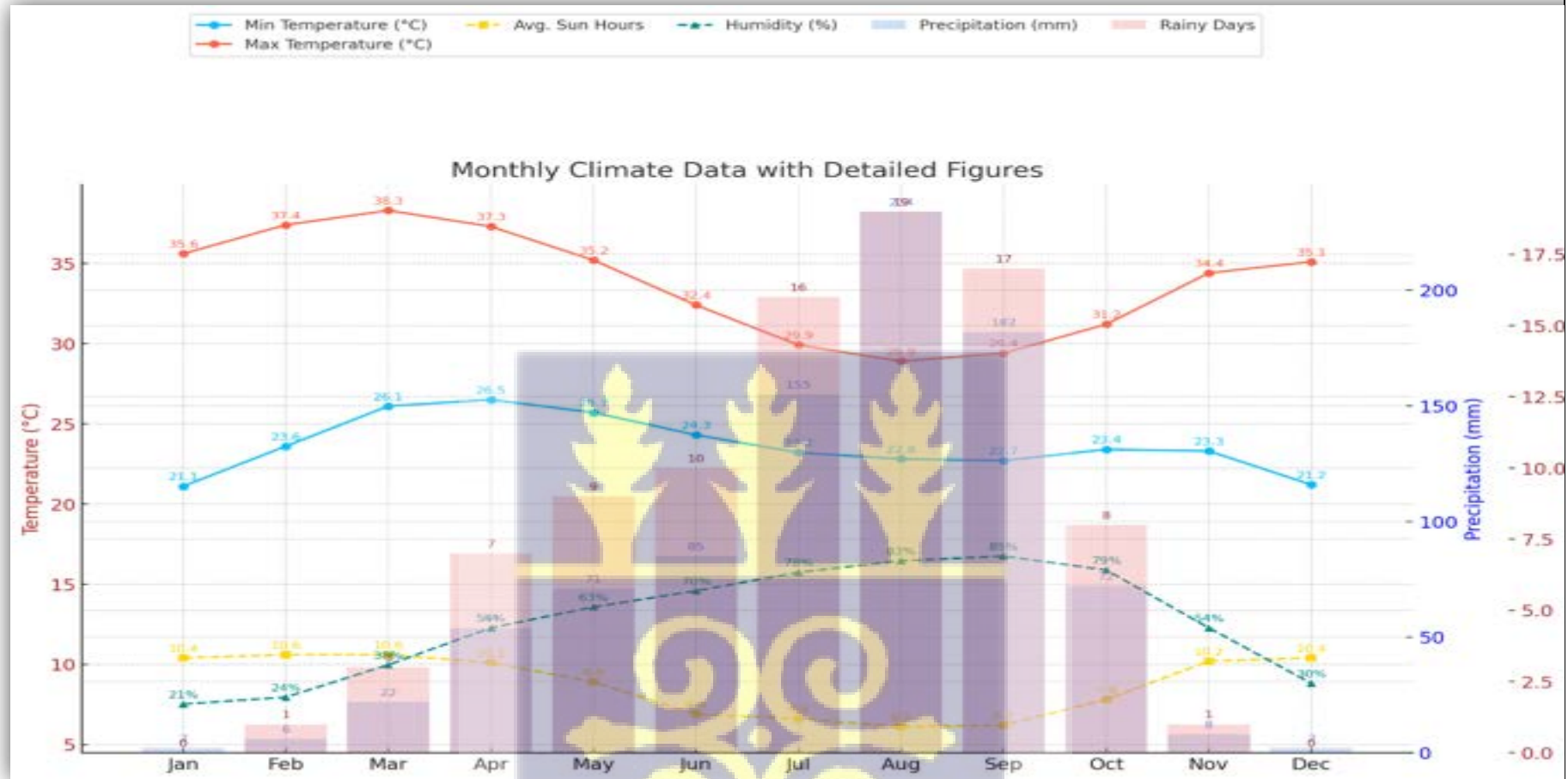


Figure 3.2 Climatic Conditions in Tamale from 1991 to 2021  
 Source: Climate Data, 2020



These studies confirm that semi-arid landscapes often experience reduced infiltration at the onset of rains, leading to rapid overland flow. By August, during the peak rainfall period, soil temperatures decline and repeated precipitation rehydrates the upper soil layers, increasing moisture retention and reducing hydrophobicity. This improves infiltration capacity; however, prolonged rainfall can still saturate the soil profile, especially on flat or gently sloping terrain, resulting in runoff and potential flooding. Hence, in Tamale, the interaction between seasonal temperature changes and soil moisture status, rather than temperature alone, is pivotal in determining runoff potential and flood risk. The transition from hot-dry to wet conditions is crucial for flood adaptation planning. Soils that have dried, hardened, or formed surface seals during the dry season may generate excessively high runoff once the rains commence, highlighting the necessity for seasonal preparedness, soil conservation, and maintaining vegetative ground cover as flood adaptation strategies.

### **3.2.1.3 Rainfall and Precipitation Patterns**

Rainfall in Tamale follows a distinct seasonal cycle with a single peak. The city's rainy season, extending from late May to early October, delivers a mean annual rainfall of 1200 mm, with rainfall concentrated in a few months, increasing the likelihood of flood occurrences (Ghana Statistical Service [GSS], 2014; MPCU, 2021). Table 3.2 shows that August experiences the highest rainfall, averaging 234 mm (9.2 inches) with up to 25 rainy days. This concentration of rainfall can easily overwhelm drainage systems, leading to flash floods in vulnerable areas.

#### **3.2.1.3.1 Humidity and Flood-Related Factors**

Humidity levels in Tamale also vary dramatically between seasons, directly impacting flood risk. The relative humidity peaks in September at 85%, a time of sustained rainfall and minimal sunshine, which reduces evaporation rates and allows floodwaters to persist in low-lying areas. Conversely, in January, humidity drops to around 21%, corresponding with the dry season

when flood risk is minimal, and soil and vegetation absorb more rain. The variation in humidity highlights the need for seasonally adaptive flood adaptation measures that address high-risk periods while considering the lower flood risks during drier months (Climate Data, 2022).

#### 3.2.1.3.2 The Northeast Trade Winds (the Harmattan)

The Harmattan winds significantly shape the spatial patterns of flood occurrence and management strategies in Tamale, influenced by their distinct seasonal impact from November to March. These winds, carrying dry, dusty air from the Sahara, notably decrease humidity and precipitation, which crucially dries up the region before the rainy season (A. Christopher, 2022; SkyLibrary, 2022; Whyte, 2024). This characteristic plays a vital role in reducing flood risk by minimising the duration and extent of seasonal water accumulation, thereby facilitating more effective flood adaptation (Ampofo et al., 2024; Sam, 2024). The interaction of the Harmattan with local climatic conditions has been the subject of detailed academic investigation. For instance, a study highlighted in *Atmospheric Chemistry and Physics* by Schepanski et al. (2017) elaborates on how the Saharan dust carried by these winds affects weather patterns, potentially impacting cloud formation and rainfall distribution, which are critical components in understanding flood dynamics. This modulation of rainfall can alter flood occurrence by changing how and where water accumulates during the rainy season. Additionally, the reduction in soil moisture due to the Harmattan's drying effects can influence the soil's absorption capacity, further affecting flood patterns. When rain does arrive, drier soils may either absorb rainwater more efficiently or, if overly desiccated, repel water, leading to increased surface runoff and potential flooding in different areas than typically expected (Whyte, 2024).

#### 3.2.1.4 Topography, Elevation and Drainage

Tamale has been selected for this study due to its distinctive topography and the significant impact that both topography and drainage have on flooding within the city (Figure 3.3). The city's landscape is primarily characterized by rolling terrain with gentle undulations, and its elevation averages around 183 meters above sea level (Topographic Maps, 2024). These variations in elevation, influenced by proximity to rivers, valleys, and isolated hills, contribute to the diversity of Tamale's landscape but also play a crucial role in its susceptibility to flooding. The shallow valleys in the northern areas of Tamale serve as natural stream courses during heavy rainfall, facilitating water flow across the landscape. However, the relatively flat terrain, combined with gentle undulations, can lead to water accumulation in low-lying areas. Water drains slowly due to the modest elevation, making these areas particularly prone to inundation. While isolated hills do not significantly impede physical development, they can disrupt natural drainage pathways if proper urban planning and drainage systems are lacking. Drainage infrastructure in Tamale presents significant challenges. The city has a scarcity of natural water bodies and limited artificial dams. The only natural water systems are a few seasonal streams that flow during the rainy season and dry up in the dry season (Laari, 2017). These streams originate from higher ground within Tamale but are insufficient for managing water flow during heavy rainfall. Artificial dams and dugouts, such as the Builpela, Lamashegu, Datoyili, and Water Works dams constructed by community members or non-governmental organisations, primarily serve as water sources for animals and domestic purposes rather than effective flood control mechanisms (MPCU, 2021). The inadequate drainage exacerbates flood risks, as there are limited means to manage excess water during intense rain events. Tamale's geographical positioning, situated approximately 35 kilometres east of the White Volta River and not directly on a major river or coastline, does not shield it from flooding. Its elevation on a plain exposes the city to flood risks, especially during heavy rainfall when water accumulates faster than it can be drained away.

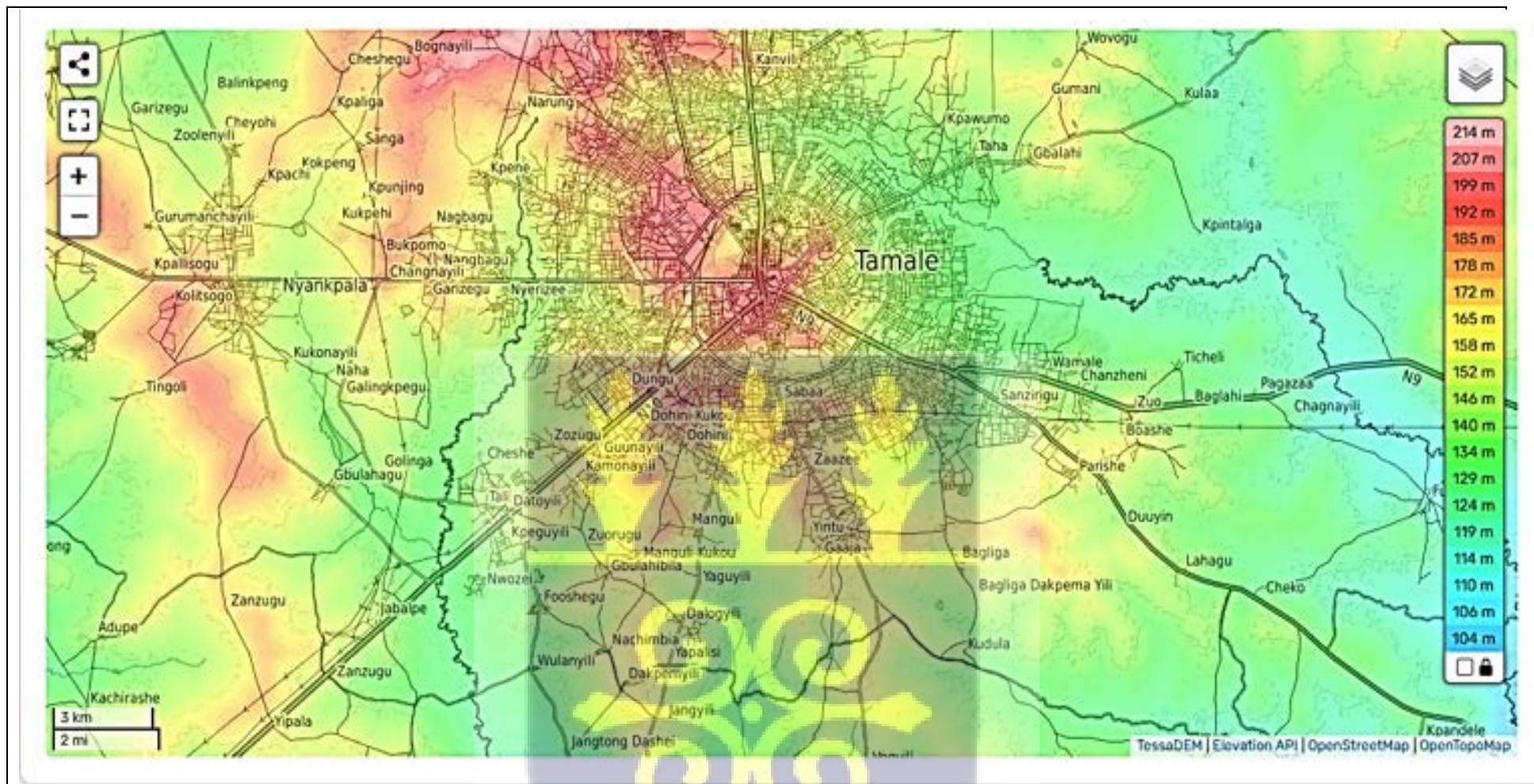


Figure 3.3 Topographical Map of Tamale

Source: Topographic Maps, 2024.

Efforts to enhance drainage infrastructure are essential. Understanding the interplay between topography, elevation, and drainage is crucial for developing sustainable flood adaptation strategies in Tamale (Topographic Maps, 2024). Tamale's unique topographical features and the significant influence of both topography and drainage on flooding make it an important case study.

### 3.2.1.5 Vegetation

Tamale, situated within the Guinean forest-savanna mosaic ecosystem, exhibits unique vegetation characteristics that significantly influence its flooding patterns. This ecological zone, the wettest among Ghana's savanna types, blends forest and savanna elements, creating a diverse yet vulnerable landscape. The region's vegetation comprises sparsely populated tree cover, shrubs, tall grasses, and deciduous trees. However, human activities and climatic factors have led to significant degradation and fragmentation of these ecosystems, increasing the area's susceptibility to flooding. Human-driven activities such as agriculture, urbanisation, and logging have contributed to deforestation. Farmers often clear forested areas to expand farmland, using fire to clear vegetation and flush out hunting game (Lindsey et al., 2013). These practices destroy tree cover and leave large tracts of land bare or fallow, diminishing the soil and vegetation's natural capacity to absorb rainfall. Deforestation practices have a significant impact on the hydrological dynamics of regions like Tamale, leading to increased surface runoff and heightened flood risks (Mensah et al., 2022). These activities destroy tree cover, leaving large tracts of land either bare or fallow, which reduces the soil and vegetation's natural capacity to absorb rainfall. Consequently, rainwater accumulates more rapidly, resulting in increased surface runoff that flows into rivers and streams. This increase can overwhelm the carrying capacity of these water bodies, resulting in flash floods during heavy rainfall events. A study conducted by Danáčová et al. (2020) in small mountainous basins in Slovakia, although in a different geographical context, provides pertinent insights into similar

hydrological impacts. The research demonstrates that deforestation results in significant changes in runoff conditions, with forest losses exacerbating the volume and peak of runoff during storm events. This, in turn, increases the likelihood of flash floods, especially under extreme weather conditions (Danáčová et al., 2020).

The loss of vegetation exacerbates flood severity in Tamale. Vegetative cover, particularly trees and grasses, plays a critical role in slowing surface runoff, enhancing soil infiltration, and reducing the erosive power of rainwater (Effiom et al., 2015). In Tamale, the removal of vegetation coupled with urban expansion significantly impacts flood dynamics, leading to increased surface runoff and heightened flood risks. These practices not only destroy tree cover, leaving large tracts of land bare or fallow, but also replace permeable surfaces with impervious materials such as roads and buildings. This transition diminishes the soil and vegetation's natural capacity to absorb rainfall, thus accelerating the accumulation of rainwater in low-lying areas and directing excessive rainfall into already strained drainage systems. As a result, this exacerbates flood risks by altering natural hydrological processes and increasing the volume and speed of runoff (Abhas et al., 2012; Danso et al., 2021; Umukiza et al., 2024). The remaining vegetation in Tamale is largely confined to protected areas or zones of marginal agricultural value, which limits its capacity to mitigate floods effectively. Moreover, the existence of "sacred groves", small patches of forest preserved due to cultural and social norms, while biodiverse and crucial for preserving ecological balance, is too limited in size to counteract the extensive loss of vegetation across urban areas effectively. Unsustainable practices such as hunting and habitat destruction not only threaten these groves but also diminish their ecological functions, further undermining their ability to support flood Adaptation (Agana et al., 2018; Bhagwat et al., 2005). Climate change introduces additional complexities by intensifying droughts and storms, which further degrade vegetation cover and exacerbate flooding during extreme weather events. Periods of drought weaken vegetation

health and coverage, reducing the land's natural ability to manage water, while intense storms overwhelm these degraded landscapes with severe flooding (IPCC, 2023c; Pizzorni et al., 2024).

### 3.2.1.6 Soil Type and Composition

The soil composition in Tamale plays a critical role in influencing the city's vulnerability to flooding. Soils naturally act as sponges, absorbing and storing water within their profiles to regulate water flow. This process mitigates surface runoff and reduces flood risks (Effiom et al., 2015; Yidana et al., 2019). However, the predominant soil types in Tamale Plinthosols and Ferric Acrisols have characteristics that limit their ability to absorb water, thereby exacerbating flood risks. Plinthosols, which cover significant portions of Northern Ghana, including Tamale, are characterised by a shallow "plinthic" or ironstone layer. This layer is dense, impermeable, and has a low water storage capacity, making it difficult for rainwater to infiltrate the soil (Asiamah & Dedzoe, 1999; Effiom et al., 2015). As a result, surface runoff increases during rainfall, particularly in Tamale's flat and low-lying areas, where water accumulates rapidly. These soils are also prone to erosion, further reducing their infiltration potential and contributing to sedimentation in nearby drainage systems, which worsens flooding. Ferric Acrisols, another common soil type in the region, naturally offer better infiltration rates when under vegetative cover. Their porous surface layers allow water to seep into the soil, reducing runoff and enhancing groundwater recharge. However, deforestation and agricultural activities often lead to the removal of vegetation, causing the soil surface to slake and form a hard crust (Effiom et al., 2015). This transformation impedes water infiltration, increasing runoff during rainfall events. In urban areas of Tamale, where natural soils are replaced with impervious surfaces such as roads and buildings, this problem is further exacerbated, contributing to severe flooding. The soil composition in Tamale interacts with the city's topography and drainage infrastructure to heighten its flood vulnerability. The low infiltration rates of Plinthosols and

degraded Ferric Acrisols contribute to rapid surface runoff, which converges in the shallow valleys and low-lying areas of the city. This runoff overwhelms the city's limited drainage systems, particularly during heavy rainfall, leading to flash floods. These dynamics highlight the importance of understanding soil types when assessing flood risks and planning urban development in Tamale. The soil types in Tamale Plinthosols and Ferric Acrisols are significant contributors to the city's flooding challenges. Their characteristics, combined with deforestation, agricultural expansion, and urbanisation, result in reduced water infiltration and increased surface runoff.

### **3.2.2 Anthropogenic/Human Characteristics**

#### **3.2.2.1 Population Growth**

Tamale, Ghana's second-fastest-growing metropolis, has been chosen for this study due to its rapid urbanisation and population growth, which have significantly influenced flooding in the streets, residential areas, and low-lying areas. According to the 2021 Population and Housing Census, Tamale Metropolitan had a population of 374,744, while Sagnarigu Municipal recorded 81,000 inhabitants. The entire population of the Northern Region stood at 2,310,943 (Ghana Statistical Service [GSS], 2021b). This results in a population difference of 293,744 between Tamale Metropolitan and Sagnarigu Municipal. Comparing these to the Northern Region, Tamale Metropolitan comprises approximately 16.2% of the region's total population, while Sagnarigu Municipal accounts for around 3.5%. Most of the Northern Region's population resides outside these two areas, highlighting the region's demographic diversity and the presence of numerous smaller towns and rural areas. According to the 2021 Population and Housing Census, Tamale's population reached 374,744, with a population density of 850.8 individuals per square kilometre and an annual growth rate of 4.9% (Ghana Statistical Service [GSS], 2022). This population expansion has reshaped the city's landscape, contributing to an increase in flood risks and revealing vulnerabilities in urban planning and infrastructure. The

population growth of Tamale has accelerated over time, particularly after the year 2000, as illustrated in Figure 3.4.

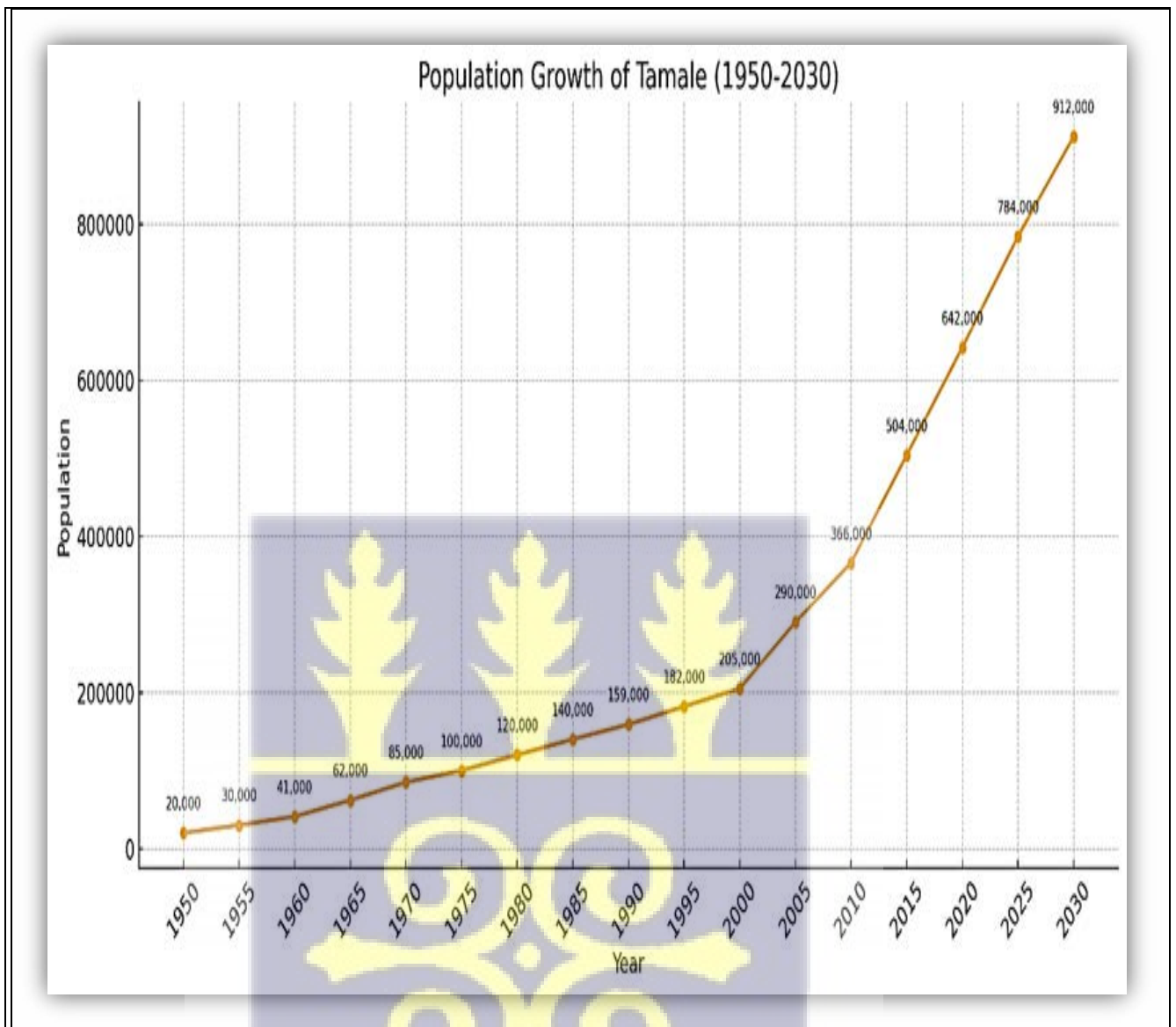


Figure 3.4 Population growth in Tamale from 1950 to 2030

<https://populationstat.com/ghana/tamale>

The surge in population has driven the conversion of natural landscapes into urbanised areas to accommodate the growing demand for housing, infrastructure, and services. Replacing natural vegetation and permeable soils with impervious surfaces such as roads, pavements, and buildings. These impermeable surfaces prevent water from infiltrating the ground, significantly increasing surface runoff during rainfall events. Increased runoff and the absence of adequate drainage infrastructure have led to frequent flooding in the city. Population growth has also

placed immense pressure on Tamale's existing drainage systems, many of which were designed for a smaller population and less developed urban environment. These systems are often inadequate to handle the volumes of surface runoff generated during heavy rains. Additionally, poor maintenance practices and the disposal of solid waste into drainage channels exacerbate the problem, causing blockages and reducing the system's capacity to manage water flow effectively. This inadequacy is evident in low-lying and densely populated areas, which experience the most severe flooding during heavy rain. Tamale's rapid population growth and urbanisation have played a significant role in increasing the city's flood risks. The transformation of natural landscapes into built-up areas, combined with inadequate drainage infrastructure and poor maintenance, has heightened the vulnerability of the metropolis to flooding. This study emphasises the crucial need for sustainable urban planning, enhanced drainage systems, and policies that effectively address the challenges posed by population growth to mitigate flooding risks in Tamale.

### **3.2.2.2 Ethnicity and Religion in Tamale**

Tamale's diverse ethnic and religious composition significantly influences its urban development and flood risk management strategies. The Dagombas constitute over 80% of the population, followed by groups such as the Gonja, Mamprusi, Nanumba, Konkomba, Asantes, Ewes, Hausa, and other minorities. This rich cultural tapestry shapes land-use practices, settlement patterns, and community governance, all of which impact the city's vulnerability to flooding. Traditional administrative structures within these ethnic groups are deeply rooted in connections to land, governance, and community decision-making processes. Leaders within these structures possess significant influence and local knowledge about land-use practices, historical flood patterns, and community needs. Understanding these cultural perspectives is essential for effective flood risk management in Tamale. Each ethnic group may have unique approaches to living harmoniously with the environment and addressing flood risks.

Religiously, approximately 90.5% of Tamale's population identifies as Muslim, with Christians comprising a significant minority. Among Christians, the Catholic community constitutes 3.0%, followed by Pentecostal/Charismatic and Protestant denominations, each accounting for 2.4%. Additionally, approximately 0.3% of the population adheres to traditional religious practices. Islamic propagation centres, such as the Central Mosque and the Ambariya mosques, play significant roles in community education and moral guidance, contributing to social cohesion. These institutions can influence spatial patterns of vulnerability to flooding by shaping settlement locations and community responses to environmental challenges. Settlement patterns influenced by ethnic and religious affiliations can concentrate populations in specific areas, thereby affecting access to resources and infrastructure. For instance, communities with strong traditional leadership may have established settlements in low-lying areas due to historical land allocations, making them more susceptible to flooding. Conversely, religious institutions often serve as centres for community gatherings and can be pivotal in disseminating information on flood risks and mobilising resources for disaster response.

Collaborative efforts that integrate diverse cultural perspectives and engage with traditional and religious leaders are crucial for developing comprehensive flood risk management strategies that cater to the needs of all communities in the metropolis. Incorporating local knowledge and respecting cultural practices can enhance the effectiveness of flood Adaptation measures and ensure equitable distribution of resources. Moreover, fostering inter-tribal cooperation and inclusive governance can help bridge disparities in access to resources and representation, thereby reducing socio-spatial inequities in flood vulnerability. Ethnic and religious diversity play a crucial role in shaping its flood risk profile. Understanding and integrating these cultural dimensions into urban planning are vital for building resilient communities capable of effectively responding to the challenges posed by flooding.

### 3.2.2.3 Housing Characteristics in Tamale

The 2021 Population and Housing Census provides a comprehensive analysis of housing characteristics in Tamale. This data highlights critical intersections between housing typologies, spatial vulnerabilities, and flood adaptation challenges. The housing landscape in Tamale, characterised by a mix of traditional and modern structures, plays a significant role in influencing the city's susceptibility to flooding. Tamale's predominant housing type, the compound house, accounts for approximately 56% of all residential units. This housing style, deeply rooted in local traditions, supports communal living but is particularly vulnerable in low-lying, flood-prone areas. These areas often experience significant surface runoff during heavy rainfall, exacerbated by the clustering of structures and limited drainage capacity. Separate houses, constituting 30% of residential units, and semi-detached houses, making up 8%, are relatively less affected due to their more dispersed layouts. The ownership status of dwellings further influences resilience, with 60% of households living in owner-occupied homes. Owners are more likely to invest in flood-resilient measures, such as elevated foundations, compared to tenants, who constitute 35% of households (Ghana Statistical Service [GSS], 2022).

The materials used in housing construction have a significant impact on flood vulnerability. Approximately 65% of houses in Tamale have walls made of cement blocks or concrete, materials known for their durability and water resistance. However, 30% of houses rely on mud bricks or earth, which deteriorate rapidly when exposed to water, particularly in peri-urban and rural areas. Roofing is primarily composed of metal sheets, which are found in over 85% of residential buildings. These are effective for shielding structures from rainfall but do little to mitigate flooding. Flooring materials, such as cement or concrete, are present in 70% of homes, offering a degree of protection from floodwaters. However, 25% of homes, particularly those in low-income areas, still rely on earth or mud floors, which are highly susceptible to water

damage (GSS, 2022). Access to utilities, such as electricity, water, and sanitation, exposes disparities in flood adaptation capacities. The census reports that 87% of households have access to electricity, enabling them to utilise early warning systems and flood Adaptation technologies. However, power outages during floods remain a concern, particularly in less urbanised areas. Water supply sources are unevenly distributed: 40% of households rely on boreholes or tube wells, 35% access piped water systems, and 25% depend on unimproved sources like rivers or ponds. This dependence on unimproved sources increases health risks during flood events due to water contamination (Ghana Statistical Service [GSS], 2022). Sanitation facilities are similarly diverse: 45% of households have access to improved sanitation, 35% rely on shared facilities, and 20% lack adequate sanitation altogether, often resorting to open defecation. These conditions exacerbate public health vulnerabilities during flooding, contributing to the spread of waterborne diseases. The socio-spatial distribution of flood-prone areas in Tamale aligns closely with the patterns of housing and utility access. Low-lying neighbourhoods and settlements near water bodies face heightened flood risks due to poor drainage infrastructure and inadequate land-use planning. Compound houses, often concentrated in these zones, are disproportionately affected by floods. Peri-urban areas with high concentrations of mud-brick houses and limited infrastructure experience recurrent inundation. Urban areas, characterised by impermeable surfaces and dense populations, suffer from flash floods as stormwater drainage systems are overwhelmed. Flood adaptation in Tamale must address these vulnerabilities through targeted interventions.

#### **3.2.2.4 Occupational Structure**

The 2021 Population and Housing Census (PHC) conducted by the Ghana Statistical Service provides a comprehensive overview of Tamale's occupational landscape, revealing significant implications for flood occurrence and adaptation strategies. Service and sales workers constitute the largest segment of the employed population in Tamale, accounting for 33.0%.

This category encompasses individuals engaged in wholesale and retail trade, repair of motor vehicles and motorcycles, and other service-oriented roles. Notably, the wholesale and retail sector employ 33.4% of the workforce, with a higher proportion of female workers (45.4%) compared to males (22.1%). The prominence of the private informal sector in Tamale's employment landscape shows the prevalence of informal economic activities. Many individuals operate as street vendors, small-scale traders, or artisans, often conducting business in areas lacking adequate infrastructure and proper drainage systems. These zones are particularly susceptible to flooding, which can disrupt daily operations and threaten livelihoods. For instance, heavy rains have led to flooding in the Central Business District of Tamale, adversely affecting numerous businesses and leaving many road users stranded. The concentration of economic activities in flood-prone areas exacerbates the vulnerability of the workforce. Informal sector workers typically lack social protection and insurance, rendering them more susceptible to the economic impacts of flooding. Flood events can lead to the destruction of goods, damage to equipment, and loss of income, with limited avenues for financial recovery.

Additionally, the prevalence of occupations in craft and related trades (21.5%) and skilled agriculture, forestry, and fishery work (17.6%) involves activities often conducted in open spaces or near water bodies. Flooding can halt production, damage tools, and destroy products, leading to significant income losses for individuals in these sectors. The reliance on these occupations for employment highlights the necessity of implementing effective flood Adaptation measures to safeguard both the workforce and the local economy. The gender disparity in employment within the wholesale and retail sectors has further implications for flood vulnerability. With a higher proportion of female workers engaged in these industries, flooding events can disproportionately affect women's livelihoods, potentially exacerbating existing socio-economic inequalities. Addressing these disparities requires inclusive flood risk

management approaches that consider the specific needs and vulnerabilities of different demographic groups. Tamale's occupational structure plays a crucial role in shaping the city's flood vulnerability. The dominance of informal economic activities, the concentration of industries in flood-prone areas, and gender disparities in employment necessitate comprehensive and inclusive flood risk management strategies.

### 3.2.2.5 Urbanisation

Tamale, the second-fastest-growing metropolis in Ghana, is undergoing rapid urbanisation and population expansion, resulting in a densely inhabited and increasingly complex urban environment (Figure 3.5).



Figure 3.5 Urbanization and Housing Density in Tamale  
Field Data, 2023

The predominance of the urban population constituting 80.8% of the total (Ghana Statistical Service [GSS], 2021a) has accelerated the demand for housing and infrastructure, placing pressure on existing drainage systems during intense rainfall events. The widespread use of compound housing, combined with a persistent housing deficit and varied construction materials, further contributes to stormwater management challenges across the metropolis (Ghana Statistical Service [GSS], 2022; MPCU, 2021). The aerial image in Figure 3.5 depicts a highly built-up section of central Tamale characterised by densely clustered residential units, commercial structures, and extensive paved road networks. Such urban configurations are associated with large expanses of impermeable surfaces, metal rooftops, asphalted roads, and compacted ground surfaces which significantly reduce infiltration and increase the volume of surface runoff during rainfall events (Douglas et al., 2008; Gyasi et al., 2014). These conditions are widely documented in Ghanaian cities, where rapid urban development often surpasses the expansion and upgrading of drainage infrastructure (Amoako & Inkoom, 2018b; Fuseini & Kemp, 2016). While the image provides a snapshot of the metropolitan core, the concentration of impervious surfaces visible in Figure 3.5 is consistent with research indicating that central Tamale experiences frequent pluvial flooding owing to limited natural infiltration areas and inadequate stormwater channels (Abdul-Rahaman & Issahaku, 2020). The high-density development reflected in the photograph, combined with the narrow and irregular street patterns typical of older neighbourhoods, restricts space for drainage corridors and complicates maintenance efforts.

Socio-spatial variations in flood occurrence within Tamale also stem from uneven infrastructure distribution and differences in planning enforcement across neighbourhoods. Several studies have shown that informal and peri-urban settlements in Ghana often lack engineered drainage systems, are developed without adherence to land-use regulations, and may be situated in environmentally sensitive or flood-prone areas (Rain et al., 2011; UN

Habitat, 2020). In Tamale, these settlements face heightened exposure to flooding due to poor drainage connectivity, inadequate waste management, and lower adaptive capacity (Yaro, 2013). As illustrated in Figure 3.5 and supported by empirical research, the interplay between rapid urbanisation, insufficient drainage infrastructure, and spatially uneven development contributes significantly to flood occurrence and vulnerability in Tamale. The challenges associated with rapid urbanisation particularly inadequate drainage, impervious surface expansion, and irregular settlement growth extend beyond physical planning concerns. They also intersect with the state of water supply, sanitation, and waste management services across the metropolis. These WASH-related pressures significantly shape how communities experience and respond to flooding. Consequently, the following section examines Tamale's WASH infrastructure and its direct implications for flood occurrence, vulnerability, and public health.

#### **3.2.2.6 Water, Sanitation, and Hygiene**

Tamale's rapid population growth has increased to about 60.8% between 2010 and 2021 and has placed substantial pressure on its water, sanitation, and hygiene (WASH) systems (Ghana Statistical Service [GSS], 2021b). Recent studies on water security in sub-Saharan African cities, including Accra and Tamale, show that extreme rainfall events disrupt potable water supply and strain ageing urban water infrastructure (Kayaga et al., 2021). In Tamale, intermittent piped-water services lead many households to depend on alternative water sources such as wells, surface water, and vendors, which become highly susceptible to contamination during flood events (UNICEF, 2021). The White Volta, the city's principal raw water source, is increasingly impacted by farming along riverbanks, sand mining, and vegetation loss, which elevate sediment loads and turbidity. Similar basin-wide pressures in northern Ghana have been shown to reduce treatment efficiency and increase vulnerability to microbial contamination during flooding (Dzodzomenyo et al., 2022; Ntajal et al., 2022). As floodwaters mix with

surface pollutants and faecal matter, both formal and informal water sources face heightened risk of contamination (Ayeh & Ewool, 2022). Sanitation conditions in Tamale further amplify flood risk. The reliance on shared and public toilets remains high, a pattern consistent across urban Ghana, where inadequate operation and maintenance of on-site sanitation systems often lead to overflow during heavy rainfall (GSS/UNICEF, 2018).

In Tamale specifically, sanitation assessments show frequent failures of KVIPs and septic systems in low-lying communities, resulting in the spread of untreated waste into drains and streets during storms (Abarike et al., 2020). These failures significantly raise the likelihood of cholera, diarrhoeal diseases, and other water-related public health crises. Solid waste management compounds these challenges. Waste management research in Ghana indicates persistent gaps in collection, poor disposal practices, and inadequate waste segregation conditions especially pronounced in secondary cities such as Tamale (Kusi-Appiah et al., 2025). Indiscriminate dumping is strongly linked to blocked drains and increased urban flood frequency (Ofori, 2025; D. K. Okyere, 2013). In densely populated areas such as the Central Business District, uncollected waste often accumulates in open drains, causing them to overflow rapidly during rainfall (Tamale Metropolitan Assembly, 2022). Flood vulnerability in Tamale closely reflects these WASH deficits. Low-lying areas near the White Volta face the greatest contamination risk, while informal settlements with inadequate drainage and insufficient sanitation experience recurrent flooding and prolonged public health challenges. Urban surfaces dominated by impervious construction exacerbate runoff, overwhelming the drainage network during intense rainfall (Lwasa, 2014). The interactions between WASH infrastructure and flood risk highlight the multi-dimensional nature of vulnerability in Tamale. While weak drainage and environmental sanitation intensify flood impacts, socio-economic and spatial inequalities further shape how different neighbourhoods are affected.

### 3.2.2.7 Hybrid Governance and Flood Risk in Tamale

The governance system in Tamale operates under a hybrid model, integrating both formal administrative structures and traditional leadership. This dual system enables the city to navigate diverse social, cultural, and environmental challenges, including flood risk management. Local government institutions play a critical role in crafting policies, implementing flood Adaptation strategies, and overseeing disaster preparedness and response initiatives. However, the effectiveness of these measures is often contingent upon collaboration with traditional authorities, civil society organisations, and local communities (Agyei-Mensah et al., 2024). As the primary agent of formal governance, the local government in Tamale is responsible for formulating policies aimed at reducing flood vulnerabilities. This includes zoning regulations to control urban expansion, the construction and maintenance of drainage systems, and the enforcement of environmental protection standards. Additionally, local government bodies coordinate emergency response initiatives, facilitate recovery efforts, and engage in climate adaptation planning (Agyei-Mensah et al., 2024). However, urbanisation challenges, including rapid population growth and inadequate infrastructure, often outpace the capacity of local authorities to manage flood risks effectively. Limited financial resources, technical expertise, and bureaucratic inefficiencies further constrain their ability to implement large-scale flood Adaptation projects (Poku-Boansi et al., 2020; Watkins & Collins, 2024). Traditional authorities, including the Dakpema, Gulkpe Naa, Lamashe Naa, and Banvim Lana, play an integral role in local governance and decision-making processes. These leaders, along with sub-chiefs and opinion leaders, hold significant influence over land use, community development, and disaster response strategies. Their deep-rooted indigenous knowledge, based on historical flood events, local weather patterns, and geographical risk assessment, provides valuable insights that complement the technical expertise of formal governance structures (Agyei-Mensah et al., 2024).

Studies on hybrid governance in flood risk management suggest that indigenous knowledge contributes to the identification of historically flood-prone areas and facilitates the prediction of seasonal vulnerabilities (Atanga, 2020; Ibrahim et al., 2023). Moreover, traditional leaders often mobilise community members to engage in environmentally sustainable practices, such as tree planting and the maintenance of local drainage systems, reinforcing collective resilience to flood risks (Amankwaa et al., 2024). Despite their influence, traditional authorities face challenges in engaging with formal governance structures. Disparities in decision-making power, jurisdictional conflicts, and inconsistent integration of indigenous knowledge into formal flood adaptation policies limit the potential for seamless cooperation. A study by Agyei-Mensah et al. (2024) emphasises that while traditional leaders play a pivotal role in flood resilience, their contributions are often undervalued in state-led disaster preparedness programs.

Civil society organisations (CSOs), including non-governmental organisations (NGOs) and community-based organisations (CBOs), serve as intermediaries in bridging the gap between government institutions and local communities. These organisations provide technical expertise, mobilise resources, and advocate for inclusive and sustainable flood risk management strategies. For instance, CSOs have facilitated the implementation of community-led early warning systems and have played a vital role in integrating gender-sensitive approaches in disaster management (Izumi & Shaw, 2011; Lassa, 2018; Owusu et al., 2024; Syal et al., 2021). Moreover, NGOs often champion equitable resource distribution, ensuring that vulnerable communities receive adequate support during flood emergencies. Their advocacy efforts contribute to policy dialogues that align local interests with broader national and international disaster risk reduction frameworks (Lassa, 2018). While hybrid governance presents opportunities for inclusive flood adaptation, several challenges hinder its

effectiveness. One primary issue is the fragmentation of responsibilities between formal and traditional authorities. Overlapping jurisdictional mandates often lead to conflicts in decision-making, causing delays in flood prevention projects. Disputes over land use, for example, can slow down the construction of essential flood control infrastructure, such as retention ponds and drainage networks (Agyei-Mensah et al., 2024).

Moreover, local governments in Tamale face significant resource constraints in addressing flood risks. Budget limitations, inadequate technical expertise, and shortages of trained personnel make it difficult to implement large-scale flood Adaptation initiatives. Additionally, urbanisation has increased the complexity of flood risks by escalating population density, promoting unregulated construction, and encouraging encroachments along flood-prone waterways, further straining governance capacities (Kosoe et al., 2021; Poku-Boansi et al., 2020). Coordination gaps among stakeholders also present a significant challenge. Effective flood risk management requires collaboration between governmental bodies, traditional leaders, civil society organizations, and local communities. However, the absence of clear communication channels and well-defined roles often impedes cooperation. While traditional authorities wield considerable influence in mobilizing communities, formal governance structures sometimes struggle to engage marginalized groups effectively, leading to inequitable resource distribution and reduced participation in flood risk adaptation programs capacities (Kosoe et al., 2021; Poku-Boansi et al., 2020).

CSOs, despite their critical role, also face constraints in scaling their operations and aligning their efforts with government policies. The lack of long-term financial sustainability for many community-driven flood adaptation initiatives limits their effectiveness in sustaining disaster resilience programs. Despite these challenges, the hybrid governance system in Tamale presents unique opportunities to enhance flood risk management through collaborative

approaches. By formalising the role of traditional authorities in disaster management policies, local government structures can leverage indigenous knowledge to develop more context-specific and culturally sensitive flood Adaptation strategies (Agyei-Mensah et al., 2024). Additionally, enhancing coordination mechanisms among governmental institutions, traditional leaders, and civil society organisations (CSOs) can improve resource allocation and streamline disaster preparedness programs. Institutional capacity-building efforts, including training local government officials on climate adaptation planning and integrating community-based disaster risk reduction approaches, will be instrumental in ensuring that flood risk governance in Tamale remains proactive and inclusive (Poku-Boansi et al., 2020). Moreover, investing in sustainable flood control infrastructure, such as nature-based solutions, wetland restoration, and improved drainage systems, can provide long-term benefits for flood resilience. Engaging local communities in participatory planning processes will further promote ownership and ensure the sustainability of flood Adaptation initiatives. By recognizing the complementary strengths of formal governance, traditional authorities, and civil society organisations, Tamale can develop a holistic and resilient flood risk management framework that safeguards lives, livelihoods, and infrastructure.

### **3.3 Research Methodology**

This section explains the methodological approaches used to investigate the socio-spatial dynamics of flood occurrence and adaptation in the Tamale Metropolitan Area (TaMA). It outlines the research paradigm, design, analytical framework, hypotheses, variable operationalisation, sampling procedures, data collection instruments, data analysis techniques, and ethical considerations. The mixed-methods approach adopted in this study enabled a rigorous integration of quantitative indicators with qualitative insights to understand the multidimensional nature of flood occurrence and adaptation in TaMA.

### 3.4 Philosophical Paradigm of the Study

The philosophical foundation of this study is grounded in pragmatism, which is articulated and conceptualises knowledge as practical, action-oriented, and focused on identifying what works within real-world contexts (Dewey, 1916, 1922; James, 1898, 1907). Pragmatism rejects rigid adherence to a single methodological tradition, instead advocating the use of multiple approaches to address complex societal and environmental issues. Cameron (2011) similarly highlights that pragmatism prioritises the practical dimension of problem-solving, making it particularly suitable for research situated at the intersection of scientific inquiry, community needs, and policy action. In the context of urban flood adaptation, a pragmatic paradigm supports the comprehensive evaluation of diverse interventions. These range from traditional engineering solutions such as dams and drainage infrastructure to more innovative and integrative strategies, including community-based early warning systems, distributed green infrastructure, and nature-based solutions such as wetland restoration and river corridor rehabilitation (Aerts et al., 2014; Kabisch et al., 2017; Liao, 2012). Pragmatism's emphasis on experimentation and methodological flexibility ensures that interventions are assessed not only for theoretical robustness but also for feasibility, adaptability, and contextual appropriateness within specific geographical and socio-economic settings. This orientation is aligned with using multiple methods to address complex societal and environmental issues.

Recent scholarship further underscores the importance of such a holistic and context-sensitive approach. Pecharroman and Hahn (2023) draw attention to systemic inequalities embedded in flood adaptation efforts, arguing that adaptation strategies often disproportionately benefit more privileged groups. Similarly, Ma and Mostafavi (2024) demonstrate how urban form and spatial configuration contribute to unequal patterns of property-level flood exposure. These insights highlight the need to address the underlying structural drivers of vulnerability, including socio-spatial inequities, governance gaps, and historically embedded land-use

decisions (Meerow et al., 2016). Understanding these dynamics requires methodological pluralism capable of capturing both qualitative lived experiences and quantitative patterns of risk. By drawing on pragmatism as the philosophical foundation and implementing a mixed-methods research strategy, this study addresses the multidimensional nature of urban flood hazards and vulnerabilities. The approach facilitates the integration of scientific evidence, community-generated knowledge, and policy analysis, ultimately supporting the development of interventions that are socially just, contextually relevant, and practically feasible. This aligns with the pragmatic commitment to generating actionable knowledge capable of informing real-world decision-making and contributing to the resilience and well-being of flood-prone communities.

### **3.5 Research Design**

The study employed a cross-sectional research design, collecting data from selected communities at a single point in time (Creswell & Creswell, 2018). This design was appropriate because the study sought to examine existing conditions specifically patterns of flood occurrence and adaptive capacity especially institutional support and community based adaptation across communities with varying socio-economic characteristics. Cross-sectional research is particularly suitable for exploring socio-spatial variations without manipulating variables or requiring follow-up observations over time. In the context of flood research, a cross-sectional design makes it possible to compare household and community differences in flood experiences within the same flood season.

By capturing data from multiple neighbourhoods simultaneously, the design supports the identification of inequalities in exposure and adaptation, consistent with the study's theoretical grounding in Urban Political Ecology (UPE) and Urban Resilience Theory (URT). The design therefore provided the structural basis for a broader mixed-methods strategy.

### 3.6 Research Approach

A Sequential Exploratory Mixed-Methods Approach (Bryman, 2012; Creswell & Plano Clark, 2023) guided the study. Mixed-methods research was necessary because flood occurrence is multidimensional, involving physical, socio-economic, and institutional factors that no single method can adequately capture. The study began with a qualitative phase aimed at understanding community experiences, local flood histories, institutional practices, and adaptation strategies. This phase drew on key informant interviews with agencies responsible for hydrology, meteorology, spatial planning, disaster management, sanitation, and community mobilisation; focus group discussions with residents of urban, peri-urban, and rural communities; participant observation to document housing conditions, physical infrastructure, and environmental stressors; and photographic documentation of flooded areas, damaged structures, and drainage systems. Together, these methods generated in-depth insights that informed the design of the quantitative household survey, ensuring contextual relevance and alignment with lived realities. The second phase used a structured household survey derived from qualitative insights to measure key variables such as flood occurrence, exposure, and adaptive capacity and test emerging patterns. Integration occurred through triangulation at two points: qualitative findings shaped the survey's design, and quantitative results were interpreted in light of qualitative accounts. This strengthened validity, reduced bias, and provided a more comprehensive understanding of flood occurrence in TaMA as a socio-ecological phenomenon.

### 3.7 Analytical Framework and Hypotheses

This study draws upon the theoretical foundations presented in Chapters One and Two to construct an analytical framework that explains the socio-spatial patterns of flood occurrence and adaptation in the Tamale Metropolitan Area (TaMA). Grounded in Urban Political Ecology (UPE) and Urban Resilience Theory (URT), the framework shows how structural inequalities, political and institutional arrangements, environmental conditions, and community capacities

shape the differentiated experiences of flood risk and adaptation across socio-economic groups. UPE emphasises how socio-economic inequality, land-use politics, and uneven infrastructural investment create spatially differentiated exposure to hazards. URT complements this perspective by explaining how material resources, knowledge, and social networks influence adaptive capacity, preparedness, and recovery. Together, these theoretical lenses position flood risk in TaMA as a socially produced, spatially embedded, and institutionally mediated phenomenon.

### **3.7.1 Conceptualising SES as the Independent Variable**

Socio-economic status (SES) serves as the primary independent variable in this study. SES captures both household-level characteristics and broader socio-spatial stratification across different neighbourhoods. It is measured using monthly household income educational attainment of household head, occupation of household head housing quality and building material and permanency of dwelling structure. These indicators were standardised and combined into a composite SES index. In addition, community-level SES classifications defined by Ghana Statistical Service (GSS) and TaMA as high-, middle-, and low-income neighbourhoods were used as spatial proxies. Income data collected in this study validated these official SES categories, confirming their suitability for socio-spatial analysis.

### **3.7.2 Dependent Variables and Mediating Factors**

Based on the theoretical and empirical foundations, the analytical framework identifies three dependent variables: 1. Flood occurrence (frequency, extent, penetration into homes), 2. Institutional flood adaptation support (warnings, emergency response, relief, drainage investment) and 3. Community-based adaptation strategies (communal drain clearing, embankment construction, sandbagging, household measures). These outcomes are influenced by multiple mediating variables, grouped into natural/environmental and

anthropogenic/governance categories. These variables explain why SES differences translate into spatial patterns of flood exposure and adaptation. The natural/environmental mediators include rainfall intensity, frequency, and seasonal patterns, temperature trends and soil hardening, elevation and topography, proximity to water bodies and drainage paths, vegetation cover and green buffers and drainage capacity and hydrological flow patterns. The anthropogenic and governance mediators include waste disposal practices (especially plastic waste), land-use changes, illegal structures, encroachment, housing typologies and construction materials, road infrastructure and impervious surfaces, drainage design, size, maintenance, and accessibility, zoning enforcement (or lack thereof), institutional support distribution, political attention, resource allocation and traditional authority land allocation practices. Together, these mediators operationalise how socio-economic structures translate into differentiated flood risks and adaptation pathways.

### **3.7.3 Integration within a Sequential Exploratory Mixed-Methods Design**

In line with the methodological strategy adopted in Chapter Three, the analytical framework is structured to support a Sequential Exploratory Mixed-Methods Design:

1. Qualitative Phase (Exploration): KIIs, FGDs, and field observations identify the key socio-spatial, environmental, and governance mechanisms that shape flood risk and adaptation. These qualitative findings guide variable selection, indicator construction, and hypothesis formulation.
2. Quantitative Phase (Testing): Household survey data test the relationships identified qualitatively, using statistical procedures (chi-square, Kruskal–Wallis) to determine whether SES significantly predicts flood occurrence and adaptation patterns.

3. Spatial Integration (Contextualisation): GIS data refine interpretation by linking SES-based exposure and adaptation patterns to physical geography, drainage networks, housing density, and environmental constraints.

The framework therefore blends theory, qualitative insight, quantitative testing, and spatial evidence into a coherent analytical structure. These relationships are illustrated in Figure 3.6, which presents the analytical framework used to structure the empirical analysis.

### 3.7.4 Hypotheses of the Study

Drawing from UPE, URT, and the mediating pathways discussed, the analytical framework proposes three core hypotheses:

#### **Hypothesis 1: Socio-economic status and frequency of flood occurrence**

These hypotheses are based on UPE's assertion that inequality in land-use planning and infrastructure generates spatially uneven environmental risks (Douglas et al., 2008; Swyngedouw & Heynen, 2003).

*Null Hypothesis ( $H_{01}$ ):*

*$H_{01}$ : There is no significant relationship between community socio-economic status and the frequency of flood occurrence in the Tamale Metropolitan Area.*

*Alternative Hypothesis ( $H_1$ ):*

*$H_{12}$ : There is a significant relationship between community socio-economic status and the frequency of flood occurrence in the Tamale Metropolitan Area.*

The basis of this hypothesis is that socio-economic status (SES) measured through indicators such as income, education, occupation, and housing quality is widely used in environmental vulnerability studies (Amoako & Inkoom, 2018). UPE suggests that low-income groups are more likely to reside in low-lying or under-serviced areas due to exclusion from formal planning and secure tenure, resulting in higher flood impacts.

#### **Hypothesis 2: Socio-economic characteristics and institutional flood adaptation support**

These hypotheses draw from UPE's critique of uneven state intervention and "resilience gentrification" (Anguelovski et al., 2016; Gould & Lewis, 2021) and URT's focus on governance and institutional responsiveness (Ziervogel et al., 2017).

*Null Hypothesis (H<sub>02</sub>):*

*H<sub>02</sub>: "There is no significant relationship in the level of institutional flood adaptation support across communities with different socio-economic characteristics."*

*Alternative Hypothesis (H<sub>12</sub>):*

*H<sub>12</sub>: "There is significant relationship in the level of institutional flood adaptation support across communities with different socio-economic characteristics."*

The basis of this hypothesis stems from the fact that research in Ghana shows that agencies such as NADMO and local government bodies tend to distribute support unevenly, often favouring wealthier or more visible neighbourhoods over marginalised ones (Manful & Opoku-Ankomah, 2021).

### **Hypothesis 3: Socio-economic status and adoption of community-based adaptation**

These hypotheses are grounded in UPE's view that autonomous, community-driven adaptation emerges from institutional neglect (Chaffin et al., 2016; Swyngedouw & Heynen, 2003), and URT's notion of *everyday resilience* (Friend & Moench, 2013; Sharpe, 2018)

*Null Hypothesis (H<sub>03</sub>):*

*H<sub>03</sub>: "There is no significant relationship in the level of adoption of community-based flood adaptation strategies across communities with different socio-economic characteristics"*

*Alternative Hypothesis (H<sub>13</sub>):*

*H<sub>13</sub>: "There is significant relationship in the level of adoption of community-based flood adaptation strategies across communities with different socio-economic characteristics"*

#### **3.7.5 Summary of the Analytical Framework**

Figure 3.6 (Analytical Framework Diagram) illustrates the relationships between:

- Independent Variable: SES
- Mediating Variables: natural/environmental + anthropogenic/governance

- Dependent Variables: flood occurrence, institutional support, community-based adaptation
- Theoretical Foundations: UPE + URT
- Methodological Sequence: QUAL → QUANT → SPATIAL

This integrated framework guided variable selection, survey instrument development, data analysis techniques, and the interpretation of empirical findings throughout Chapters Four, Five, and Six.

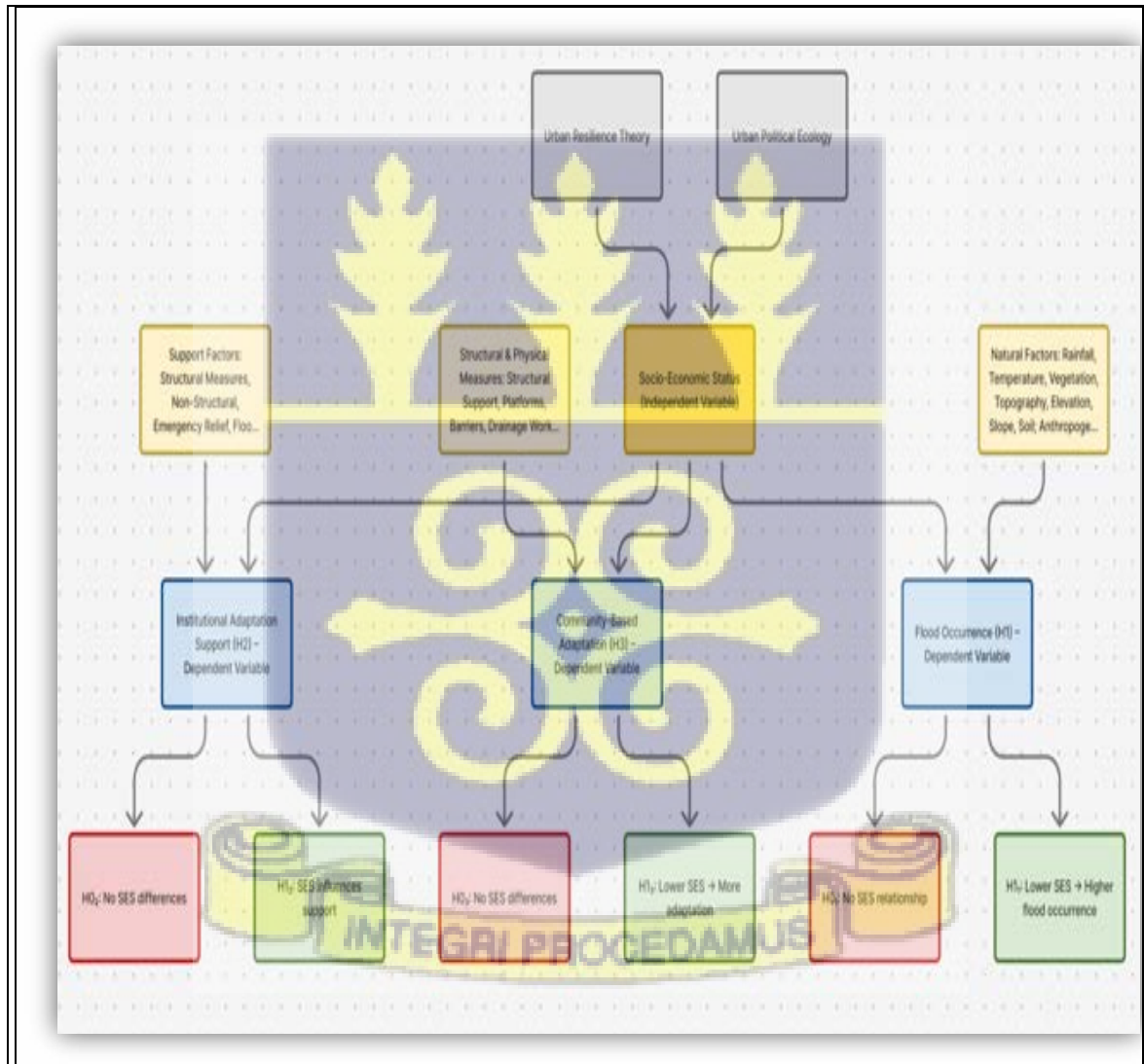


Figure 3.6 Analytical Framework for Flood Occurrence and Adaptation in the Tamale Metropolitan Area (TaMA).

Source: Author's Construct, 2024

### 3.8 Population and Units of Analysis

The study focused on three main populations:

- Households in flood-prone communities, which formed the basis of the quantitative survey. The household was the primary unit of analysis, and only adults aged 18 years and above (household heads or responsible adult representatives) were interviewed.
- Institutional stakeholders, including staff of government agencies and non-governmental organisations involved in flood management, climate risk reduction, spatial planning, and community support.
- Community members and leaders participating in FGDs to provide local perspectives on flood exposure, occurrence and adaptation.

These populations were selected to ensure that both community-level and institutional perspectives on flooding in TaMA were captured.

### 3.9 Sampling Frame and Sampling Techniques

#### 3.9.1 Quantitative Sampling (Household Survey)

The sampling frame for the household survey consisted of three communities representing different socio-economic and spatial categories within TaMA: Kalariga (high-income urban), Nalung (medium-income suburban), and Koblimahagu (low-income rural). These communities were selected purposively based on documented flood occurrence, susceptibility, and socio-economic diversity, ensuring that the study captured areas most relevant to its objectives. Within this frame, a multi-stage sampling strategy was used. First, the three communities were treated as distinct strata. A proportionate stratified sampling approach was applied to allocate the total household sample across the three communities in proportion to their estimated household populations; thus, larger communities contributed more households to the sample than smaller ones, in line with their relative population sizes a standard application of

proportionate stratified sampling to ensure adequate representation (Kalton, 2020; United Nations Statistics Division, 2008).

At the household level, simple random sampling (SRS) was conceptually intended. However, because a complete household listing (sampling frame) was unavailable or impractical, the principle of randomness was operationalized through a systematic field-walk procedure: enumerators followed predefined routes through each community and selected every second household encountered, after a random start. This approach mirrors systematic sampling (i.e., selecting every  $k$ -th element after a random start), which is commonly used in household surveys as a practical approximation to SRS when household lists are lacking and helps ensure spatial spread and manage fieldwork logistics (Scheaffer et al., 2012; Statistics Canada, 2017). In compound houses, common in the study area where a single yard may contain multiple households, only one household per compound was randomly selected. This procedure avoided overrepresentation of large compounds and reduced intra-compound clustering, preserving the assumption of independence among sampled households. Such a multi-stage design (first stratification of communities, then systematic/random-walk household selection) is consistent with established survey sampling practice (Groves et al., 2009; United Nations Statistics Division, 2008).

### **3.9.2 Qualitative Sampling (KIIs, FGDs, Photographs)**

The qualitative phase employed purposive sampling, a deliberate non-probability strategy used to recruit participants with rich, relevant, and experience-based knowledge of flooding (Palinkas et al., 2015; Patton, 2015). A maximum-variation sampling approach was adopted to capture perspectives from urban, peri-urban, and rural communities, and from both institutional and community actors, thereby ensuring heterogeneity in experiences and contextual conditions (Etikan, 2016; Patton, 2015). For the Key Informant Interviews (KIIs), participants

were selected using explicit inclusion criteria. Individuals were eligible if they: held an institutional mandate related to hydrology, meteorology, drainage, land-use planning, sanitation, disaster management, or climate adaptation; possessed technical expertise in flood forecasting, emergency response, or community resilience; had a minimum of three years of professional experience in a flood-related role; and were familiar with flood-prone localities within TaMA. Fourteen key informants were interviewed from institutions directly engaged in flood management and climate-risk reduction (see Table 3.1). This number aligns with qualitative research guidance indicating that data saturation in expert interview studies commonly occurs between 12 and 20 interviews (Guest et al., 2006; Saunders et al., 2018). In this study, saturation was reached by the twelfth interview, with subsequent interviews confirming rather than expanding core themes.

Table 3.1 Government/Non-Governmental Institutions for Key Informant Interviews (KIIs)

No.	Institution	Class	Sex	No. of Persons	Date	Medium Used
1	Ghana Meteorological Agency (GMet)	Govt	M	1	27/04/23	F2F / Otter.ai
2	Hydrological Services Division	Govt	M	1	09/05/23	Zoom
3	Land Commission	Govt	M	1	02/05/23	F2F / Otter.ai
4	NADMO South Sub-Metro	Govt	M	5	25/04/23	F2F / Otter.ai
5	NADMO Central Sub-Metro	Govt	F	1	26/04/23	F2F / Otter.ai
6	NADMO Metropolitan Office	Govt	M	3	27/04/23	F2F / Otter.ai
7	Northern Development Authority	Govt	M	1	02/05/23	F2F / Otter.ai
8	TaMA Physical Planning Department	Govt	M	1	26/04/23	F2F / Otter.ai
9	Tamale Metropolitan Assembly	Govt	M	1	27/04/24	F2F / Otter.ai
10	Community Water and Sanitation Agency	Govt	M	1	28/04/23	F2F / Otter.ai
11	Department of Urban Roads	Govt	M	1	28/04/23	F2F / Otter.ai
12	Forestry Services Division	Govt	F	1	02/05/23	F2F / Otter.ai
13	Ghana Red Cross Society, Tamale	NGO/CSO	M	1	28/04/23	F2F / Otter.ai
14	SEND Foundation	NGO/CSO	M	2	26/04/23	MS Teams

Source: Field data, 2023 (Key Informant Interviews).

At the community level, Focus Group Discussions (FGDs) were used to elicit shared experiences and perceptions of flooding. Participants were selected based on direct exposure to at least one significant flood event within the past 5–10 years, residence in flood-prone neighbourhoods, and ability to articulate impacts and coping strategies and this criteria is consistent with purposive, experience-based recruitment in disaster research (Palinkas et al.,

2015). Socio-economic and spatial diversity was ensured by including participants from Kalariga (high-income urban), Nalung (medium-income suburban), and Koblimahagu (low-income rural). Each FGD comprised a mix of residents and as well as community leaders or elders, supporting the principle of capturing multiple community perspectives (Patton, 2015).

The composition and characteristics of the FGDs are shown in Table 3.2.

Table 3.2 Focus Group Discussion (FGD) Communities

No.	Name of Community	Classification	Male	Female	Date	Medium Used
1	Nalung Chief Palace	Medium Income / Suburban	6	0	03/05/23	Face-to-face / Otter.ai
2	Kalariga Chief Palace	High Income / Urban	12	0	03/05/23	Face-to-face / Otter.ai
3	Kalariga Community	High Income / Urban	25	6	03/05/23	Face-to-face / Otter.ai
4	Koblimahagu	Low Income / Rural	6	0	04/05/23	Face-to-face / Otter.ai

Source: Field data, 2023 (Focus Group Discussions).

By the fourth FGD, thematic saturation had been achieved, as no substantially new themes emerged, a finding consistent with literature indicating that saturation in homogeneous groups is typically reached within 3–6 FGDs (Guest et al., 2017; Namey et al., 2020). Photographic documentation gathered during fieldwork supplemented verbal data, offering visual evidence of flooded streets, damaged infrastructure, and affected households. These images served as corroborative material, enhancing contextual understanding and supporting triangulation of qualitative findings (Creswell & Poth, 2018).

### 3.10 Sampling Procedure and Sample Size Determination

The household survey employed a multi-stage sampling design that combined population projections, estimation of household units, and statistically grounded sample-size calculations. The household constituted the basic sampling unit. To ensure adequate representation across the three study communities of Nalung, Koblimahagu, and Kalariga, the sample size was determined using Cochran (1977) formula for categorical data, adjusted for finite population

effects and supplemented with a non-response buffer. The final allocation was made proportionally to each community’s estimated number of households.

### 3.10.1 Estimating the 2023 Household Population

As no updated community-level population data existed beyond the 2010 Population and Housing Census, projected 2023 population values were generated using the official annual growth rate of 3.6% for the Tamale Metropolitan Area. The projections were calculated over a 13-year period (2010–2023) using standard exponential growth functions. The projected population for each community was subsequently converted into estimated numbers of households using the regional average household size of 6.3 persons, as reported by the Ghana Statistical Service (GSS, 2010). Table 3.3 presents the projected 2023 population and estimated number of households for each community.

Table 3.3 Projected 2023 Population and Estimated Number of Households

Community	2010 Population	Growth Rate	Years	Projected Population (2023)	Average HH Size	Estimated No. of Households
Nalung	6,215	3.6%	13	7,906	6.3	1,255
Koblimahagu	3,067	3.6%	13	3,902	6.3	619
Kalariga	2,439	3.6%	13	3,103	6.3	493

Source: Field data and projections based on GSS (2010).

### 3.10.2 Determining the Sample Size Using Cochran’s Formula

Given the categorical nature of the key survey variable household experiences with flooding Cochran’s (1977) sample size formula for large populations was applied. Because the true proportion of households experiencing flooding was unknown, the estimated proportion ( $p$ ) was conservatively set at 0.5, a standard approach that maximizes the required sample size by assuming maximum variance (Kish, 1965; Lohr, 2010). A 95% confidence level ( $Z = 1.96$ ) and a 10% margin of error ( $e = 0.10$ ) were adopted, consistent with established conventions in social science research for balancing precision with feasibility (Babbie, 2013; Fink, 2017). The initial sample size was calculated as:

$$n_0 = \frac{Z^2 p(1-p)}{e^2} = \frac{(1.96)^2(0.5)(1-0.5)}{(0.10)^2} = 96.04$$

Because each community has a finite and relatively small household population, a Finite Population Correction (FPC) was applied using:

$$n = \frac{n_0}{1 + \frac{n_0 - 1}{N}}$$

where  $N$  is the estimated number of households in each community (from Table 3.3). Finally, an 18% buffer was added to account for non-response and incomplete questionnaires a common practice in field surveys under similar socio-demographic conditions. Table 3.4 presents the FPC-adjusted sample size and the final sample per community.

Table 3.4 Sample Size Calculation for the Study Communities

Community	Estimated No. of Households (N)	Cochran Base Value ( $n_0 = 96.04$ )	FPC-Adjusted Sample	18% Buffer Applied	Final Sample Size
Nalung	1,255	96.04	89.27	105.34 → 106	106
Koblimahagu	619	96.04	83.27	98.26 → 99	99
Kalariga	493	96.04	80.56	95.06 → 95	95
Total	—	—	—	—	300

Source: Field data and projections based on GSS (2010).

### 3.10.3 Final Sampling Strategy

The final achieved sample size was 300 households, distributed proportionally across the three communities based on the FPC-adjusted and buffer-corrected sample sizes. This approach ensured a statistically defensible precision levels, adequate representation of each community, comparability across geographic units, and sufficient power to identify patterns in household experiences with flooding. The combined use of Cochran's formula, finite population adjustments, a clearly defined non-response buffer, and proportional allocation produced a transparent and rigorous sampling framework suitable for the study's objectives.

### 3.11 Data Collection Methods and Instruments

### 3.11.1 Quantitative Instruments

The main quantitative tool was a questionnaire-based household survey. The questionnaire comprised 173 questions organised into five sections: Background information of respondents, household characteristics (e.g., housing type, materials, facilities), flood occurrences and experiences, flood vulnerability, focusing on exposure and susceptibility and perceptions, coping, recovery strategies, resilience, and adaptive capacity. Most items were closed-ended, aligned with the study objectives, while a few open-ended items allowed respondents to elaborate on key issues (Creswell & Creswell, 2018). As many respondents could not read or interpret the questions independently, a structured interview approach was used. Trained research assistants administered the questionnaire verbally in Dagbani or English. Research assistants received training on ethical conduct, question delivery, and translation to ensure standardisation. Each questionnaire took approximately one hour to complete. When the household head was not available, the next responsible adult (e.g., spouse or adult child) was interviewed. A pilot test with three households in Nalung was conducted to refine wording and estimate interview time (Grimm, 2010). This improved clarity around terms such as “flood vulnerability” and “flood occurrence”.

### 3.11.2 Qualitative Instruments

Qualitative data were collected through: Key Informant Interviews (KIIs) using semi-structured guides to elicit expert views on flood drivers, vulnerabilities, governance, and adaptation. Focus Group Discussions (FGDs) to explore shared community experiences, perceptions of risk, and collective coping strategies and Participant observation and visual documentation, including photographs and observational notes, to capture real-time conditions such as inundation levels, housing conditions, drainage blockages, and infrastructure damage. The semi-structured format of interviews and FGDs allowed flexibility in probing emerging themes while maintaining alignment with research questions. Face-to-face interactions also

enabled observation of non-verbal cues, adding depth to the data. Observations were recorded in a research diary, and photographs were used as an additional layer of evidence, supporting and contextualising participants' narratives.

### 3.12 Secondary Data

Secondary data were obtained from multiple reputable sources to complement primary data and provide historical and spatial context. These included:

- Socio-economic data (e.g., enumeration area characteristics) from the Ghana Statistical Service (GSS).
- Spatial data (shapefiles, elevation, soil, geology, land use/land cover, and drainage patterns) from the the Physical Planning Department of TaMA.
- Historical flood events and records from NADMO, Hydrological Services, Tamale Metropolitan Assembly, the Northern Development Authority, and the Ghana Meteorological Agency.

These datasets were essential for mapping flood-prone areas, examining temporal trends, and integrating environmental and socio-economic dimensions of flood occurrence.

### 3.13 Data Analysis

The study adopted a Sequential Exploratory Mixed-Methods Design, in which qualitative data were analysed first and used to shape the quantitative phase, including the construction of survey instruments, the operationalisation of variables, and the specification of hypotheses. Accordingly, both qualitative and quantitative datasets were subjected to systematic analytical procedures, followed by an integration stage that merged findings from both strands supported by spatial data to produce a comprehensive socio-spatial interpretation of flood occurrence and adaptation in TaMA.

### 3.13.1 Qualitative Data Analysis

The qualitative phase formed the foundation of the research and was analysed first, consistent with the sequential exploratory design (Creswell & Plano Clark, 2018, 2023; Katz-Buonincontro, 2024). Data from Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and field observations were audio-recorded (with consent), transcribed verbatim, and uploaded into NVivo for detailed analysis (Jackson & Bazeley, 2019; Lumivero, 2025). A thematic analysis approach was employed, beginning with open coding to identify recurring ideas and context-specific insights regarding flood occurrence, governance, infrastructure, adaptation strategies, and community vulnerability (V. Braun & Clarke, 2006; Strauss & Corbin, 1998). An initial codebook was developed inductively, drawing from both the research questions and emergent concepts from the transcripts. As analysis progressed, codes were refined, merged, or expanded to reflect deeper conceptual patterns. Axial coding was then used to establish relationships between themes, for example, linking drainage deficiencies with governance failures, or connecting socio-economic status to adaptation behaviour (Delve, 2024; Strauss & Corbin, 1998). Thematic categories were finalised following iterative comparison across respondent groups and community contexts. Verbatim quotes were extracted to illustrate key findings and ensure that interpretations reflected the lived experiences of residents and institutional actors. Field observations and photographs were used to triangulate themes, particularly those relating to drainage, settlement form, vegetation loss, and informal adaptation practices (Denzin, 1978; McLeod, 2024). Findings from this qualitative stage directly informed the design of the household survey, selection of variables, and framing of the three hypotheses tested in the quantitative phase (Creswell & Plano Clark, 2018; SAGE, 2024).

### 3.13.2 Quantitative Data Analysis

Quantitative data were collected through a structured household survey administered via KoboToolbox (KoboToolbox, 2023), checked for completeness, and exported to IBM Statistical Package for Social Sciences (SPSS) Statistics (Version 29) for analysis (IBM Corp, 2022). Data cleaning involved identifying missing values, outliers, and inconsistencies, which were corrected through verification with field records (Cunningham & Muir, 2023; Sharifnia et al., 2025). Descriptive statistics (frequencies, percentages, means) were used to summarise household characteristics, flood experiences, and adaptation measures (Cooksey, 2020). Cross-tabulations were employed to explore socio-spatial patterns across the three communities of interest (Jenkins-Smith, 2024). Key constructs such as socio-economic status (SES), institutional support, and community-based adaptation were operationalised using multiple indicators. Where appropriate, indices were computed, such as the SES index based on income, education, occupation, and dwelling quality (Vyas & Kumaranayake, 2006). Inferential statistics were used to test the hypotheses derived from the qualitative phase: Chi-Square Tests of Independence examined relationships between SES categories and flood occurrence (Pearson, 1900; Statology, 2021). One-way ANOVA / Kruskal–Wallis tests compared mean levels of institutional support and community adaptation across SES groups (Feir-Walsh & Toothaker, 1974; Kruskal & Wallis, 1952). Microsoft Excel was used for further data visualisation, including the production of charts and tables used in Chapters 4,5 and 6 (Microsoft, 2021). Quantitative results were later linked to spatial datasets to demonstrate patterns of flood occurrence (Ball & Duke, 2015).

### 3.13.3 Integration of Qualitative, Quantitative, and Spatial Data

Mixed-methods integration followed a Sequential Exploratory Design, in which qualitative findings informed the development of the quantitative phase, and final interpretation involved merging evidence from all strands. Integration occurred at three interconnected levels. First,

instrumental integration ensured that qualitative themes directly shaped the survey questions, the construction of key variables, the categorisation of socio-ecological systems (SES), and the formulation of hypotheses ( $H_1$ – $H_3$ ). Second, methodological integration involved comparing quantitative results with qualitative narratives to identify areas of convergence where findings reinforced one another, complementarity where each method illuminated different dimensions of the phenomenon, and divergence where contradictory evidence revealed underlying socio-political complexities. Third, spatial integration incorporated GIS outputs to contextualise both qualitative and quantitative findings by mapping flood-prone neighbourhoods. Together, this triangulated approach enhanced the reliability and validity of the findings and enabled a comprehensive socio-spatial interpretation of flood occurrence and adaptation in TaMA.

#### 3.13.4 Hypothesis Testing Strategy, Analytical procedures used and Decision rule

Three hypotheses were tested, each addressing a specific relationship between SES and flood-related outcomes:

1.  $H_1$ : SES and Flood Occurrence
  2.  $H_2$ : SES and Institutional Adaptation Support
  3.  $H_3$ : SES and Community-Based Adaptation
- Chi-square tests assessed associations between SES groups and categorical flood experiences (e.g., frequency of flooding).
  - Kruskal–Wallis tests compared levels of institutional support and adaptation strategies across SES strata.
  - Spatial overlays supported interpretation by linking statistical results to environmental and infrastructural contexts.

For all hypotheses:

- If  $p < 0.05 \rightarrow$  reject the null hypothesis ( $H_0$ ).
- If  $p \geq 0.05 \rightarrow$  fail to reject the null hypothesis.

Results of these tests are presented in Chapters 4, 5, and 6, corresponding to the three objectives. The variable test summary table is present for clarity.

Table 3.5 Variable Test Summary Table

Hypothesis	Independent Variable (IV)	Dependent Variable (DV)	Statistical Test	Spatial Support
<b>H<sub>1</sub>: SES <math>\rightarrow</math> Flood Occurrence</b>	SES Index / SES Category	Flood occurrence; frequency of floods; penetration into homes	Chi-Square Test	Elevation, drainage, land cover, online/FGD perceptual maps
<b>H<sub>2</sub>: SES <math>\rightarrow</math> Institutional Support</b>	SES Index / SES Category	Access to warnings, emergency support, relief, infrastructure	Kruskal-Wallis	Distribution of public infrastructure and institutional presence
<b>H<sub>3</sub>: SES <math>\rightarrow</math> Community-Based Adaptation</b>	SES Index / SES Category	Frequency and type of community-led adaptations	Kruskal-Wallis	Community layouts, housing density, drainage maintenance

### 3.14 Ethical Considerations in Human-Subjects Research

Ethical approval for the study was obtained from the Ethics Committee for the Humanities (ECH) of the University of Ghana (Reference: ECH 194/22–23; see Appendix E) (University of Ghana, 2023). The study adhered to core ethical principles, including respect for persons, beneficence, and justice (Resnik, 2024). Informed consent was obtained from all participants. For the household survey, the consent statement was included on the questionnaire, and respondents provided verbal consent and ticked the consent box before proceeding. For KIIs and FGDs, the aims and procedures were explained in the local language, and oral consent was obtained and recorded. Participants were informed of their right to decline any question or withdraw at any time without penalty. When photographs were taken that might include identifiable individuals, explicit permission was sought prior to capturing the images.

Confidentiality and anonymity were strictly maintained. Personal identifiers were removed from datasets and transcripts and replaced with codes. A master list linking codes to identities

was stored separately in a secure, password-protected location accessible only to the researcher. Electronic files were stored on encrypted devices, and hard copies (e.g., consent forms) were kept in locked cabinets. Audio recordings and identifiable images will be retained for the minimum period required by institutional policy (typically three years) and then destroyed.

Although the study was considered minimal risk, additional precautions were taken due to the context of the COVID-19 pandemic. Data collection took place when local case numbers were low, but face masks, hand sanitiser, and physical distancing were used during interviews and discussions in line with public health guidance (Pfizer Inc, 2025; Tibbels et al., 2022). No material incentives were provided; however, participants were informed that their involvement could indirectly benefit their communities by informing better flood risk management and adaptation planning.

### **3.8 Chapter Summary**

This chapter has outlined the research methodology used to examine flood occurrence and adaptation in the Tamale Metropolitan Area. A cross-sectional, sequential exploratory mixed-methods design was adopted, integrating household surveys, GPS mapping, key informant interviews, focus group discussions, and visual documentation. Sampling strategies and sample size determination were carefully structured to ensure representativeness and methodological rigour, with households as the primary unit of analysis and qualitative participants purposively selected for their expertise and lived experience. Data analysis combined descriptive and inferential statistics with thematic analysis, supported by GIS and qualitative software, to generate a nuanced and triangulated understanding of flood dynamics. Ethical considerations were embedded throughout the research process to protect participants' rights, privacy, and well-being. The next chapter presents the empirical results derived from these methods, highlighting the socio-spatial patterns of flood occurrence and adaptation in TaMA.

## **SOCIO-SPATIAL PATTERNS OF FLOOD OCCURRENCE IN THE TAMALE METROPOLITAN AREA**

### **4.1 Introduction**

The previous chapter outlined the methodologies employed to achieve the thesis objectives, including both quantitative and qualitative approaches, supported by a content analysis of online media, alongside an introduction to the study area of Tamale. This chapter presents the results and integrated discussion for Objective One, which examines the socio-spatial patterns of flood occurrence in the Tamale Metropolitan Area (TaMA). Using a sequential exploratory mixed-methods approach, the analysis draws on perceptual mapping, household survey data, climatic records, spatial analysis, and qualitative insights from FGDs and KIIs as well as online media analysis of flood events. The chapter evaluates how natural and anthropogenic factors interact with socio-economic status (SES) to shape the uneven distribution of flood risk across communities. It is organised into five main sections: perceptual mapping of flood-prone areas; natural and climatic drivers; anthropogenic and infrastructural factors; housing and governance influences; and statistical hypothesis testing.

### **4.2 Socio-Spatial and Historical Context of Flooding in TaMA**

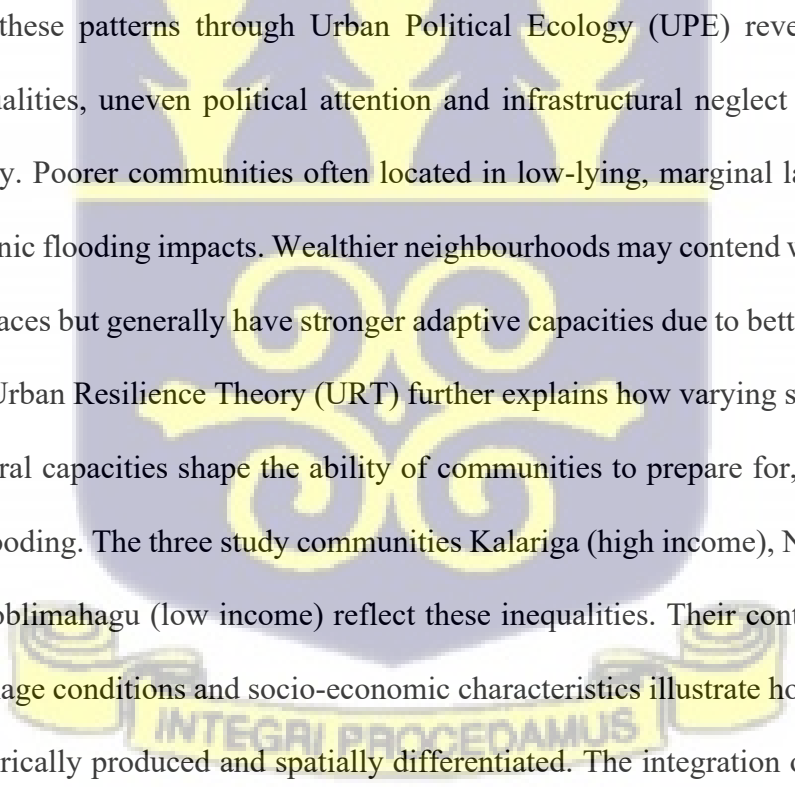
Flooding in the Tamale Metropolitan Area (TaMA) has evolved markedly over the past three decades, shifting from episodic, region-wide rainfall disasters to recurrent, localised, urban-centred flooding. Early major events were driven primarily by exceptional rainfall and river overflow. The 1999 floods, for example, displaced over 120,000 people in the Northern Ghana, destroyed more than 13,000 houses and triggered a deadly cholera outbreak (IRIN News, 1999). Similarly, the 2007 floods, exacerbated by prolonged rainfall and the Bagre Dam spillage, affected more than 275,000 people and devastated property, crops and livestock across northern Ghana (Citi News, 2014; Lolig et al., 2014). These large-scale events formed part of a

broader regional hydrological crisis. By the early 2010s, the character of flooding in TaMA began to shift toward more urban-focused, infrastructure-driven events. In 2011, continuous torrential rainfall and blocked drains displaced hundreds in communities including Gumani, Lamashigu and Kukuo (Modern Ghana News, 2011; National Disaster Management Organisation, 2011). The 2012 flood, driven by heavy rains and the Bagre Dam spillage, displaced approximately 1,820 people and submerged thousands of rooms, with officials identifying poor drainage as a significant contributor (GNA/Modern Ghana News, 2012).

Between 2013 and 2016, flood events increasingly reflected the effects of unplanned development, inadequate drainage systems and settlement expansion onto low-lying land. In 2013, residents of Nyashegu blamed flooding on narrow gutters and municipal inaction (MyJoyOnline, 2013). Severe flooding in 2015 in Bilpela and Kalariga was linked to an unfinished road project that lacked drainage infrastructure (MyJoyOnline, 2015). In 2016, a seven-hour downpour caused one fatality in Kulnyevila and displaced hundreds in suburbs such as Datoyili, Sawaba, and Bilpela, with disaster officials reporting insufficient relief supplies (Citi News, 2016; Starrfmonline.com, 2016). From 2017 to 2022, flooding became recurrent even during relatively short rainfall events. A cloudburst in 2017 caused four deaths, inundating Sakasaka, Gumbihini, Kalariga and Fuo, and prompting major emergency responses (AfricaNews, 2017; GhanaWeb, 2017; Graphic Online, 2017; MyJoyOnline, 2017). Short intense rainfall in 2018 flooded homes and shops along the Tamale–Nyankpala highway (Ghana News Agency, 2018). In 2019, prolonged rainfall displaced hundreds across Gumani, Kalariga, Nyanshegu and Fuo, with residents attributing the flooding partly to an unfinished drainage project (Modern Ghana, 2019; Peacefmonline.com, 2019). The 2020 flood displaced more than 1,350 people across Gumbihini, Kalariga and Sawaba, with officials citing undersized drains and refuse dumping as key causes (Diamond FM, 2020; Graphic Online,

2020). In 2022 also displaced hundreds in communities such as Gumani, Jisonayili and Kunyevila, sweeping away vehicles and flooding major roads (Daily Graphic, 2022).

Recent patterns show that flooding continued into 2023–2025, though without a single catastrophic regional-scale disaster. In January 2023, heavy rainfall rendered many Tamale residents homeless (West Africa Democracy Radio (WADR), 2023). In October 2023, flooding stranded students around Tamale, prompting rescue interventions (University for Development Studies (UDS), 2023). A 2024 heavy downpour again flooded large sections of the city, including central Tamale and nearby suburbs (GhanaWeb, 2024). In 2025, localised flooding persisted in known hotspots such as Gumani and the Sagnarigu lowlands, with residents still experiencing disruptions during peak rainfall (ModernGhana, 2025).

The logo of the University of Ghana is a watermark in the background of the text. It features a shield with three golden flames at the top, a central golden emblem, and a banner at the bottom with the Latin motto "INTEGRUM PROCEDEMUS".

Understanding these patterns through Urban Political Ecology (UPE) reveals how socio-economic inequalities, uneven political attention and infrastructural neglect shape exposure and vulnerability. Poorer communities often located in low-lying, marginal lands experience deeper and chronic flooding impacts. Wealthier neighbourhoods may contend with runoff from impervious surfaces but generally have stronger adaptive capacities due to better infrastructure and resources. Urban Resilience Theory (URT) further explains how varying social, economic and infrastructural capacities shape the ability of communities to prepare for, respond to and recover from flooding. The three study communities Kalariga (high income), Nalung (medium income) and Koblimahagu (low income) reflect these inequalities. Their contrasting housing structures, drainage conditions and socio-economic characteristics illustrate how flood risks in TaMA are historically produced and spatially differentiated. The integration of climatic data, GIS outputs and community narratives demonstrates that flood occurrence is neither random nor evenly distributed, but embedded in long-term socio-spatial and governance dynamics.

### 4.3 Perceptual Mapping and Socio-Spatial Occurrence of Flooding

This section examines how flooding in the Tamale Metropolitan Area (TaMA) is perceived, experienced, and spatially recognised by triangulating evidence from three interlinked sources: online media reports covering the period 2011–2024, primary qualitative accounts from Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) conducted in 2023, and community-level Socio-Economic Status (SES) classifications. The perceptual mapping process integrates these datasets by aligning each community's SES category (high-, medium-, or low-income) with the frequency of flood mentions derived from both the media and qualitative narratives. This approach enables a spatially grounded assessment of how class, visibility, and geography interact to shape the recognition and governance of flood risks. Figures 4.1 show a maps of flood prone communities and 4.2 illustrate frequency of communities that are most flooded based on mentions.

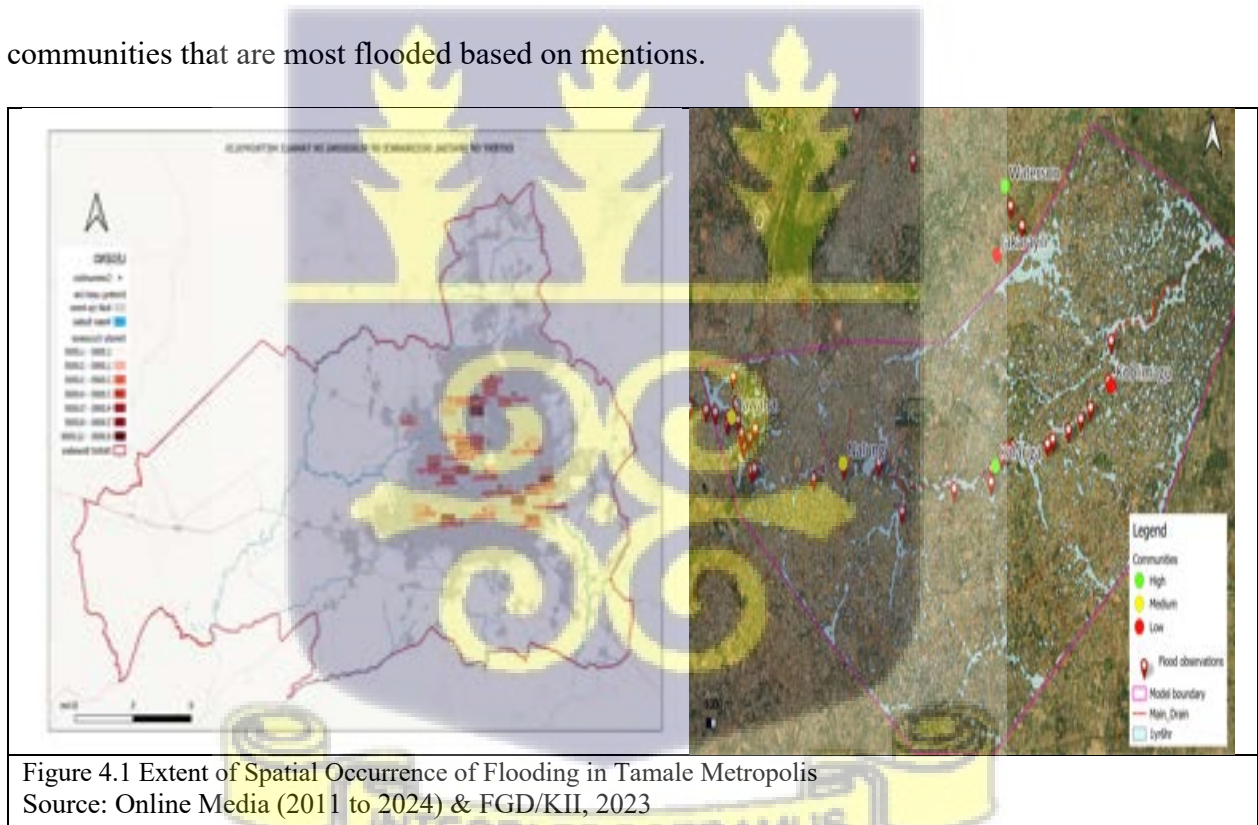


Figure 4.1 Extent of Spatial Occurrence of Flooding in Tamale Metropolis  
Source: Online Media (2011 to 2024) & FGD/KII, 2023

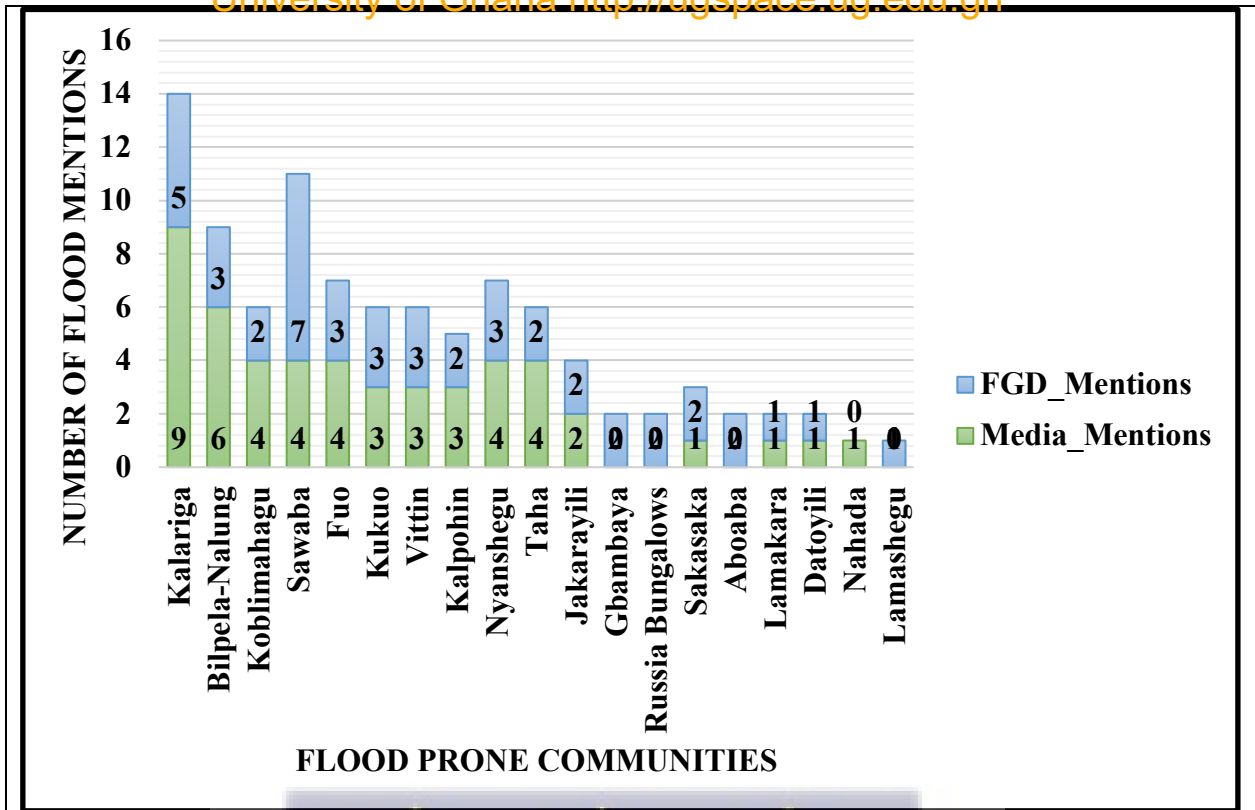


Figure 4.2 Perceptions of Flood-Prone Communities in TaMA  
 Source: Online Media (2011 to 2024) & FGD/KII, 2023

The vertical axis in figures is labelled “Number of Flood Mentions,” and the values represent raw counts rather than percentages, allowing a direct comparison of visibility disparities across communities. The perceptual maps demonstrate that references to flooding in TaMA are unevenly distributed across the metropolitan landscape. They concentrate in specific communities where infrastructural vulnerabilities, social status, and locational attributes create distinct experiences of both flood impact and public visibility. This unevenness underscores a core premise of Urban Political Ecology (UPE), which argues that environmental risk is mediated through sociopolitical processes that produce unequal forms of exposure, representation, and institutional response. In this context, perceptual mapping functions as an analytical lens, revealing not only the spatial clustering of flood events but also the social dynamics that shape which communities become prominent in public discourse.

Kalariga, a high-income neighbourhood, emerges as the most frequently referenced community in online media, with nine mentions, and appears prominently in FGDs and KIIs. Its elevated

visibility, despite its relative affluence, indicates that wealth does not necessarily protect urban residents from flooding. Instead, extensive compound paving, disrupted flow paths, and poorly functioning drainage systems intensify surface runoff. This is consistent with resilience scholarship, which emphasises that material wealth alone does not confer resilience when adaptive systems are inadequate or overwhelmed. Kalariga's case thus illustrates how high-income environments can inadvertently amplify hydrological risks through certain urban design practices. Medium-income communities such as Bilpela–Nalung and Sawaba exhibit vulnerabilities that arise from both infrastructural constraints and governance deficits. Bilpela–Nalung receives considerable attention across datasets, appearing six times in media reports and three times in FGDs and KIIs. This pattern reflects its susceptibility to flooding and the insufficiency of institutional support mechanisms available to residents. Sawaba, while frequently mentioned in community narratives, appears less prominently in media accounts. This disparity suggests that despite the frequency and severity of flood impacts, the community's experiences receive limited metropolitan-level attention. Such selective visibility aligns with UPE's notion of unequal recognition, where the struggles of certain groups remain marginalised within broader public and political discussions.

Low-income communities exhibit even more pronounced visibility gaps. Koblimahagu, historically flood-prone and socio-economically marginalised, appears four times in online media but only twice in FGDs and KIIs. Its limited representation across these sources underscores the chronic under-recognition of risks faced by poorer neighbourhoods. Although such communities bear some of the most persistent and severe impacts of flooding, their visibility in public reporting remains disproportionately low. This dynamic reinforces long-standing critiques within UPE, highlighting how urban marginality constrains a community's ability to have its experiences acknowledged and addressed within formal risk governance processes. Beyond the three focal communities, several other patterns emerge. Medium- to high-income neighbourhoods such as Fuo, Kukuo, Vittin, and Kalpohin demonstrate moderate

presence across both datasets, suggesting recurrent but relatively manageable flooding. These communities fall within what can be described as “ambient risk zones,” where flooding is noticeable but insufficiently catastrophic to provoke heightened media or governmental attention. In contrast, low-income communities such as Nyanshegu, Taha, Jakarayili, and Gbambaya appear frequently in FGDs but are underrepresented in online media accounts, reflecting systemic biases that shape whose experiences are circulated and legitimised in public narratives. Conversely, communities like Datoyili, Nahada, and Lamashegu are largely absent from both datasets. Their omission may be attributable to spatial marginalisation, limited media access, or structural failures in risk mapping, each of which contributes to their invisibility in both perception and policy.

Overall, the combined dataset reveals that flood occurrence in TaMA is neither spatially uniform nor socially neutral. Visibility and vulnerability are profoundly shaped by SES-linked variables such as infrastructure quality, political attention, and proximity to the metropolitan core. The three study communities illustrate these dynamics sharply: Kalariga exemplifies affluent exposure, Nalung embodies middle-income fragility, and Koblimahagu reflects persistent low-income vulnerability. While flooding affects communities across all SES categories, its frequency, severity, and long-term consequences are disproportionately concentrated among low-income neighbourhoods. At the same time, media narratives tend to disproportionately highlight events in high-income or centrally located communities. Perceptual mapping therefore illuminates not only the physical geography of flood risks but also the political and discursive geographies that determine whose experiences become visible, audible, and actionable within the governance landscape of TaMA.

#### 4.4 Frequency of Flood Occurrence at Community and household Level

Figure 4.3 presents the frequency of flood occurrence at both the community and household levels across Kalariga (high-income), Nalung (medium-

income) and Koblimahagu (low-income). The results reveal clear socio-spatial differences in how flood risk is experienced in the Tamale Metropolitan Area (TaMA). About a third of households in Kalariga (31%) and Koblimahagu (31%) reported flooding in most years,

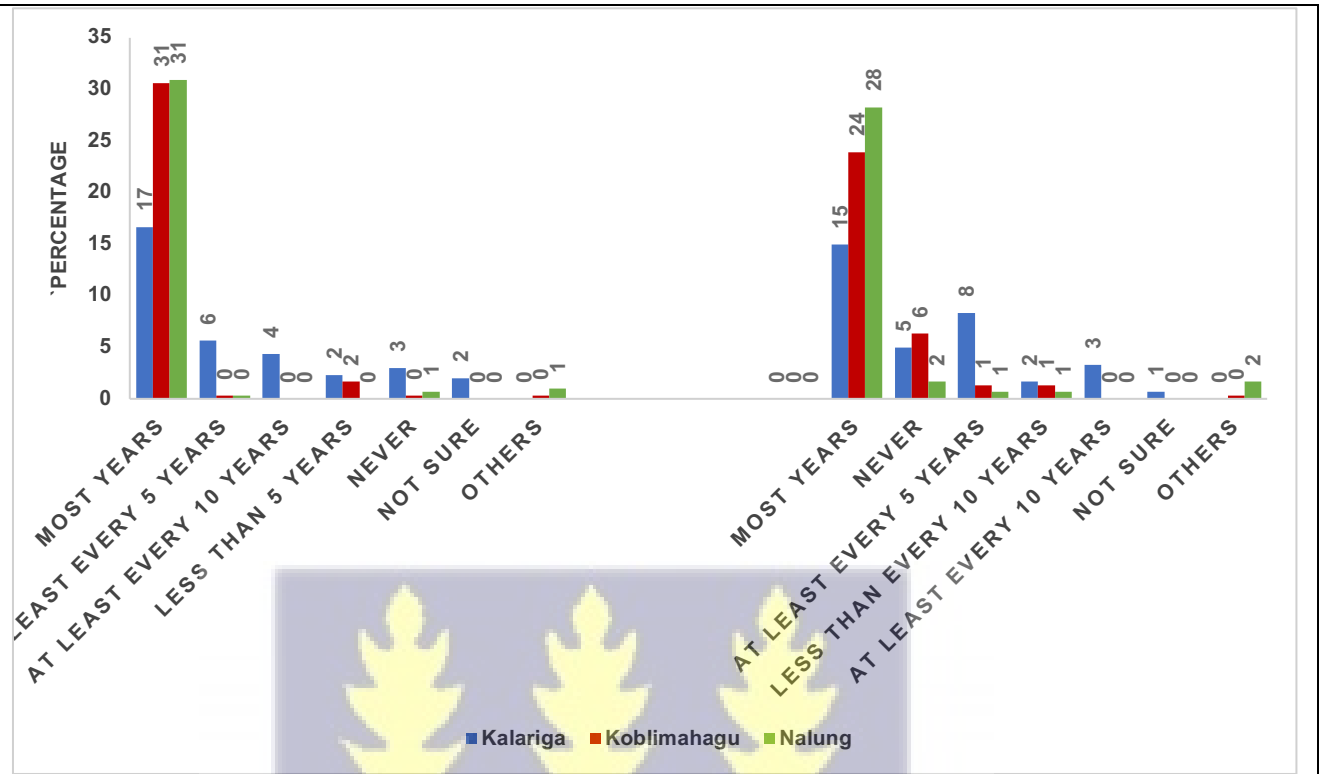


Figure 4.3 Frequency of Flood Occurrence at Community and Household Level  
 Source; Field data, Household Questionnaire Survey

compared with 17% in Nalung. This demonstrates that surface and compound flooding is not confined to low-income areas; high-income neighbourhoods also experience frequent runoff due to extensive paving, concretised compounds, and limited drainage. Similar patterns have been observed in Accra, where both affluent and low-income areas face surface flooding linked to urban expansion and inadequate infrastructure (Amoako & Boamah, 2014; Amoako & Frimpong Boamah, 2020). At the household level, where floodwater enters homes, disparities are more pronounced. Koblimahagu recorded the highest exposure, with 29% of households reporting frequent indoor flooding and 33% experiencing it occasionally. In Kalariga, 20% experienced such events in most years and 13% occasionally, while Nalung recorded the lowest levels (6% and 11%, respectively). As a resident from Koblimahagu noted:

These findings align with studies in Lagos and Dar es Salaam, where low-income neighbourhoods face severe flood impacts due to weak infrastructure and governance constraints (Salami et al., 2017). Taken together, the results show that although surface flooding affects all communities, indoor flooding disproportionately affects low-income households. The reasons include poorer housing quality, low-lying terrain, and inadequate drainage. Conversely, high-income households employ protective measures such as raised foundations and engineered drainage systems, reducing the likelihood of water entering homes despite frequent neighbourhood flooding. This pattern reflects broader inequalities documented across African cities (Adelekan, 2010).

Through the lens of Urban Political Ecology (UPE), these inequalities illustrate how flood vulnerability is socially produced, shaped by uneven development, planning decisions, and differentiated access to infrastructure (Swyngedouw & Heynen, 2003). Overall, the evidence demonstrates that while approximately 30% of households across socio-economic groups experience community-level flooding, low-income households face the most severe impacts, particularly water entering dwellings. These findings strongly support Hypothesis 1, confirming that socio-economic status significantly shapes the frequency of flood occurrence in TaMA.

#### **4.5 Natural Drivers of Flood Occurrence**

Understanding the spatial variation of flood occurrence in the Tamale Metropolitan Area requires careful examination of the natural and climatic factors that shape hydrological behaviour across the landscape. In line with Objective One and Hypothesis 1, this section analyses rainfall patterns, temperature trends, vegetation cover, and topographic and drainage characteristics to demonstrate how environmental conditions interact with socio-economic and

infrastructural factors to produce uneven flood exposure. The analysis draws on 30 years of meteorological data (1991–2022).

#### 4.5.1 Rainfall and Flood Occurrence

Rainfall is a primary environmental driver influencing flood dynamics in the Tamale Metropolitan Area (TaMA), but its influence must be interpreted with methodological precision. Flooding in urban environments does not result from total annual rainfall alone. But rather, it is the temporal concentration, intensity, and distribution of rainfall events together with their interaction with local physical and infrastructural characteristics that determine flood-generating conditions. For this reason, this analysis places greater emphasis on monthly and event-based rainfall patterns, as these offer more hydrologically meaningful indicators of flood risk than cumulative totals. A senior official of the Ghana Meteorological Agency (GMet) articulated this distinction clearly, noting that:

*“Rainfall does not cause flooding; it is when the rain becomes too much and suddenly drops that it triggers flooding in Tamale”* (GMet Official, KII,2023).

This observation underscores the hydrological significance of short-duration, high-intensity rainfall episodes, which are far more influential in generating surface runoff than aggregated yearly totals. The annual rainfall record for Tamale from 1991 to 2022 (Figure 4.4) therefore provides climatic context rather than a direct explanation for flood occurrence. The data reveal pronounced variability characteristic of the Sudan–Sahelian zone, with exceptionally wet years such as 1991 (1579.8 mm), 2008 (1470.2 mm), 2010 (1306.8 mm), 2018 (1312.7 mm), and 2022 (1238 mm). While these wet years created environmental conditions conducive to flooding, actual flood events were triggered by specific high-intensity rainfall days rather than by the annual totals themselves. Conversely, markedly dry years (e.g., 1992, 2002, 2017) contributed to soil compaction and crusting, reducing infiltration and amplifying runoff when intense rains eventually occurred. This hydrological behaviour is consistent with broader

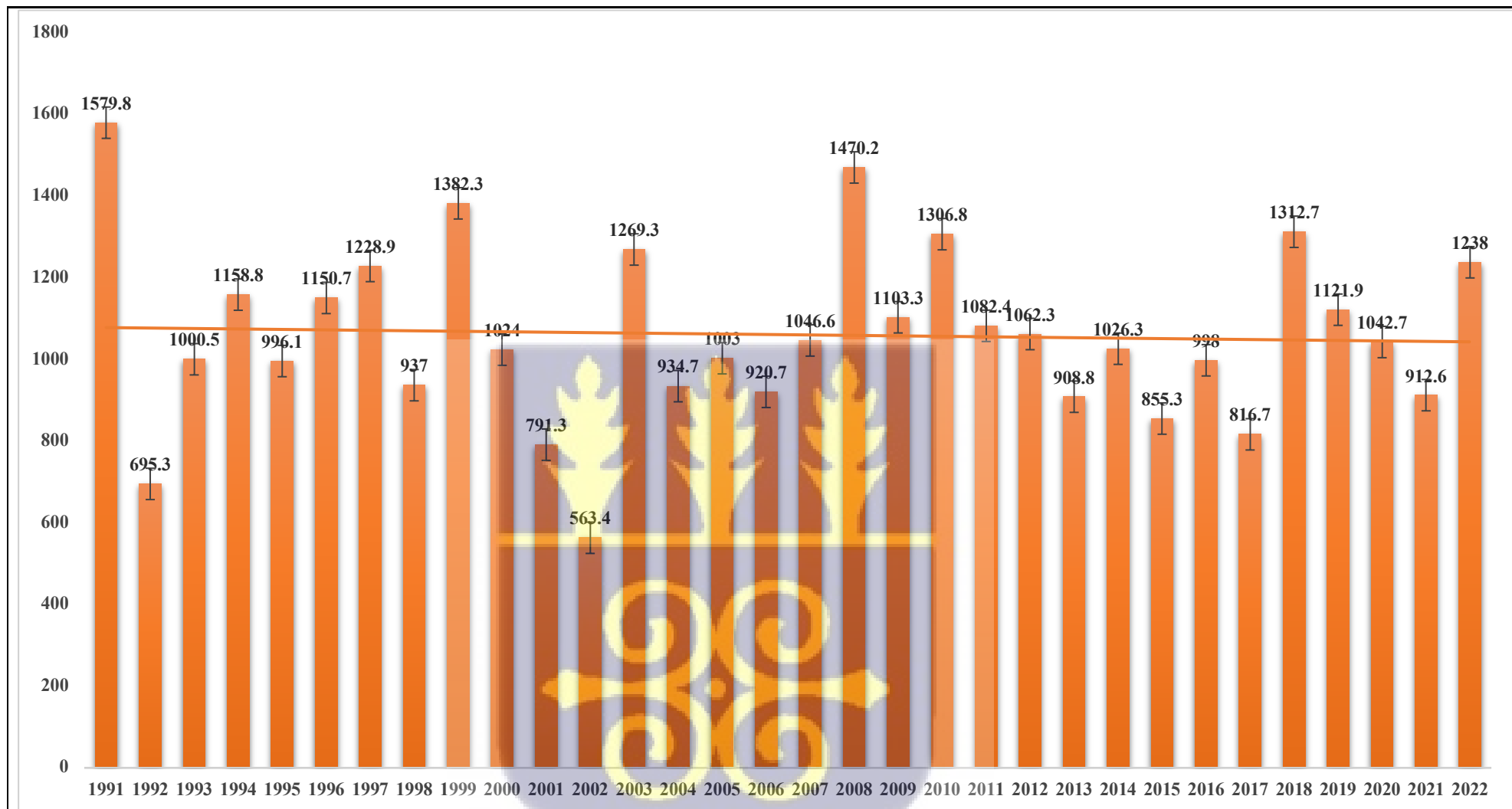
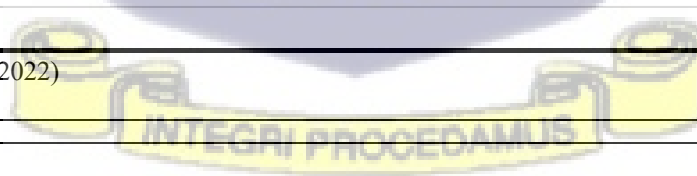
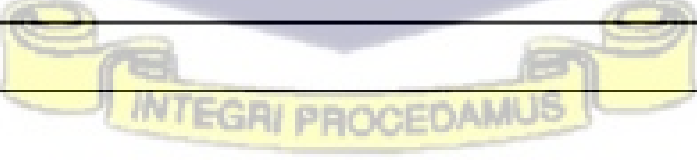
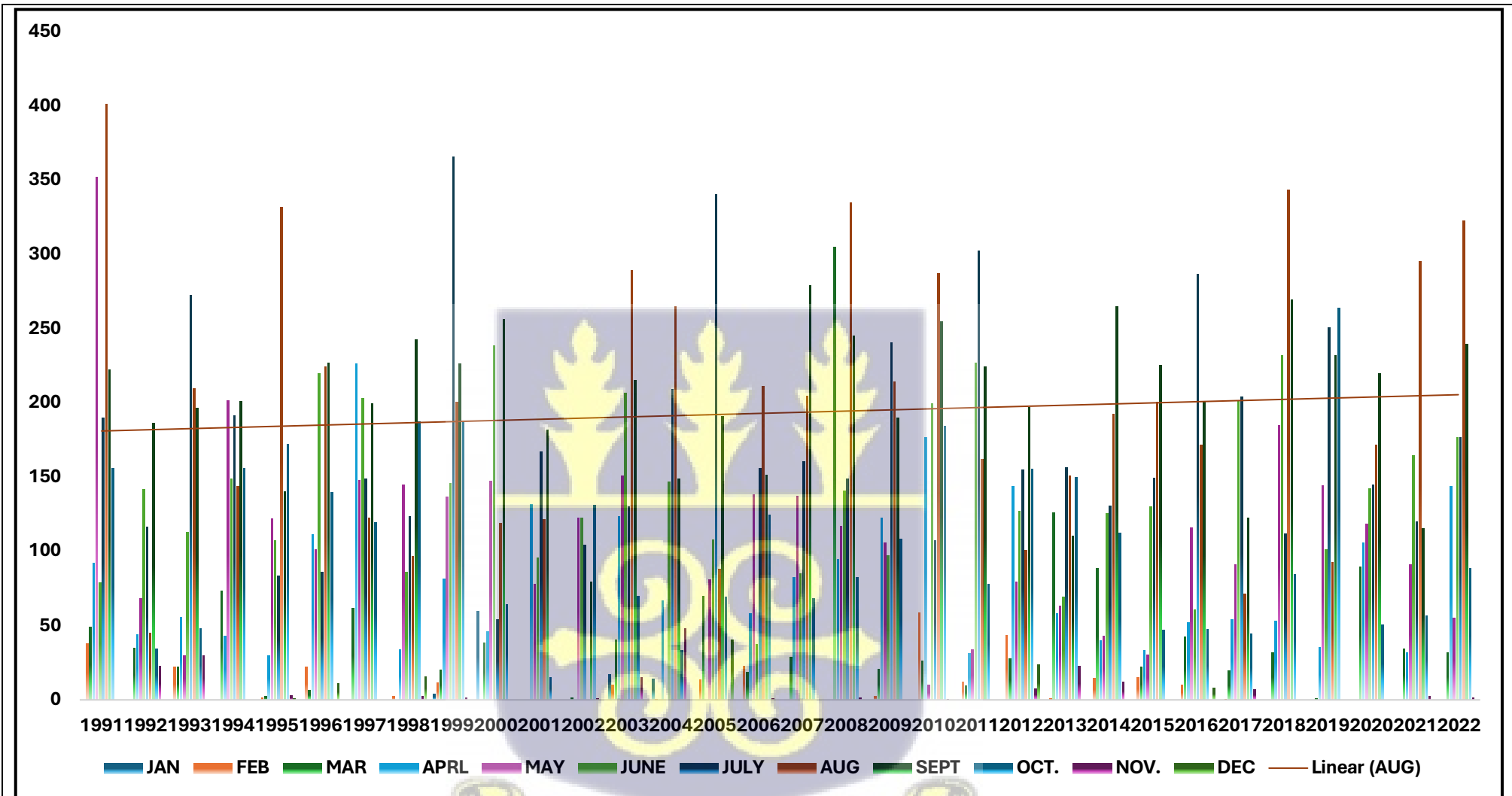


Figure 4.4 Total Annual Rainfall for Tamale (1991-2022)

Source: Ghana Meteorological Authority, Tamale





Sahelian patterns, where declining mean rainfall coexists with increasing frequencies of extreme rainfall events that heighten flood risk (Niang et al., 2014; Nicholson, 2017).

Monthly rainfall patterns, depicted in Figure 4.5, more directly reflect the mechanisms that generate flooding. The June–September rainy season dominates the hydrological cycle, with August consistently emerging as the peak month. Flood-associated years such as 1991 and 2008 recorded particularly intense rainfall concentrations in August (401.3 mm and 334.6 mm, respectively), exceeding the absorptive and conveyance capacities of the drainage system and resulting in widespread inundation. Similarly, in 2010, the combined effect of intense August (287.2 mm) and September (255.0 mm) rainfall produced rapid runoff and flood conditions in several parts of the city. Evidence from GMet data, NADMO reports, and community accounts indicates that flooding in TaMA is typically triggered when rainfall intensity surpasses local hydrological thresholds. These thresholds can be quantified as approximately 70–100 mm of rainfall occurring within a single day, or cumulative rainfall exceeding about 150 mm over a two- to three-day period. While such thresholds are indicative rather than deterministic, they represent rainfall magnitudes that frequently exceed the urban landscape’s infiltration capacity, especially given Tamale’s semi-arid soils, growing impervious surfaces, and unevenly distributed drainage networks.

Community experiences provide further insight into how intense rainfall interacts with local vulnerabilities to produce flooding. A resident of Koblimahagu explained that:

*“Flooding increases every year and every year it is more dangerous”* (Koblimahagu Community Leader, FGD, 2023).

Such perceptions reflect not only the intensification of extreme rainfall events but also the structural conditions low-lying topography, sparse vegetation cover, inadequate drainage, and rapid peri-urban expansion that convert heavy rainfall into destructive flooding. From an Urban Political Ecology (UPE) perspective, rainfall becomes a hazard not solely because of its intensity but because it interacts with historically uneven patterns of urban development and infrastructure provision. Consequently, similar rainfall amounts produce markedly different outcomes across communities: in higher-income areas such as Kalariga, intense rainfall may generate surface runoff without severe inundation, while in low-income settlements like Koblimahagu, comparable rainfall can rapidly flood homes due to limited drainage capacity, poor housing quality, and vulnerability rooted in spatial marginalisation. In summary, rainfall contributes to flood occurrence in TaMA primarily through intense and temporally concentrated events rather than through the accumulation of annual rainfall. Flooding emerges from the convergence of high-intensity rainfall, soil and land-surface limitations, infrastructural deficits, and longstanding socio-spatial inequalities. These dynamics provide a foundation for examining how residents across the three communities perceive changes in rainfall patterns and how these perceptions align with observed climatic trends.

#### **4.5.2 Perceptions of Rainfall Frequency, Rainfall Intensity and Flood Occurrence**

Community perceptions of changing rainfall patterns across Kalariga, Koblimahagu, and Nalung provide essential insights into the socio-spatial nature of climate awareness and its relationship to flood exposure. Although the three communities differ markedly in income, infrastructure, and access to information, findings indicate a widely shared recognition that rainfall patterns in Tamale have changed over the past decade. Residents interpret these changes through distinct cultural, environmental, and experiential lenses, illustrating how

socio-economic conditions shape climate perception. In Kalariga, the high-income community, perceptions of changing rainfall are closely associated with environmental awareness and access to climate information. Respondents frequently attributed variations in rainfall to human-induced environmental degradation, including deforestation (11%), climate change (9%), and bush burning (9%). As one sub-chief explained:

*“Our community has always been keen on addressing environmental degradation”*  
(Sub-Chief, Kalariga, FGD, 2023).

This perspective reflects comparatively high levels of scientific literacy and access to climate information channels, including formal education, media, and digital technologies. Similar socio-economic gradients in climate awareness have been documented in Europe and Asia, where higher-income groups tend to demonstrate stronger scientific engagement and environmental knowledge (Moser & Kleinhüchelkotten, 2018). Kalariga’s relatively low concern about intensifying rainfall (14%) is consistent with its stronger infrastructural protections such as paved surfaces and elevated dwellings which reduce direct exposure to flood impacts, as observed in affluent neighbourhoods in Arnhem, the Netherlands (Forrest et al., 2020). In Koblimahagu, a markedly different pattern emerges. As the lowest-income community in the study, Koblimahagu recorded the highest proportion of respondents more than 25% who perceived rainfall intensity to be increasing. These perceptions are grounded in direct, recurrent flood impacts experienced during rainy seasons. One resident explained:

*“Floodwaters easily enter homes during the rainy season”* (Resident, Koblimahagu, FGD., 2023)

Highlighting the community’s chronic exposure to hazardous runoff and inadequate drainage. Cultural interpretations also play a significant role: approximately 16% of respondents

attributed changing rainfall to divine will, reflecting deeply rooted spiritual worldviews. As another resident explained:

*“Rainfall is a divine blessing, and its reduction is a message from the gods”* (Resident, Koblimahagu, FGD, 2023).

Such spiritually grounded explanations align with findings from flood-prone communities in New Orleans, where socio-cultural beliefs significantly shaped perceptions of risk and climate change (Gotham et al., 2018). These interpretations illustrate how socio-economic marginality intersects with cultural frameworks to influence environmental understanding and coping strategies. These are presented in Figure 4.6

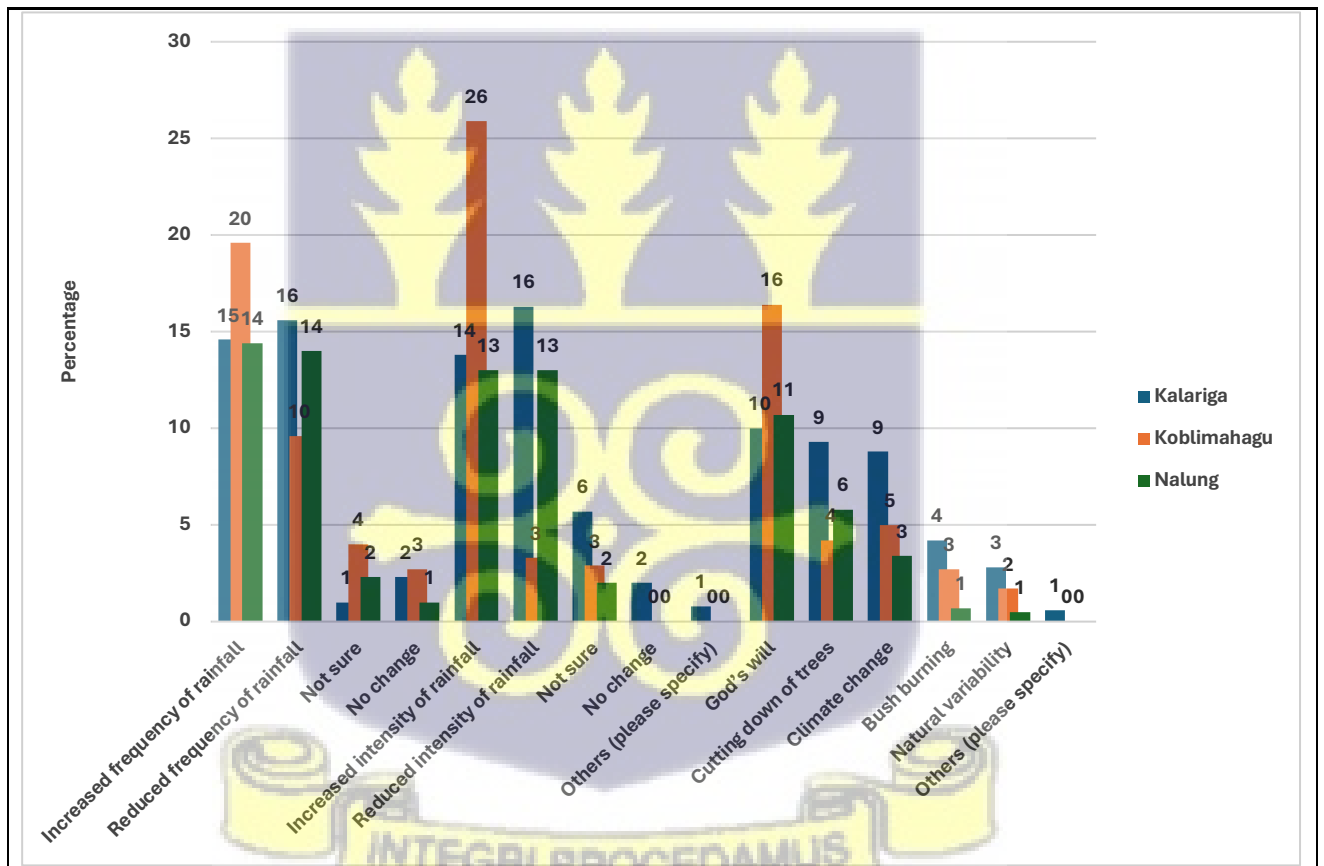


Figure 4.6 Perceptions of Rainfall Frequency, Intensity and Causes in TaMA  
Source: Field data, household questionnaire survey, 2023

Nalung, the middle-income community, presents a balanced blend of traditional and scientific interpretations. Respondents expressed moderate perceptions of both increased rainfall intensity (14%) and decreased intensity (10%). Qualitative accounts reveal a coexistence of scientific reasoning and cultural belief. A sub-chief explained:

*“While we believe the gods control rainfall, we also see how human activities like farming contribute to changes”* (Sub-Chief, Nalung, Interview, 2023).

This dual interpretive framework positions Nalung as an intermediary between the technoscientific orientation of Kalariga and the spirituality-infused perceptions of Koblimahagu. Such hybrid explanations mirror findings from Southern Europe and South Asia, where middle-income communities often bridge scientific and traditional knowledge systems (Antronico et al., 2020). Across the three communities, the proportion of respondents who reported “no change” or were “not sure” about rainfall trends was low. Rather than indicating questionnaire ambiguity, these minimal uncertain responses reflect varying degrees of climate-information access and confidence in interpreting environmental phenomena patterns widely observed in climate-perception literature (Bryan et al., 2013; Howe et al., 2015). The consistent and widespread recognition of rainfall variability across socio-economic groups demonstrates an informed awareness of climatic shifts, even if the explanatory frameworks differ.

From Urban Political Ecology (UPE) perspective, these findings underscore how environmental knowledge is shaped by the intersection of socio-economic inequality, exposure to risk, and uneven infrastructural development. In Koblimahagu, where drainage systems are inadequate and floodwater frequently enters homes, rainfall is perceived as increasingly intense because its impacts are immediate and damaging. In Kalariga, infrastructural protection dampens experiential exposure, producing a different interpretive relationship with rainfall.

UPE argues that climate hazards such as flooding are not merely natural events but are co-produced through political, infrastructural, and spatial inequalities. In this sense, rainfall becomes a hazard not because of its meteorological characteristics alone but because different communities possess unequal capacities to buffer its impacts. Together, these findings show that rainfall perceptions in Tamale are both socially produced and spatially differentiated. They are shaped by lived experience, cultural frameworks, infrastructural conditions, and socio-economic status factors that collectively structure how communities understand and respond to changing flood risks.

### 4.5.3 Real Temperature Patterns and Flood Occurrence

The Analysis of long-term temperature data for Tamale (1991–2022) (Figure 4.7) indicates a clear warming trend, consistent with broader patterns across the Sudan–Sahel ecological zone.

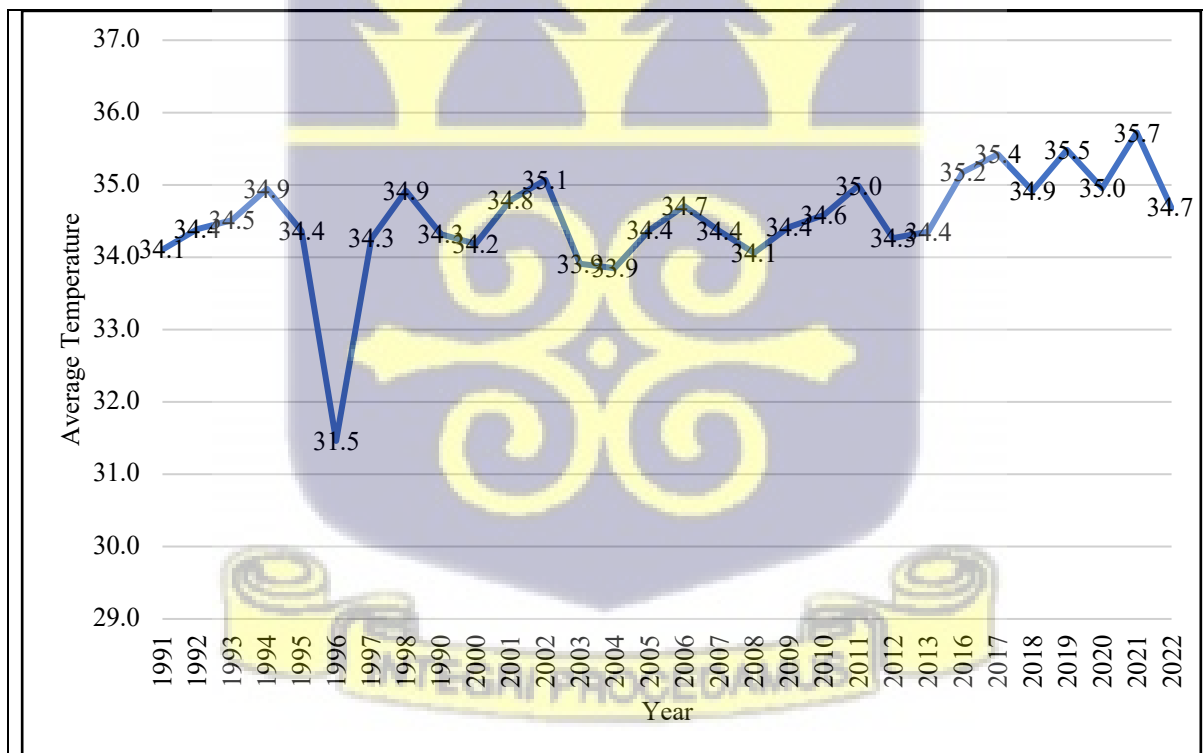


Figure 4.7 Average Annual Temperature for Tamale, 1991 to 2022  
Source: Ghana Meteorological Agency, Tamale

Average annual temperatures fluctuate between years, but the overall trajectory particularly from the 2010 onward shows progressively hotter conditions. This trend aligns with regional findings that West Africa has experienced substantial warming over the past four decades, driven by global climate change and land-surface modifications (IPCC, 2023a; Nicholson, 2001; Nicholson et al., 2018). The highest temperatures typically occur between March and April, during the pre-rainy season, when solar radiation peaks and humidity remains low. Cooler months correspond with the rainy season (July–September), when cloud cover reduces daytime heating. This seasonal fluctuation is well documented in tropical climate systems and is consistent with empirical evidence from other Sahelian cities such as Ouagadougou and Niamey (Taylor et al., 2017).

Although rising temperatures do not directly cause flooding, they influence hydrological processes in ways that shape urban flood sensitivity. Elevated temperatures intensify evapotranspiration, alter soil moisture balance, and increase the atmospheric capacity to hold moisture. This can lead to short-duration but high-intensity rainfall events extremes that have been widely reported in Sahelian meteorological studies (Sylla et al., 2016). Higher dry-season temperatures also harden soils, reducing infiltration and causing rapid runoff when rains begin, a dynamic that increases the likelihood of flash floods in vulnerable urban areas.

From an Urban Political Ecology (UPE) perspective, the implications of rising temperatures are unevenly distributed. Temperature increases interact with existing spatial inequalities such as inadequate housing, lack of shading vegetation, and poor drainage creating differentiated exposure across neighbourhoods. Communities with limited resources, such as Koblumahagu, experience amplified heat-related stress and greater sensitivity to subsequent runoff-driven floods because their built environments lack buffering infrastructure. In contrast, higher-

income areas like Kalariga have more adaptive features (e.g., better ventilation, shaded compounds, paved and elevated courtyards) that mitigate the compounding effects of heat and rainfall. A community leader in Koblimahagu emphasised this dual impact of heat and subsequent flooding, stating,

*“The heat is becoming worse every year, and when the rains start, the water enters our homes because the ground is already too hard.”* (Community Leader, Koblimahagu, FGD, 2023)

Such accounts illustrate how environmental and infrastructural inequalities intersect to shape differentiated vulnerability to both climatic warming and flood impacts.

#### 4.5.4 Perceived Temperature Changes Across Communities

Community perceptions of temperature changes across Kalariga, Nalung, and Koblimahagu (Figure 4.8) reveal a high degree of awareness regarding rising temperatures.

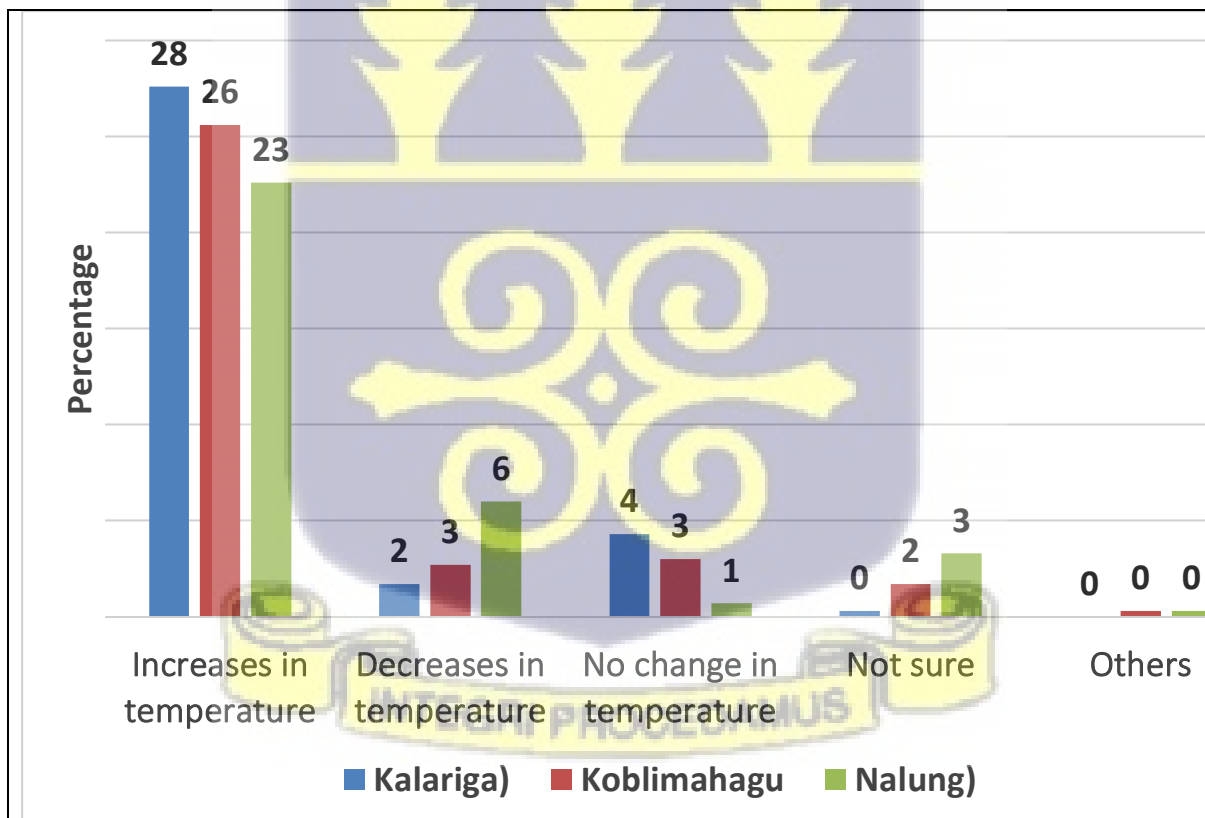


Figure 4.8 Perceptions of Temperature in Kalariga, Koblimahagu and Kalariga  
Source: Field data, household questionnaire survey, 2023

Approximately 28% of respondents in Kalariga, 26% in Koblimahagu, and 23% in Nalung believe that temperatures have increased in recent years. These widespread perceptions reflect the visibility of warming in daily life, particularly during prolonged dry seasons when heat stress is most acute. In Kalariga the high-income community, respondents frequently interpreted temperature increases through scientific or environmental reasoning. Many linked rising heat to broader climate change patterns. As one respondent explained:

*“The weather has changed, and the heat is too much now. We hear it on the news and can confirm it ourselves.”* (Kalariga resident, FGD, 2023)

Such interpretations align with studies showing that higher socioeconomic groups often exhibit stronger engagement with climate information and scientific explanations (Moser & Kleinhüchelkotten, 2018). In Koblimahagu the low-income community, perceptions were more directly grounded in lived experience, with residents linking increased temperatures to discomfort and livelihood impacts. A resident stated:

*“The sun now burns more than before, and we feel it because we don’t have shade or cooling in our homes.”* (Koblimahagu resident, FGD, 2023)

This aligns with findings from urban resilience research showing that low-income groups perceive climate change through immediate physical hardship, rather than abstract environmental discourse (Gotham et al., 2018). Nalung, the medium-income community, exhibited the highest proportion of uncertainty (3%) and a larger share of respondents (6%) who believed temperatures had decreased. This reflects a mixture of traditional belief systems and emerging environmental awareness. As one household head in Nalung explained:

*“We believe God controls the weather, but people cutting trees and farming too much also change the heat.”* (Nalung resident, FGD, 2023).

Such dual interpretations are characteristic of communities undergoing socioeconomic transition, where traditional knowledge and scientific explanations coexist. Across all three

communities, very few respondents (about 3–4%) reported no change in temperature, indicating broad awareness of climatic shifts. This shared acknowledgement supports the view that warming is widely recognizable across socio-economic groups, even if the underlying explanations differ.

From a UPE perspective, these perceptual differences reflect underlying socio-spatial inequalities. Access to information, type of housing, exposure to outdoor work, and micro-environmental conditions (e.g., shading, ventilation, building materials) shape how residents experience and interpret temperature change. Wealthier communities can mitigate heat stress through infrastructural investments, while poorer communities confront heat directly, often in the absence of adequate cooling or shading. These uneven experiences reinforce differentiated vulnerability to climate hazards including floods across the urban landscape. Having examined long-term temperature patterns and community perceptions, the next section considers how vegetation cover interacts with topography and land use to influence spatial variations in flood occurrence across the study communities.

#### **4.5.5 Vegetation Cover and Flood Occurrence**

Vegetation cover across the Tamale Metropolitan Area (TaMA) varies considerably, and although vegetation alone does not determine flood outcomes, its interaction with topography, land-use change, and socio-economic conditions contributes to differences in surface runoff and localised flooding. The three study communities Koblimahagu, Kalariga, and Nalung exhibit distinct vegetation patterns that shape their environmental conditions. Aerial imagery (Figures 4.9, 4.10 and 4.11) demonstrates generally sparse vegetation across all three sites, though the density, distribution, and landscape context differ.





Figure 4.11 Aerial View of Nalung Community showing sparse vegetation.  
Source: Google Maps

While the imagery is limited in resolution resulting in faint labels and some difficulty in visually locating all vegetated pockets the available data nonetheless indicate that vegetation is unevenly distributed within each neighbourhood. Koblimahagu, situated in the northeastern part of Tamale, has minimal vegetation cover combined with relatively flat terrain. This combination reduces soil infiltration and increases surface runoff during intense rainfall events.

As an official from the Forestry Services Department explained:

*“In a bare land where there are no trees, the water absorption is poor, so we plant trees there. Trees play many roles, including reducing waterlogging in flood-prone areas.”* (Official, FSD, KII, 2023)

This statement indicates that vegetation does not “stop” water in a literal sense but instead improves infiltration and slows runoff, helping to moderate flow accumulation. This distinction

is important because a common local perception is that trees physically “block” or “hold back” water. This view was expressed by a resident:

*“The rains leave us struggling because there are no trees to stop the water or places to drain it.”* (Resident, Koblimahagu, KII, 2023)

Trees do not function as hard barriers, but their roots and canopy slow overland flow, reduce soil sealing, and enhance infiltration. Residents are therefore describing, in experiential terms, the loss of ecological buffers that would otherwise soften runoff. Beyond environmental characteristics, Koblimahagu’s residents face heightened vulnerability to flood impacts, particularly recurrent waterlogging, property damage and difficulties evacuating water from compounds. The community’s limited financial capacity constrains the ability to invest in engineered or household-level drainage measures. This socio-economic constraint interacts with environmental conditions, reinforcing exposure to flood hazards. Kalariga, despite its high-income profile and location in the southeastern part of Tamale, also shows sparse vegetation. An official affirmed the ecological role of vegetation:

*“Trees and vegetation are crucial for reducing the risk of flooding, especially in flat terrains like Tamale.”*(Official, FSD, KII, 2023)

However, Kalariga’s households typically possess greater capacity to compensate for vegetation loss through engineered interventions such as paved compounds with internal drainage channels, raised plinths, and perimeter walls. Consequently, similar environmental conditions produce different outcomes across communities, demonstrating that resilience is mediated by socio-economic resources. This aligns with empirical findings that wealthier groups offset ecological deficits with infrastructural protections ((Fielding, 2007).

Nalung, located in the southwestern part of the metropolis, combines sparse vegetation with rocky terrain, which accelerates runoff and limits water infiltration. As an official noted:

*“Vegetation in urban and rural settings serves as a natural flood control mechanism by increasing water infiltration and reducing surface runoff.”* (Official, HSA, KII, 2023)

Yet, Nalung’s geology makes increasing vegetation challenging. A community leader explained:

*“We are trying to plant trees where we can, but the rocky ground makes it difficult.”* (Community Leader, Nalung, Interview, 2023)

The difficulty in establishing vegetation means the community remains exposed to rapid runoff during heavy rains despite moderate socio-economic status. When comparing the three communities, a clear socio-environmental pattern emerges. Koblimahagu faces the greatest flood risk due to flat topography, sparse vegetation, and low-income constraints. Kalariga, despite similar vegetation limitations, is less affected because affluent households invest in engineered solutions. Nalung occupies a middle position its rocky terrain amplifies runoff, while its moderate income level permits only limited mitigation. A governmental official summarised the importance of vegetation in urban flood management by noting,

*“Planting trees in degraded and flood-prone areas helps mitigate flooding by absorbing water and reducing runoff.”* (Official, FSD, interview, 2023)

From a Urban Political Ecology (UPE) perspective, vegetation patterns are not only ecological features but outcomes of socio-political processes such as differential land allocation, unregulated urban expansion, and uneven distribution of planning resources. Koblimahagu’s lower vegetation cover intersects with its limited infrastructural investment and marginalised governance status, while Kalariga’s household-level adaptations illustrate how socio-economic privilege mediates environmental risk. Vegetation scarcity thus becomes part of a wider landscape of inequality in which environmental buffers and infrastructural protections are unevenly distributed across space and class.

#### 4.5.6 Topography, Elevation and Drainage and Flood occurrence

The physical landscape of the Tamale Metropolitan Area significantly shapes the spatial pattern of flooding, particularly through its gently undulating topography, varying elevations, and constrained drainage pathways. Tamale lies within the Guinea Savannah ecological zone, characterised by shallow valleys and low-gradient slopes that channel runoff into natural depressions during heavy rainfall. Elevations across the metropolis range from approximately 110 to 219 meters above sea level (Topographic Maps, 2024). While these gradients are moderate, rapid urbanisation and limited engineered drainage have amplified the hydrological pressures exerted during intense rainfall events. As one official highlighted:

*“Tamale has a good number of drains, but their functionality is low due to poor design and lack of maintenance”* (Official, HSD, KII, 2023).

This indicates that the challenge is not merely the presence of drainage channels but the mismatch between their capacity and the rainfall intensities experienced in recent years.

Across the three study communities, differences in elevation and terrain interact with socio-economic conditions to create distinct flood vulnerabilities. In Kalariga, which lies between 152 and 167 meters above sea level, the slightly rolling terrain supports natural water movement, but the limited vegetation cover and partially developed drainage networks allow localised ponding during storms. A resident explained:

*“When the rains are heavy, the drains overflow, but we’ve been able to build barriers and channel the water away from our homes”* (Resident, Kalariga, FGD, 2023).

Such coping strategies highlight how higher-income households can deploy private engineering solutions to offset environmental risks. These observations mirror findings from Accra, where wealthier communities often mitigate exposure through compound paving, elevated plinths, and boundary walls, even as overall runoff is worsened downstream (Amoako & Boamah, 2015). From a UPE perspective, Kalariga’s experience illustrates how socio-

economic privilege shapes flood outcomes: the physical system may expose the community to flooding, but social and material advantages moderate the severity of impacts.

Nalung, located between approximately 147 and 183 meters above sea level, presents a contrasting geomorphological profile. Its predominantly rocky terrain significantly limits infiltration, causing rapid overland flow during heavy rains. Although some engineered drains exist, their capacity is inadequate for the speed and volume of runoff generated on the compacted surfaces. A community leader observed:

*“The rocky ground does not allow the water to sink in, so it flows fast, causing more damage”* (Community Leader, Nalung, FGD, 2023).

This terrain-imposed vulnerability complicates adaptation efforts, as traditional measures such as tree planting are constrained by shallow soils and exposed bedrock. Similar dynamics have been documented in other African cities, such as Tamale’s neighbouring municipalities in the Northern Region, where rocky upland areas produce high-velocity runoff that overwhelms drains in downslope settlements (Songsore, 2017). Likewise, studies in Kigali, Rwanda, show that steep and rocky surfaces increase flash flood intensity where drainage infrastructure lags behind urban expansion (Cook et al., 2020). Nalung’s medium-income status provides some degree of resilience, but terrain-induced runoff remains a major challenge that requires more sophisticated engineering than community resources can support.

Koblimahagu, situated between 140 and 165 meters above sea level, occupies some of the lowest-lying areas among the three communities. Its flat terrain, combined with clay-rich soils and sparse vegetation cover, leads to widespread waterlogging during and after storms. Residents repeatedly described how rainfall accumulates due to the absence of sufficiently designed drainage channels. As one community leader remarked:

*“The water just collects everywhere because there are no proper drains. It feels like no one cares about fixing it here”* (Community Leader, Koblimahagu, FGD, 2023).

According to a NADMO official:

*“The communities with the least resources often face the worst flooding impacts because they lack both natural and engineered flood adaptation systems”* (Official, NADMO, KII, 2023).

This situation mirrors conditions described in African literature: unplanned, low-income settlements in cities such as Accra, Kampala and Dar es Salaam experience aggravated flooding due to flat topography, limited drainage, and constrained municipal investment (Vedeld et al., 2015). Koblimahagu thus represents the intersection of physical vulnerability and political-economic marginality, a core concept emphasised by UPE scholars who argue that flood risks in African cities are “produced through uneven development and persistent infrastructural inequalities” (Swyngedouw & Heynen, 2003).

Collectively, these findings show that topography, elevation, and drainage cannot be understood in isolation from the socio-economic and infrastructural context in which they operate. Kalariga, despite moderate elevation and limited vegetation, reduces exposure through private structural investments. Nalung, with its rocky terrain, faces runoff challenges exacerbated by limited infiltration and Koblimahagu, at relatively lower elevations and without engineered drainage or vegetation buffers, experiences the most severe and widespread flooding. This pattern aligns with both local and continental evidence that flood vulnerability is shaped as much by socio-political processes as by physical geography (Lwasa, 2014). Under UPE, the spatial distribution of flood risk in Tamale reflects the interaction between natural hydrological processes and uneven infrastructural provision a condition that positions lower-income communities as disproportionately exposed to the burdens of environmental change.

#### 4.6 Anthropogenic Drivers and Flood Occurrence

##### 4.6.1 Income Distribution and Flood Occurrence

Income distribution across Kalariga, Nalung, and Koblimahagu (Figure 4.12) reveals clear socio-economic differences that shape flood exposure and adaptive capacity in significant ways.

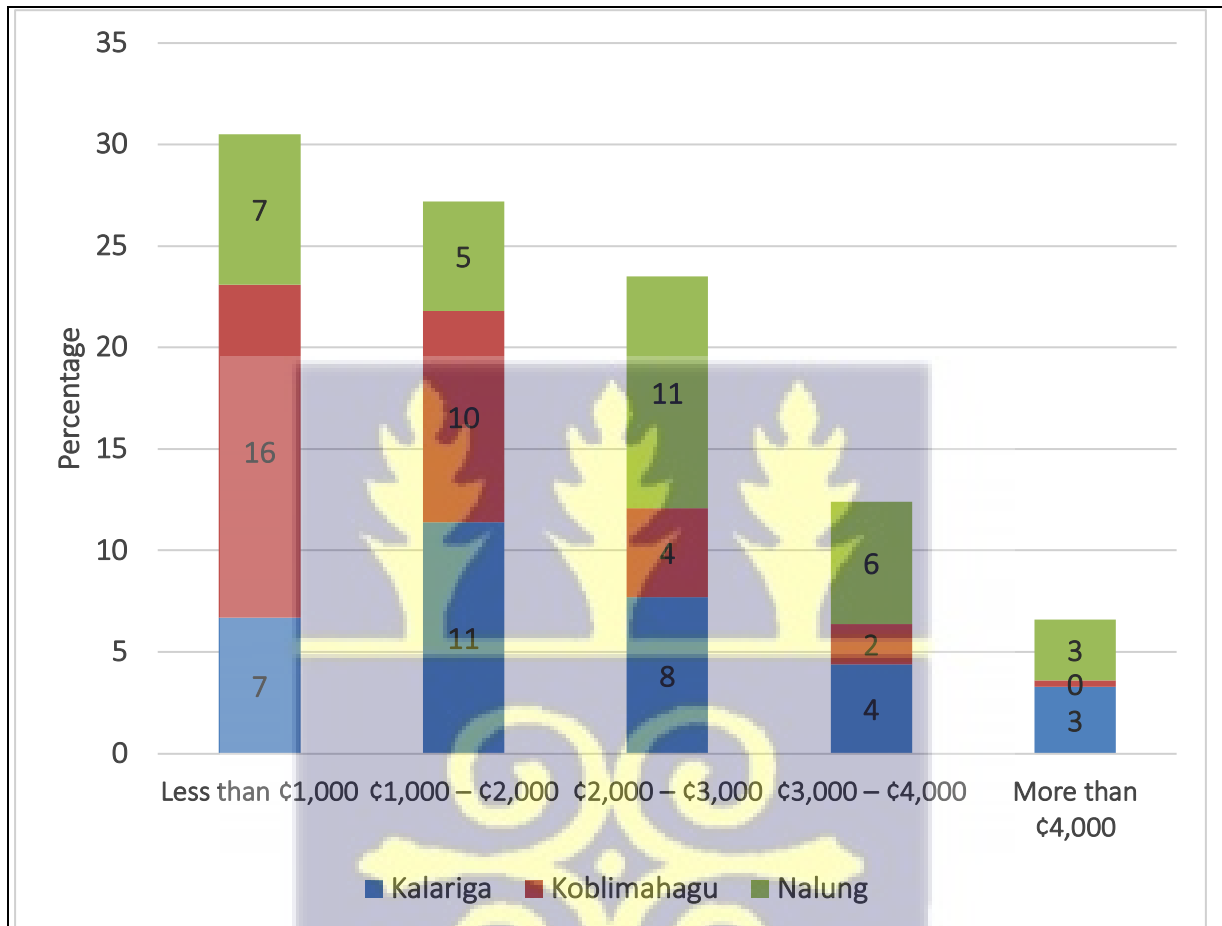


Figure 4.12 Income distribution across communities  
Source: Field Data, 2023, Household Questionnaire Survey

During the household survey, income information was collected directly using structured monthly income ranges. To improve accuracy given the prevalence of informal and irregular income sources in Tamale these self-reported income categories were cross-checked against detailed household expenditure data covering food, utilities, transport, rent, school fees, and other recurrent costs. The differences between reported income and computed expenditure

levels were marginal, confirming the internal consistency of the data and strengthening the reliability of the resulting socio-economic classification. This dual-measurement approach is recognised as good practice in contexts with widespread informal earnings (GSS, 2014). Kalariga, identified as the high-income community, shows the highest concentration of households in the middle-to-upper income bands. Approximately 11% of households fall within the ₵1,000–₵2,000 category, 8% within ₵2,000–₵3,000, and smaller proportions occupy the ₵3,000–₵4,000 (4%) and above ₵4,000 (3%) categories.

These patterns align closely with qualitative insights that highlight the community’s comparatively strong infrastructural investments and economic opportunities. As one resident explained:

*“Our households invest in modern building structures to withstand floods”* (Resident, Kalariga, FGD, 2023).

Such investments indicate an enhanced capacity to reduce exposure and recover quickly from flood events. Similar patterns have been documented in affluent neighbourhoods in Accra, where higher-income households deploy private adaptation strategies in the absence of adequate citywide infrastructure (Amoako & Frimpong Boamah, 2015).

Nalung’s income distribution reflects its status as a middle-income settlement. The largest share of households (11%) falls within the ₵2,000–₵3,000 range, with moderate representation across both lower and higher bands. The presence of approximately 7% of households in the lowest income category indicates intra-community inequality. As a chief noted:

*“Some families struggle with basic needs, while others have moved to build concrete homes”* (Chief, Nalung, Interview, 2023).

Nalung therefore exhibits a coexistence of vulnerability and resilience, a pattern consistent with mid-income neighbourhoods in other African cities such as Kampala, where mixed housing conditions and uneven access to infrastructure produce varied flood outcomes (Lwasa, 2014). Koblimahagu, designated as the low-income community, displays the greatest economic precarity. Over 16% of households fall below the ₵1,000 income threshold, with very limited representation in higher income ranges. Residents frequently linked this economic hardship to their inability to invest in durable housing or flood-resistant measures. One respondent observed:

*“We lack resources to rebuild our homes after floods because they are made of weak materials”* (Resident, Koblimahagu, FGD, 2023).

Such constraints reduce both preventive and recovery capacities. These findings mirror broader evidence from low-income communities in cities such as Dar es Salaam and Accra, where economic marginalisation heightens flood vulnerability by limiting access to infrastructure, secure housing, and institutional support (Vedeld et al., 2015).

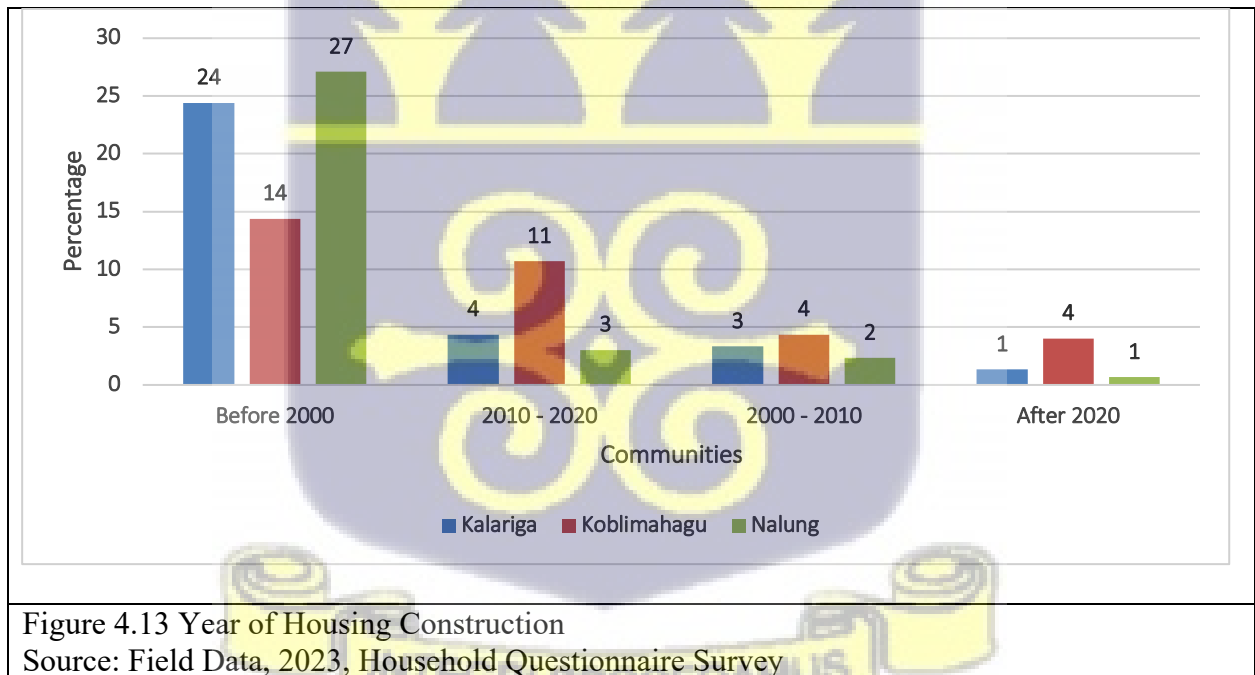
Overall, the income distribution across the three communities highlights significant socio-spatial disparities that shape differential flood risk. While income alone cannot fully determine vulnerability or resilience, it directly influences the quality of housing, opportunities for preventive investments, household exposure profiles, and capacity to recover after flood events. From a UPE perspective, these socio-economic inequalities are not incidental but reflect broader historical and political processes that unevenly distribute risk across the urban landscape (Swyngedouw & Heynen, 2003). Income therefore functions as a key mediating factor interacting with infrastructure, governance, and geography to produce the distinct flood vulnerabilities observed across Kalariga, Nalung, and Koblimahagu.

#### 4.7 Housing Characteristics and Flood Occurrence

Housing characteristics age of construction, type of dwelling, and building materials provide important insights into how socio-economic conditions shape flood vulnerability across Kalariga (high-income), Nalung (middle-income), and Koblimahagu (low-income). These characteristics also reflect larger patterns of urban development, planning gaps, and community-based adaptation strategies in Tamale.

##### 4.7.1 Year of Housing Construction

The distribution of housing age (Figure 4.13) shows marked contrasts across the three communities. A large proportion of houses in Nalung (27%) and Kalariga (24%) were built before 2000, reflecting older housing stock with structural conditions shaped by earlier building norms.



Such older homes often exhibit deteriorating foundations, narrower drainage corridors, and weaker roofing, all of which may heighten vulnerability to floods, as noted in similar contexts

such as Maputo and Accra where ageing housing stock contributed to household-level flood impacts (Bigi et al., 2021). By contrast, Koblimahagu the least affluent community has a smaller share of older houses (14%) and a relatively higher proportion of more recent constructions, particularly between 2010–2020 (11%) and after 2020 (4%). This pattern reflects ongoing urban expansion at the periphery of Tamale rather than improved living standards. As low-income households are increasingly pushed outward due to rising central land values, many settle and construct homes in marginal, flood-prone areas lacking drainage and infrastructure, a trend also observed in peri-urban Accra, Lagos, and Dhaka (Mortoja & Yigitcanlar, 2020; UN-Habitat, 2020). A planning official highlighted gaps between housing expansion and proper land-use regulation, noting:

*“Before every land is planned, we identify lowland areas and ensure proper schemes are prepared to leave reserve areas for water flow. However, implementation is often weak.”* (Official, LC, KII, 2023)

This weak implementation contributes to the proliferation of newly built yet flood-exposed housing in low-income settings.

#### **4.7.2 Housing Types and Settlement Form**

Compound houses remain the dominant dwelling type in all three communities (Figure 4.14), accounting for 23% in Nalung, 17% in Kalariga, and 15% in Koblimahagu. These horizontally spread structures accommodate multiple households within enclosed courtyards and often lack adequate drainage or setback spaces. Their impervious courtyards and dense layout reduce infiltration and block natural flow paths, increasing localised flooding during heavy rainfall. Similar relationships between courtyard housing and flood accumulation have been documented in Kano, Accra, and Ibadan (Douglas et al., 2008). Unexpected variations

challenge the assumption that affluent communities universally exhibit high-quality housing typologies. Koblimahagu records a surprisingly high share of flats/apartments (10%), exceeding Kalariga (5%) and Nalung (2%).

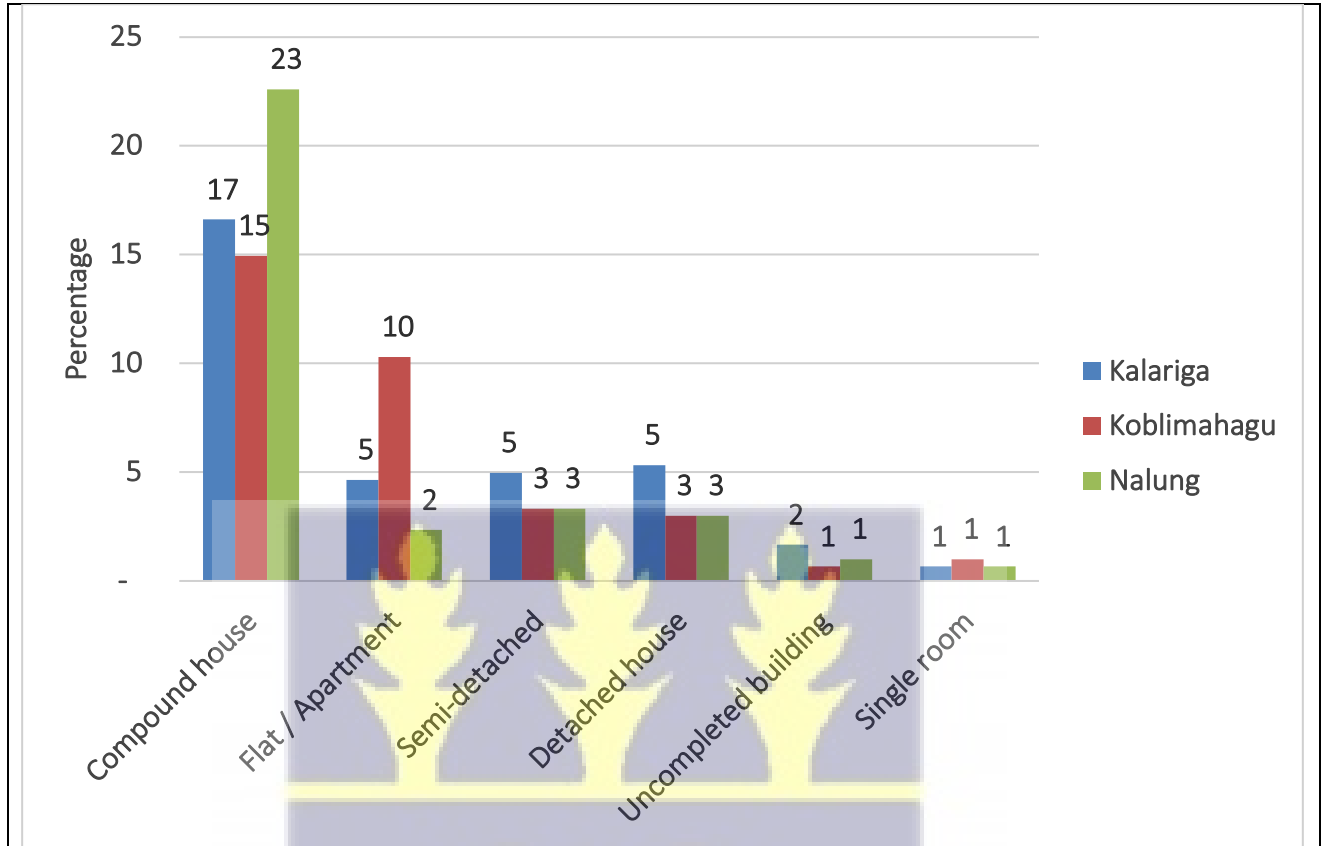


Figure 4.14 Type of Housing  
Source: Field Data, 2023, Household Questionnaire Survey

This suggests horizontal densification driven by land scarcity rather than formal multi-storey development. Such patterns mirror the expansion of compact, informal low-rise apartments in Dhaka and Nairobi’s low-income areas (Braun & Aßheuer, 2011). Similarly, semi-detached and detached houses typically associated with higher socio-economic status show only modest variation: 5% in Kalariga, 3% in Koblimahagu, and 3% in Nalung. These mixed patterns underscore complex socio-economic layering within Tamale’s neighbourhoods, where proximity to employment and social networks often outweighs income-based residential sorting.

### 4.7.3 Building Materials and Structural Flood Resilience

The materials used in house construction (Figure 4.15) reinforce the socio-economic variations observed above but also reveal counterintuitive adaptive behaviours. Koblimahagu, the lowest-income community, records the highest use of concrete blocks (27%), surpassing Nalung (26%) and high-income Kalariga (21%).

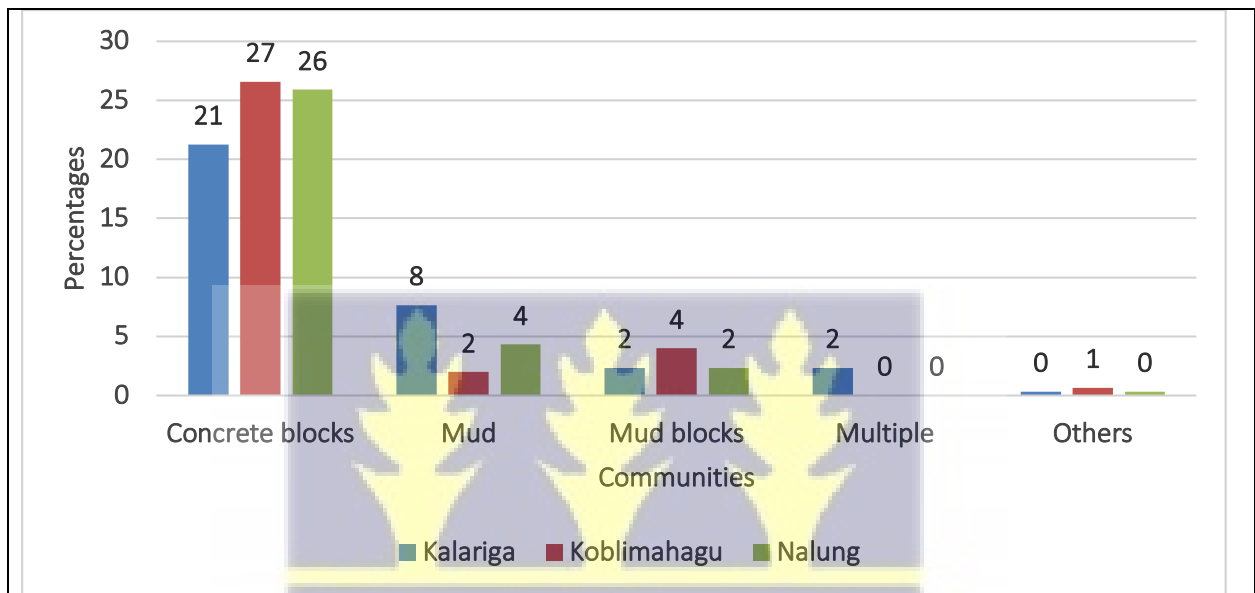


Figure 4.15 Type of Building Material Used  
Source: Field Data, 2023, Household Questionnaire Survey

This pattern reflects a significant community-driven investment in durable materials as a protective response to persistent flooding threats. A resident explained:

*“We lack resources to rebuild our homes after floods because they are made of weak materials.”* (Resident, Koblimahagu, FGD, 2023)

Such self-financed resilience aligns with findings from Lilongwe and Kampala, where low-income residents strategically invest in durable materials to reduce future flood losses despite financial hardship (Manda & Msasa, 2025). In contrast, Kalariga unexpectedly records a notable presence of traditional mud buildings (8%). This suggests pockets of intra-community income disparity or cultural preferences for traditional construction methods. These mixed-

material landscapes highlight the UPE principle that vulnerability is not determined by income alone but shaped by historical, cultural, and political dynamics (Amoako, 2016; Ekoh & Teron, 2023). A state official emphasised the complementary role of ecological and engineered solutions in enhancing structural resilience:

*“Vegetation serves as a natural flood control mechanism by increasing water infiltration and reducing surface runoff. However, this must be complemented by engineered systems.”* (Official, HAS, KII, 2023)

#### 4.7.4 Integrating Housing Characteristics and Flood Vulnerability

When examined collectively, the housing data reveal a complex interplay between socio-economic status, settlement form, and structural resilience. Kalariga, despite its affluence, retains pockets of older and traditional housing that undermine resilience. Nalung, with its ageing housing stock and mixed material use, occupies a transitional resilience position, balancing moderate adaptive capacity with structural challenges. Koblimahagu, though the poorest, shows proactive investment in durable materials but remains constrained by settlement in marginal flood-prone zones and limited drainage infrastructure. Through the lens of Urban Political Ecology (UPE), these patterns illustrate that flood vulnerability is not merely a consequence of poor housing but emerges from deeply rooted inequalities in land allocation, service provision, and planning enforcement. Urban Resilience Theory adds that the capacity to absorb, adapt, and recover from floods varies across communities, shaped by both material conditions and access to resources (March & Swyngedouw, 2022). Overall, the housing characteristics of Tamale’s three communities reflect intertwined socio-economic and environmental processes that create differentiated exposure and adaptive capacity.

#### 4.8 Waste Management, Drainage Obstruction and Flood Occurrence

Waste management emerged as a critical anthropogenic driver of flooding across Kalariga, Nalung, and Koblimahagu. Field observations and interviews reveal that poor waste disposal practices particularly the deposition of plastics, organic waste, and construction debris into drainage channels significantly reduce hydraulic capacity and intensify flood severity during moderate and heavy rainfall events. The photographs (Figures 4.16 and 4.17) illustrate the condition of drains in Koblimahagu and parts of Nalung, where accumulated refuse obstructs water flow and leads to stagnant, polluted water even during the dry season.



Figure 4.16 Waste disposal (Koblimahagu)

Figure 4.17 Plastic waste disposed in a drain (Nalung)

These observations directly support the study's objectives, which seeks to identify natural and anthropogenic drivers of flood occurrence in TaMA, and institutional adaptation responses. A city engineer emphasised the scale of the challenge, noting that:

*“The drains fill up quickly not only because they are small, but because people dump refuse into them daily”* (Official, Urban Roads, KII, 2023).

Observations from the field confirmed drains blocked by plastic bags, food packaging, silt, and vegetation, resulting in stagnant pools of water (Figure 4.17). These findings are consistent

with studies in Accra and Kumasi showing that uncollected waste and drain obstruction are key determinants of perennial urban flooding (Cromwell, 2021; Kombiok & Naa Jaaga, 2023).

In Nalung, waste disposal issues were less severe but still contributed to localised flooding, particularly around community markets and roadside drains. One community member explained:

*“When the market women pour rubbish into the drains, the water has nowhere to go during the rains”* (Resident, Nalung).

This indicates that waste disposal practices are mediated not only by poverty, but by behavioural norms and the absence of regular monitoring by city authorities. Even in high-income Kalariga, some respondents acknowledged that poor waste disposal in adjacent communities influences downstream areas. As one resident indicated:

*“we clean our drains, but the waste from upstream comes down to us”* (Resident, Kalariga, FGD, 2023).

This underscores the interconnectedness of drainage systems, highlighting how upstream practices can increase downstream flood risk regardless of local affluence a core tenet of Urban Political Ecology (UPE), which emphasises the shared and socially produced nature of urban environmental burdens. The images presented in this section (Figures 4.16 and 4.17) therefore serve as evidence of the material pathways through which poor waste management increases flood occurrence. Blocked drains reduce conveyance capacity, cause overflow during rainfall, and amplify the impacts of inadequate drainage a challenge repeatedly mentioned in interviews with NADMO and the Hydrological Services Department. NADMO officials stressed that:

*“The combination of poor waste disposal and undersized drains” is a major driver of recurrent flooding* (Official, NADMO South Sub-Metro, KII, 2023).

Taken together, the household survey, field observations, and institutional interviews demonstrate that ineffective waste management is a pervasive anthropogenic factor influencing flood occurrence across all three communities. The problem is most acute in Koblimahagu due to limited municipal waste services and lower enforcement of sanitation by-laws, but structural vulnerabilities in the drainage system mean all communities are ultimately affected. In line with Urban Political Ecology, this section highlights how social inequality, governance gaps, and uneven access to waste management services collectively shape flood vulnerability in TaMA.

#### 4.9 Hybrid-Governance and Flood Occurrence

Flood occurrence in the Tamale Metropolitan Area (TaMA) is shaped not only by environmental factors but also by a hybrid governance system comprising formal state institutions and traditional authorities. These overlapping governance structures influence land allocation, enforcement of planning regulations, infrastructure provision, and community mobilisation each of which plays a pivotal role in shaping the spatial distribution of flood vulnerability across Kalariga, Nalung, and Koblimahagu. In line with Urban Political Ecology (UPE), this section demonstrates how governance processes rooted in power, inequality, and institutional fragmentation produce uneven geographies of risk. In Kalariga, Tamale's high-income enclave, governance failures manifest primarily through weak enforcement of zoning regulations and inadequate maintenance of drainage systems. Although the area benefits from better roads and engineered drains, institutional follow-through is inconsistent. As one community leader explained:

*“Illegal structures on waterways are a major problem. Even when the government constructs drains, these buildings block the flow of water, and we are left dealing with floods that could have been avoided”* (Local Leader, Kalariga, FGD, 2023).

This reflects a governance paradox: infrastructure exists, but institutional enforcement is insufficient to preserve its function. Similar patterns have been observed in Accra's Ridge and Cantonments, where affluent neighbourhoods also suffer localised flooding due to governance lapses in development control (Amoako, 2016).

Nalung, the medium-income community, demonstrates a different governance failure which is poorly tailored infrastructure that does not align with the community's rocky terrain. Despite having tarred roads and some drains, these structures are insufficient for the magnitude and speed of runoff generated by the impermeable landscape. As a community representative noted:

*"The gutters the government installed are too small for the floodwater"* (Community Leader, Nalung, FGD, 2023).

Stakeholders frequently described the local assembly's approach as reactive drains are cleaned only after severe flooding occurs. This mirrors patterns in Kumasi, where drains in middle-income neighbourhoods are regularly overwhelmed due to a mismatch between environmental context and infrastructural design (Agyabeng et al., 2024). Koblimahagu, the low-income community, faces the most acute governance neglect. Here, the absence of engineered drains, limited municipal waste collection, and patchy engagement by state authorities create a structural vulnerability that transforms even modest rainfall into damaging floods. A local leader articulated this frustration:

*"We have no proper drains here because the government prioritises wealthier areas. We only get promises of development, but nothing changes"* (Community Leader, Koblimahagu, FGD, 2023).

The lack of state investment is compounded by unregulated land allocation practices. A local NGO representative stated:

*“Flooding here is not just about the rain; it is about neglect. The government has forgotten these people”* (Official, SEND Ghana, KII, 2023).

These findings align with studies in Mombasa and Kampala, where institutional neglect in low-income settlements intensifies exposure to pluvial flooding (Okaka & Odhiambo, 2019).

Traditional governance systems particularly the roles of chiefs in land administration further shape flood risks. Chiefs possess authority to allocate land independently of municipal planning controls, and in several cases, flood-prone areas have been converted into residential plots. A TaMA official noted:

*“Chiefs are selling lands that should be reserved for water flow. When this happens, it becomes difficult to enforce planning regulations, and the result is increased flooding”*(Official, TaMA, KII, 2023).

This tension between statutory planning and customary land control is a longstanding challenge in Ghanaian urban governance and has been widely documented in cities such as Accra, Wa, and Cape Coast (Mintah et al., 2021; Yaro, 2010). As UPE argues, environmental risks often emerge where competing governance interests intersect, producing landscapes of unequal protection. Traditional leaders can, however, contribute positively to flood management through community mobilisation, though such efforts remain largely ad hoc. As one Nalung resident noted:

*“The chiefs tell us to clear the gutters, but there is no follow-up from the government”* (Resident, Nalung, FGD, 2023).

Without integration into formal planning processes, such initiatives lack continuity and the technical support needed for sustained risk reduction. The cumulative effect of these hybrid governance failures is a spatially uneven pattern of flood vulnerability across Tamale. Kalariga benefits from better infrastructure but suffers from enforcement gaps. Nalung contends with infrastructure ill-suited to its environmental context. Koblimahagu faces systemic neglect,

minimal investment, and decisions by traditional authorities that exacerbate exposure. A TaMA official summarised this challenge:

*“We have the laws, but enforcing them is the problem. Developers bypass regulations, and there are no consequences because enforcement is weak”* (Official, TaMA, KII, 2023).

A NADMO representative added:

*“Flood adaptation needs more than just emergency response it requires planning, and that is missing because the government is not prioritising it”* (Official, NADMO, KII, 2023).

These governance patterns mirror findings from Nairobi, where unplanned development, weak enforcement, and competing land interests increase vulnerability in informal settlements (Owuor & Mwiturubani, 2022). They also echo challenges in Lusaka and Dar es Salaam, where hybrid governance systems undermine coherent urban planning, producing highly uneven flood impacts (Croese et al., 2023; Vedeld et al., 2015).

Taken together, the evidence demonstrates that flood risk in Tamale is not simply the outcome of climatic or environmental processes, but a product of hybrid governance dynamics. Weak regulatory enforcement, fragmented institutional responsibilities, uneven infrastructural investment, and uncoordinated land allocation collectively produce socio-spatial inequalities that expose certain communities particularly Koblimahagu to disproportionate flood impacts. Lessons from Botswana’s co-production models, where chiefs and local councils jointly implement land-use decisions, offer a potential pathway for strengthening coordination and reducing vulnerability (Lekorwe & Mpabanga, 2007). Addressing these governance gaps is therefore essential for building long-term flood resilience and advancing equitable urban development in TaMA.

#### 4.10 Hypothesis Testing of Objective One

To evaluate whether socio-economic status (SES) significantly influences household flood occurrence in the Tamale Metropolitan Area, a chi-square test of independence was conducted using the indicator “frequency of floods entering households.” This measure was selected because it captures the severity of flood impact more accurately than surface flooding, and is widely used in urban flood vulnerability assessments. The hypothesis guiding this analysis, drawn from the analytical framework in Chapter Three, states that lower-SES households and communities experience significantly higher flood occurrence than their higher-income counterparts. The null hypothesis ( $H_{01}$ ) posits no significant relationship between SES and flood occurrence, while the alternative hypothesis ( $H_{11}$ ) proposes that flood occurrence is socio-economically differentiated. Observed frequencies of indoor flooding were extracted from household survey data and presented in Table 4.1.

Table 4.1 Observed Counts Used in Analysis

Community	Households	Frequent Indoor Flooding	Occasional Flooding	Rare/None
Kalariga (High SES)	95	19	30	46
Koblimahagu (Low SES)	99	29	33	37
Nalung (Middle SES)	106	6	20	80

*These totals were derived proportionally from percentages of households.*

Kalariga (high SES) recorded 19 cases of frequent flooding out of 95 households, Koblimahagu (low SES) recorded 29 cases out of 99 households, and Nalung (middle SES) recorded only 6 cases out of 106 households. These patterns already suggested a socio-spatial gradient, with the low-income community experiencing the highest internal flood penetration. The chi-square analysis confirmed this trend, yielding  $\chi^2 = 28.14$  with 4 degrees of freedom and a p-value of 0.00007, which is highly significant ( $p < 0.001$ ). *Based on this result, I fail to accept the null hypothesis.* The test provides clear statistical evidence that SES is significantly associated with

flood occurrence in TaMA, validating the alternative hypothesis that lower-income households experience disproportionately higher flood intrusion.

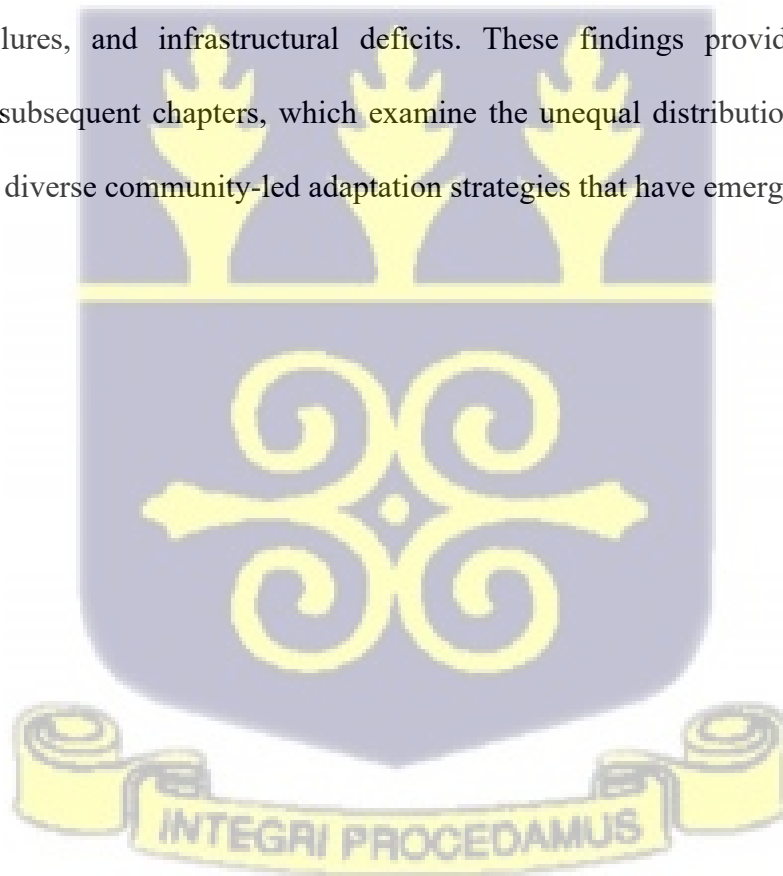
The distribution of responses indicates that Koblimahagu faces the most severe and recurrent household flooding, reflecting its low-lying terrain, limited drainage infrastructure, poor housing conditions, and restricted adaptive capacity. Nalung displays moderate exposure, consistent with its transitional socio-economic position, where some infrastructural support exists but remains insufficient to fully mitigate flood risk. In contrast, while Kalariga experiences noticeable surface runoff and compound flooding, its households report substantially fewer instances of water entering living spaces. This pattern reflects the community's elevated buildings, paved compounds, boundary walls, and investment in protective measures. The results therefore illustrate that although flooding is not exclusive to any income group, the severity and direct household impact are overwhelmingly concentrated in low-income areas. These findings align strongly with the wider literature on urban flood vulnerability. Studies in Accra (Asumadu-Sarkodie et al., 2015; Okyere et al., 2013), Lagos (Ekoh & Teron, 2023), Ibadan (Olaniyan, 2024), consistently demonstrate that low-income settlements endure more severe flood risks due to historical marginalisation, inadequate services, informal land allocation, and poor drainage conditions. Similar patterns have been observed in Dhaka, Dar es Salaam, Nairobi, and Mumbai, where infrastructural deficits and weak planning expose poorer communities to frequent and damaging floods. The statistical results from TaMA therefore reinforce theoretical insights from Urban Political Ecology and Urban Resilience Theory, which argue that flood risk is socially produced and unequally distributed within cities. The significant relationship between SES and flood occurrence found

in this study confirms that structural inequalities, spatial planning practices, and resource disparities play central roles in shaping flood vulnerability in Tamale.

#### 4.11 Chapter Summary

Objective One sought to analyse the socio-spatial variation in flood occurrence within the Tamale Metropolitan Area and to examine the natural and anthropogenic factors shaping these patterns. The integrated quantitative, qualitative, and spatial analyses demonstrate that flood occurrence in TaMA is not random but follows a clear socio-spatial gradient shaped by inequalities in environmental exposure, infrastructural provision, governance, and adaptive capacity. Natural drivers including rainfall variability, temperature trends, topography, elevation, and vegetation cover play a significant role in determining baseline hydrological vulnerability. The climatic analysis shows increasing rainfall intensity and pronounced seasonal variability, both of which exacerbate runoff and drainage overload. Vegetation analysis reveals that sparse vegetative cover in communities such as Koblimahagu and parts of Nalung reduces infiltration and intensifies surface flooding. Topographic and elevation patterns further differentiate flood risk, with low-lying and rocky areas experiencing faster and more damaging runoff, while poorly maintained natural drainage channels fail to manage peak flows. Anthropogenic factors intensify these geographic vulnerabilities. Income distribution shapes residents' ability to invest in protective infrastructure, maintain housing quality, and engage in preventive measures. Housing typologies, building materials, and settlement densities contribute directly to differential exposure, with compound houses and unplanned densification amplifying flood impacts. Waste management failures emerged as a major flood driver, with plastic waste and informal dumping practices obstructing drainage systems across multiple communities. Governance issues—including weak enforcement of zoning laws, poor

drainage maintenance, inequitable resource allocation, and unregulated land sales by traditional authorities further entrench spatial inequalities in flood risk. The hypothesis testing provided statistical confirmation of these patterns, demonstrating a significant association between socio-economic status and flood occurrence ( $\chi^2 = 28.14, p < 0.001$ ). Low-income Koblimahagu experiences the highest frequency of indoor flooding, reflecting its compounded environmental and infrastructural vulnerabilities. Middle-income Nalung shows moderate risk shaped by terrain and infrastructural inadequacies, while high-income Kalariga experiences less internal flooding due to structurally robust housing and better adaptive investments, despite its surface runoff challenges. In sum, Objective One demonstrates that flood occurrence in Tamale is the result of a complex interplay between environmental conditions, socio-economic inequalities, governance failures, and infrastructural deficits. These findings provide the empirical foundation for subsequent chapters, which examine the unequal distribution of institutional support and the diverse community-led adaptation strategies that have emerged in response.



## CHAPTER 5

### EVALUATION OF INSTITUTIONAL ADAPTATION STRATEGIES IN TAMALE

#### 5.1 Introduction

Chapter Four examined the spatial patterns of flood occurrence in Tamale, showing how natural and anthropogenic factors interact with socio-economic status (SES) to shape differential exposure and vulnerability. This chapter shifts the focus from risk to response by evaluating institutional flood adaptation strategies in the Tamale Metropolitan Area (TaMA), using Kalariga (high-income), Nalung (medium-income), and Koblimahagu (low-income) as comparative case studies. The analysis centres on the second objective of the study: to evaluate planned and externally supported flood adaptation strategies across socio-economic settings in Tamale. Planned adaptation is understood here as formal, institutionally driven measures both structural (e.g., dams, drains, flood walls) and non-structural (e.g., early warning systems, land-use planning, emergency response, and flood education).

These interventions are contrasted with community-based and household adaptations, which are addressed in Chapter Six. The chapter draws on quantitative survey data, key informant interviews (KII) with officials from NADMO, GMET, TaMA, Urban Roads, the Hydrological Services Department, the Forest Services Division, NGOs, and traditional authorities, as well as focus group discussions (FGDs) in the three communities. Through the lenses of Urban Political Ecology (UPE) and Urban Resilience Theory (URT), the chapter assesses not only the existence of planned adaptation measures but also their spatial distribution, effectiveness, and the extent to which they reinforce or help redress socio-spatial inequalities. It concludes with a hypothesis test for Objective Two and a synthesis of key findings.

## 5.2 Flood Adaptation in Tamale

Flood adaptation are organised into two domains in this study. Institutional adaptation and community-based adaptation (CBA). Institutional adaptation refers to formal, often top-down interventions initiated by state or quasi-state institutions. These include structural measures such as dams, engineered drainage networks, culverts, and (in principle) flood walls, intended to regulate water flow, store excess runoff, and protect built-up areas (Grigg, 2024). Non-structural measures such as zoning and land-use regulation, early warning systems (EWS), flood-related policy frameworks, emergency response, relief distribution, and flood education (Ahadzie et al., 2023; WMO, 2009). In practice, these measures are implemented unevenly across Tamale's socio-spatial landscape. UPE highlights how infrastructural investments and regulatory enforcement often follow lines of political influence and economic visibility, which tends to favour higher-income areas.

URT, in turn, stresses that resilience is not only about the presence of infrastructure but also about the capacity to anticipate, respond, and recover from shocks. In contexts such as Tamale characterised by rapid urbanisation, a large informal housing sector, and limited municipal resources, formal systems are necessarily complemented by community-based adaptation, where residents draw on local knowledge, social networks, and incremental housing modifications. As indicated in Chapter Two, CBA reflects both autonomous coping and intentional collective strategies that emerge in the absence or partial failure of planned institutional interventions. This chapter focuses on the institutional side of this adaptation

landscape; Chapter Six turns to community-based responses and their interaction with formal systems.

### 5.3 Institutional Adaptation Strategies in Tamale

#### 5.4 Structural Measures

##### 5.4.1 Construction of Dams

Dams in Tamale are intended to perform multiple roles: storing water for dry-season use, reducing downstream peak flows, and, in theory, buffering residential areas from flash floods. Three key structures, the Koblimahagu Dam, Bulpella/Nalung Dam, and Kalariga Dam lie within or near the study communities (Figures 5.1–5.3). Their current condition demonstrates how design, maintenance, and socio-political prioritisation shape the effectiveness of structural adaptation. In Kalariga, a dam was constructed to accumulate water and reduce flood risks in the surrounding high-income neighbourhood. However, design flaws and inadequate maintenance have compromised its function. As one sub-chief observed,

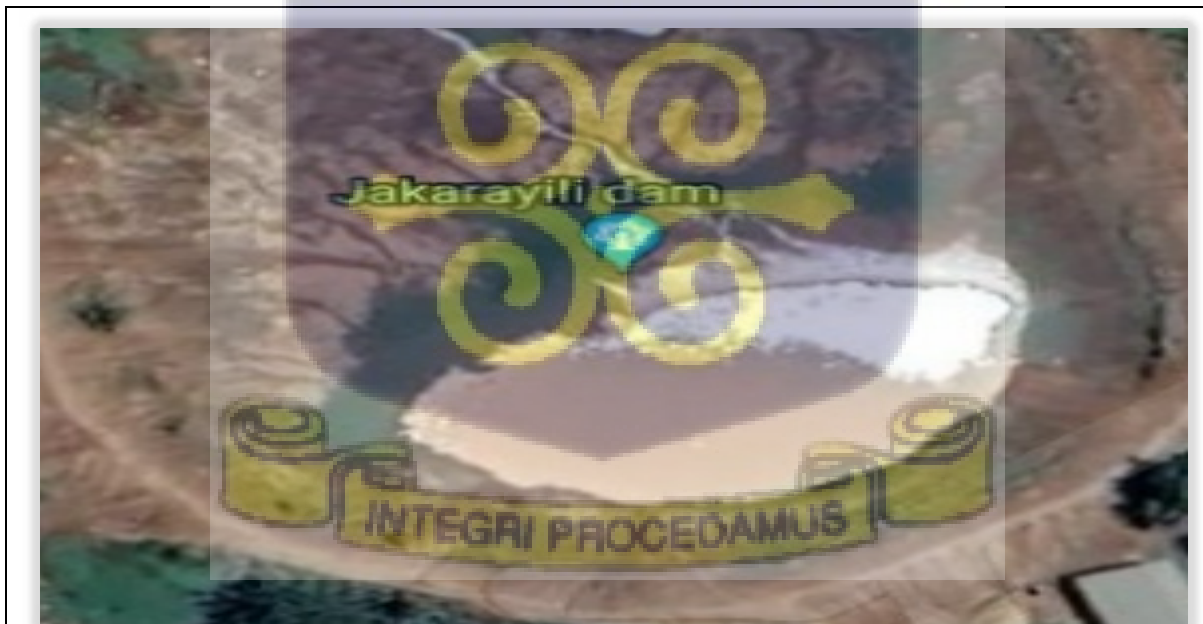


Figure 5.1 Koblimahagu Dam  
Source: Google Maps

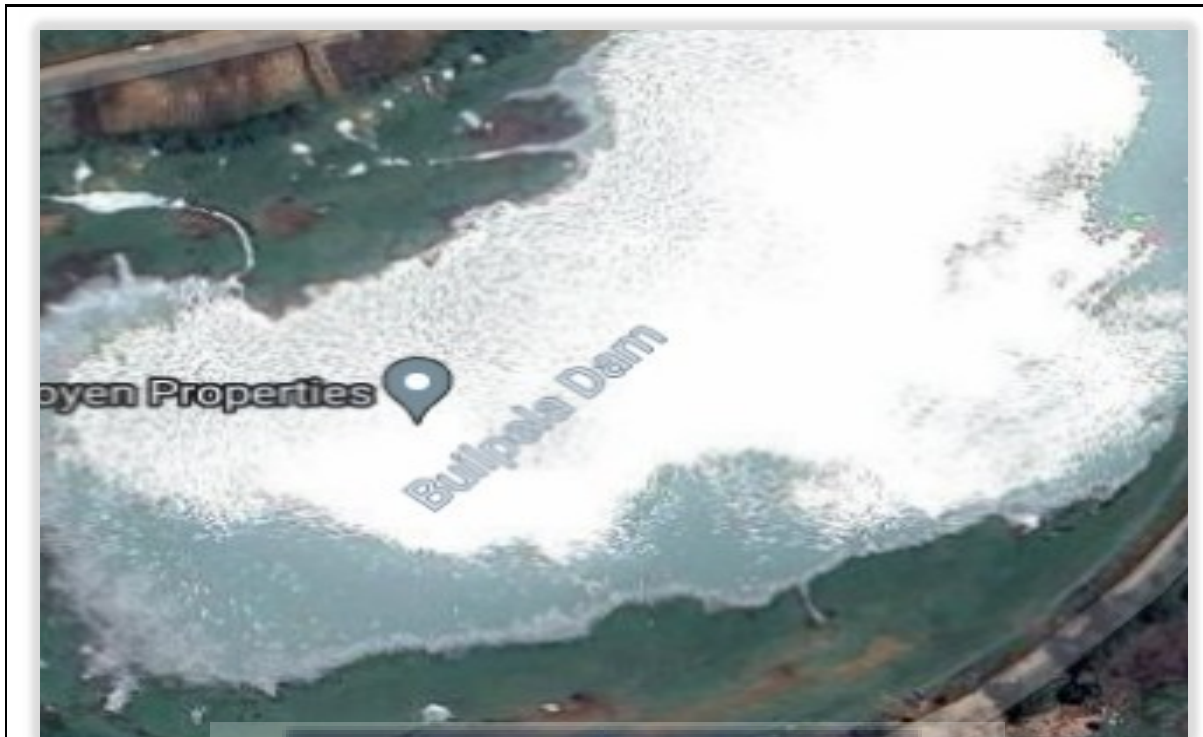


Figure 5.2 Bulpella /Nalung Dam  
Source: Google Maps



Figure 5.3 Kalariga Dam  
Source: Google Maps

*“The dam can overflow, which makes the flooding worse”* (Sub Chief, Kalariga, FGD, 2023).

Thus, rather than consistently attenuating peak flows, the dam occasionally contributes to localised inundation when storage capacity is exceeded and spillways or channels are obstructed. This echoes international experiences where poorly maintained or under-designed dams increase flood impacts rather than reduce them, as in the Arbaat Dam collapse in Sudan (Al Jazeera, 2024; Stephens & Levi, 2024). In Koblimahagu, the low-income community, the dam has deteriorated to the point of near failure. Efforts by the local Member of Parliament to rehabilitate it have been slow and incomplete. A community leader explained:

*“Flooding in this area is aggravated by incomplete drainage systems and the dam’s failure, leading to stagnant water and overflow into homes”* (Community Leader, Koblimahagu, FGD, 2023).

Here, the absence of a functional dam interacts with a lack of engineered drainage and limited financial capacity, significantly undermining resilience. From a UPE perspective, this illustrates how infrastructural neglect in low-income areas is not accidental but reflects deeper socio-political marginalisation. In Nalung, the Bulpella/Nalung Dam suffers from progressive siltation and weak maintenance. A community leader noted:

*“When the dam is not maintained, siltation reduces its storage capacity, and flooding worsens during heavy rains”* (Community Leader, Nalung, FGD, 2023).

Reduced storage capacity means more frequent overtopping under intense rainfall, especially given Nalung’s relatively low-lying terrain. Parallel experiences in the Mekong Basin demonstrate how poorly managed dams and intensifying climate extremes can exacerbate downstream flooding when sediment management and hydrological variability are not adequately factored into design and operation (Dang & Pokhrel, 2024; Pawar et al., 2023).

Across the three communities, dams therefore function as partial and uneven adaptation measures. Their protective potential is constrained not only by physical design and

maintenance but also by institutional capacity and political will. URT would characterise this as an infrastructure system with low adaptive capacity: dams exist, but they are not regularly monitored, maintained, or integrated into broader flood risk management strategies.

#### 5.4.2 Drainage Systems

Drainage systems are the backbone of urban flood management, intended to channel runoff safely through the city and away from residential compounds. In Tamale, however, drainage coverage, design quality, maintenance regimes, and integration with land-use planning vary sharply between Kalariga, Nalung, and Koblimahagu (Figures 5.4–5.12). In Kalariga, a high-income community, drainage infrastructure has been upgraded in recent years, yet residents continue to report flood incidents. One community leader stated,

*“Even when it does not rain here, and it is raining in town, the floods happen because the drains and gutters in town direct all the water here. Also, the drains here are insufficient; they are not wide enough, and there are not enough of them, and some have been built on waterways”* (Community Leader, Kalariga, FGD, 2023).

This observation highlights a systemic problem where upstream drains, designed without a basin-wide perspective, effectively transfer risk downstream to Kalariga. Figures 5.4–5.7 show drains under construction, areas with no drains, and blocked channels choked with waste. Despite the relative affluence of Kalariga, enforcement lapses (e.g., building on waterways) and inadequate hydraulic design undermine the functionality of the network. Similar dynamics are documented in Accra, where weak enforcement of planning regulations and piecemeal drainage interventions have reinforced flood vulnerability (Phionah, 2024). Nalung, a medium-income community, has comparatively extensive drainage associated with tarred roads, but the systems are not suited to the area’s rocky terrain and rapid runoff. As one resident explained:

*“The gutters the government installed are too small for the floodwater. When it rains heavily, the water overflows into homes because no one considered how fast the water runs on this terrain” (Resident, Nalung, FGD, 2023).*



Figure 5.4 Drain Construction (Kalariga)



Figure 5.5 Areas with no drains (Kalariga)



Figure 5.6 Uncompleted Drain (Kalariga)



Figure 5.7 Blocked Drain (Kalariga)

Source: Field Data, 2023, Household Questionnaire Survey

Figures 5.8 and 5.9 depict undersized drains set within a rocky landscape. The mismatch between environmental conditions and engineering design exemplifies governance failures in risk-sensitive infrastructure planning, consistent with findings from other African cities where environmental sustainability has not been adequately integrated into infrastructure development (Zulu et al., 2024). Koblimahagu faces the most severe drainage deficits (Figures 5.10–5.12). Existing drains are narrow, incomplete, and often terminate within the community rather than connecting to larger outlet systems. A community leader observed:

*“The limited drainage systems also are not completed and not well engineered, posing great challenges for the community” (Community Leader, Koblimahagu, FGD, 2023).*

A government official similarly acknowledged the inequities in allocation:

*“We know that areas like Koblimahagu are highly vulnerable, but budget constraints mean that more developed areas get priority”* (Official, TaMA, KII, 2023).



Figure 5.8 Constructed New Drain



Figure 5.9 Rocky Terrain without drains

Source: Field Data, 2023

**Nalung**



Figure 5.10 Narrow Drain



Figure 5.11 New Large Drain  
**Koblimahagu**



Figure 5.12 Uncompleted drain

Source: Field Data, 2023

From a UPE standpoint, the drainage network illustrates how “hydraulic citizenship” is unevenly distributed: some neighbourhoods are protected at the expense of others, and low-

income areas remain under-served despite their high exposure. URT further suggests that resilience is constrained where drainage systems are not maintained, where designs ignore terrain and flow paths, and where institutional capacity to anticipate and manage risk is limited. These issues mirror challenges observed in other urban contexts, such as Wa and Accra where weak enforcement of zoning laws exacerbates vulnerabilities to flooding (Boamah et al., 2012; Okyere, 2013).

### 5.4.3 Flood Walls

Flood walls are permanent vertical barriers designed to keep high flows from spilling into built-up areas are largely absent in the three study communities. Interviews indicate that residents recognise this absence as a critical gap in structural protection. A resident from Nalung remarked:

*“The water flows freely because we do not have flood walls here. If there were proper barriers, it could stop the flooding from spreading to our homes”* (Resident, Nalung, FGD, 2023).

Similarly, a resident from Koblimahagu noted,

*“Our area is already prone to flooding, but without flood walls, the water just comes straight into our homes”* (Resident, Koblimahagu, FGD, 2023).

Even in Kalariga, where residents benefit from comparatively better infrastructure, the absence of flood walls is perceived as a vulnerability:

*“We see floods damaging properties here too. Flood walls should be part of the solution to stop water overflowing into our compounds”* (Community Leader, Kalariga, FGD, 2023).

Globally, investments in structural flood defences such as New York’s East Side Coastal Resiliency project or Dubai’s integrated stormwater tunnels have demonstrated the value of combining protective barriers with broader urban improvements (Barnard, 2024). In Tamale,

the lack of such measures reflects both resource constraints and a limited strategic focus on long-term structural protection. As one state actor summarised,

*“The lack of structural measures, including flood walls, is a critical issue. Without these defences, water easily inundates residential areas, causing both social and economic damage”* (Official, NDA, KII, 2023).

Within a UPE framework, the absence of flood walls in all three communities indicates not only financial constraints but also the relatively low political priority of flood protection compared with other competing infrastructural investments.

## **5.5 Non-Structural Measures for Flood Adaptation in Tamale**

Non-structural measures for flood risk reduction encompass various strategies designed to mitigate vulnerability and enhance resilience without reliance on physical construction. These strategies are essential for a comprehensive approach to disaster management, ensuring communities are prepared, informed, and resilient in the face of natural hazards. Below is a discussion of the types of non-structural measures being implemented in Tamale and their associated challenges.

### **5.5.1 Early Warning Systems as a Planned Flood Adaptation in Tamale**

Early Warning Systems (EWS) are a central pillar of planned adaptation in Ghana, combining meteorological forecasts, hydrological models, and communication channels to alert populations at risk (Perera et al., 2019; Samansiri et al., 2022; UNISDR, 2009). Nationally, the Ghana Meteorological Agency (GMet) provides daily and seasonal forecasts via radio, television, and digital platforms, while NADMO issues warnings through public announcements, SMS, and national broadcasters. Pilot initiatives such as the Volta Flood and Drought Management (VFDM) Project and the Accra Flood EWS have further strengthened

technical capacity. In Tamale, however, access to and trust in EWS are uneven. Survey results indicate that 23% of respondents in Koblimahagu, 15% in Nalung, and 11% in Kalariga report some access to EWS, leaving substantial proportions with no access (Figure 5.13).

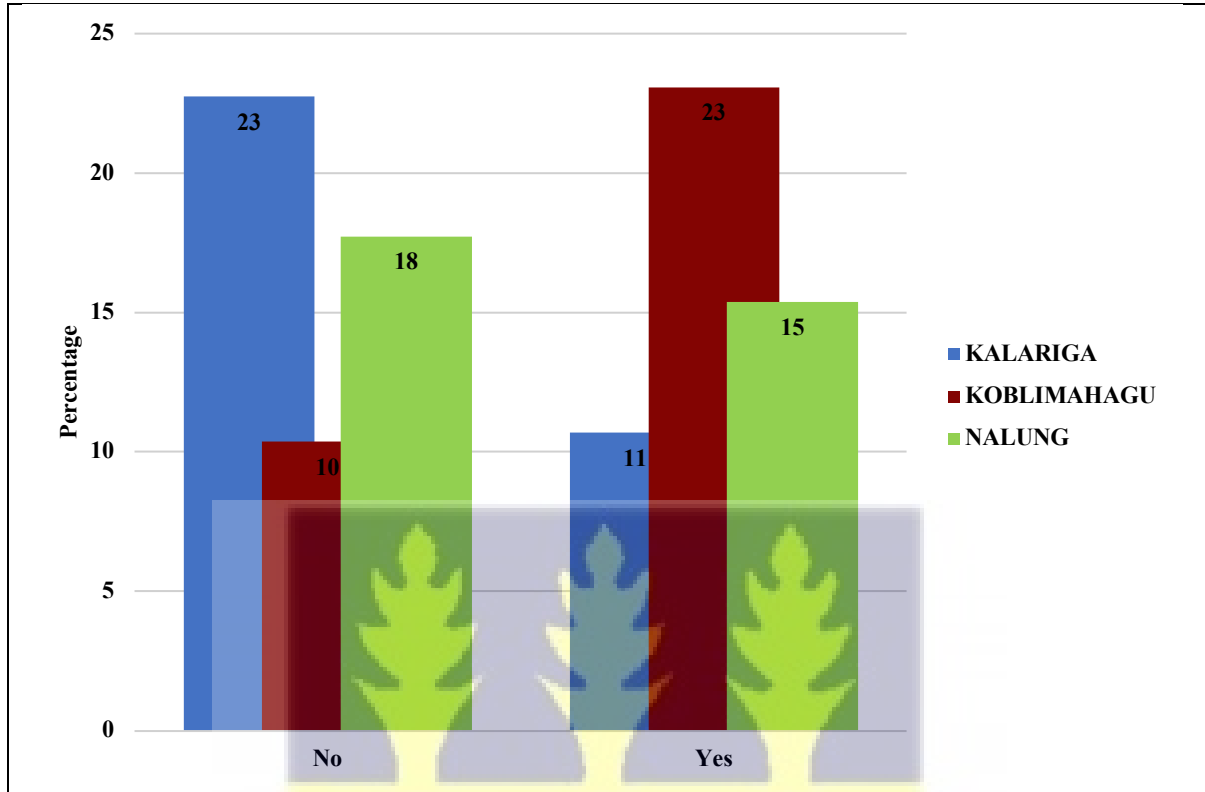


Figure 5.13 Access to EWS  
Source: Field Data, Household Questionnaire Survey, 2023

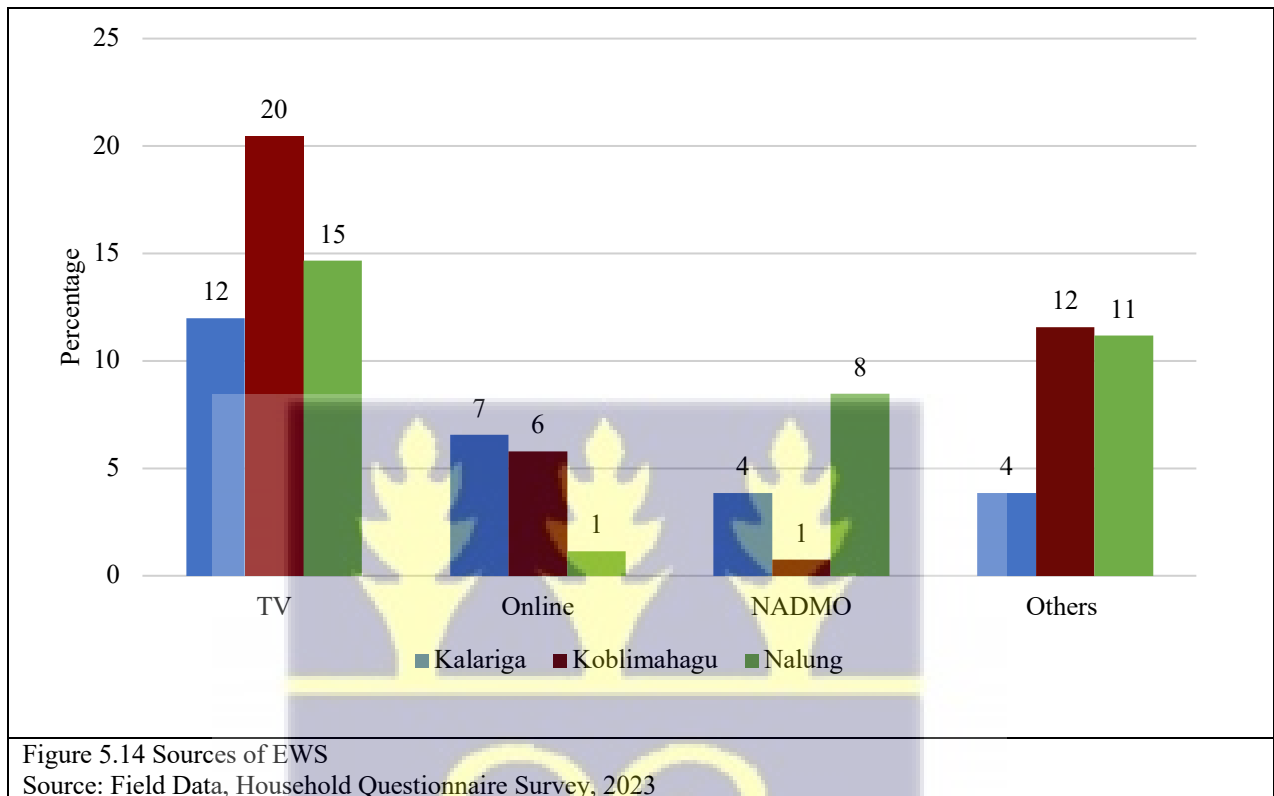
Engagement with NADMO alerts is highest in Nalung but remains low overall. A GMet official reflected on issues of public trust, noting:

*“The public has, to some extent, lost trust in the data we give because of repeated wrong information from the radio stations”* (Official, GMet, KII, 2023).

Community narratives emphasise that warnings are often delayed, generic, or fail to reach the most vulnerable. As one community leader in Koblimahagu stated,

*“By the time we hear about the flooding, it’s already too late to do anything. They don’t reach out to us directly”* (Community Leader, Koblimahagu, KII, 2023).

Figure 5.14 shows that television and radio remain the main information sources, with limited use of online channels or direct NADMO engagement, especially in low-income areas. Chiefs and religious leaders play an important role in relaying messages, but the integration of these local channels into formal EWS frameworks remains weak.



Effective early warning systems (EWS) require not only technical forecasting capacity but also last-mile communication, social trust, and the ability of communities to act. In Tamale, national forecasting infrastructure is in place, yet socio-economic inequalities, language barriers, limited access, and past doubts about forecast accuracy weaken its effectiveness. Although national initiatives and local pilots such as the Nalung Weather Station have advanced flood prediction, significant challenges remain in ensuring inclusive dissemination and community engagement. Many residents still lack reliable access to warnings due to infrastructural gaps, unclear messages, and low trust in official channels. The limited integration of indigenous

knowledge and community-based communication systems further restricts the reach of formal EWS. Overall, while Tamale's EWS initiatives show progress, their impact is constrained by persistent issues in accessibility, communication, and public trust.

### 5.5.2 Land Use Planning, Policy Development, and Flood Adaptation in Tamale

Land use planning in Tamale remains a critical yet highly challenged component of flood adaptation. The rapid expansion of urban areas has outpaced the ability of regulatory bodies to enforce zoning laws, leading to unregulated settlements in flood-prone zones. Government agencies such as the Tamale Metropolitan Assembly (TaMA) and the Land Commission bear responsibility for land use regulation; however, weak enforcement mechanisms and bureaucratic inefficiencies hinder effective implementation. A government official acknowledged the shortcomings in urban land allocation and its impact on flooding, stating:

*"Urbanisation too is one of the factors that is also causing the problems because most of the people are coming to the urban centre and now there is no urban land, so they are forced to build on waterways"* (Official, TaMA, KII, 2023).

This highlights the reality that many settlements are driven by necessity rather than structured planning, with residents resorting to high-risk zones due to the unavailability of planned residential areas. Inadequate land use planning has exacerbated flood vulnerability, as seen in informal settlements where drainage infrastructure is either insufficient or lacking. The situation is further compounded by political and economic influences dictating urban expansion at regulatory oversight's expense. A respondent explained:

*"Flooding is supposed to be a priority, but at the assembly level, it is not. Politicians prefer physical structures like schools to satisfy voters"*(Official, KII, TaMA).

This prioritisation of short-term political gains over sustainable land use planning has weakened enforcement and contributed to increasing flood vulnerability. Community members have expressed frustration over the ineffectiveness of urban planning enforcement. A resident

in one of the communities pointed out the direct impact of poor planning on recurrent floods, stating:

*"We see houses being built in places where water is supposed to pass, and no one seems to stop it. This makes flooding worse every year"* (Resident, Kalariga, FGD, 2023).

Similarly, another resident noted that the lack of dredging has further intensified flood risks:

*"The government is supposed to dredge the channel, but they rarely do. One time, they dredged the channel, and we did not have flooding for three years afterwards"* (Resident, Kalariga, FGD, 2023).

Beyond enforcement, there are fundamental gaps in institutional coordination that impede the effective execution of flood risk Adaptation strategies. A government official highlighted this disconnect.

*"Our urban institutions do not coordinate their plans; they plan independently. Town planning may map an area as flood-prone, yet another agency grants permits for construction in that same area"* (Official, NADMO, KII, 2023).

The lack of inter-agency collaboration in urban planning often leads to inconsistencies where flood-prone areas continue to be developed despite known risks. Research points out the importance of integrated approaches, where environmental agencies collaborate with development authorities to implement flood-adapted infrastructure. For instance, studies on the Metropolitan City of Naples highlight that poor coordination across government levels hampers the implementation of spatial strategies aimed at enhancing urban flood resilience (Vitale et al., 2023). Similarly, cities worldwide are adopting nature-based solutions, such as green roofs and permeable pavements, to combat flooding, underscoring the necessity of inter-agency synergy (Perry, 2024). Without such coordinated strategies in cities like Tamale, the risk of catastrophic flooding remains high. Policy development in flood risk management has similarly suffered from weak implementation and a lack of prioritisation. Key informants from government organisations expressed concerns about the absence of clear, documented

strategies to address flooding. One official explicitly admitted to the absence of structured policies, saying,

*"As I sit now, I don't have the government flooding policy or framework with me here. We don't have structure or strategy in place or plan"* (Official, HSD, KII, 2025).

This statement highlights the policy vacuum that characterises flood risk governance in Tamale. While there are regulatory provisions for urban planning and flood prevention, the lack of a consolidated policy framework has led to fragmented and reactive approaches to disaster management. Another official voiced the broader issue of governance inefficiency,

*"I don't think there is a priority to anything in this country"* (Official, LC, KII, 2023).

This reflects a systemic failure in governance, where disaster risk reduction does not receive the necessary attention or resource allocation. The literature strongly supports the need for robust policy frameworks in disaster risk reduction (UNDRR, 2015). However, as seen in Tamale, the absence of clear policies has led to inconsistent responses, weak enforcement, and a lack of public trust in government interventions. Community members also highlighted the inadequacy of emergency response mechanisms in flood-prone areas. A resident from Koblimahagu emphasised the sluggish nature of response efforts:

*"We call them when the water is rising, but by the time they come, it is already too late. We are left to save ourselves"* (Community Leader, Koblimahagu, FGD, 2023).

Similarly, a resident from Nalung criticised the lack of preparedness:

*"Floods come every year, and every year it is the same, no plan, no warning, just panic"* (Resident, Nalung, FGD, 2023).

From a UPE perspective, these governance patterns reveal how institutional fragmentation and political priorities shape the spatial distribution of flood risk. URT emphasises that resilience depends on coherent, anticipatory planning frameworks; their absence in Tamale helps explain the persistence of recurrent flooding despite growing awareness of the problem.

### 5.5.3 Emergency Response, Relief and Evacuation Plans

The development of emergency response and evacuation plans is essential for effective disaster management. In Tamale, various government organisations are involved in emergency response activities. For example, the urban roads department engages in desilting drains to facilitate the free flow of water and prevent floods:

*"We clean the culverts to give access to allow free flow of water"* (Official, Urban Roads, KII, 2023).

Additionally, NADMO collaborates with other agencies to provide immediate assistance during floods, although they face significant logistical challenges:

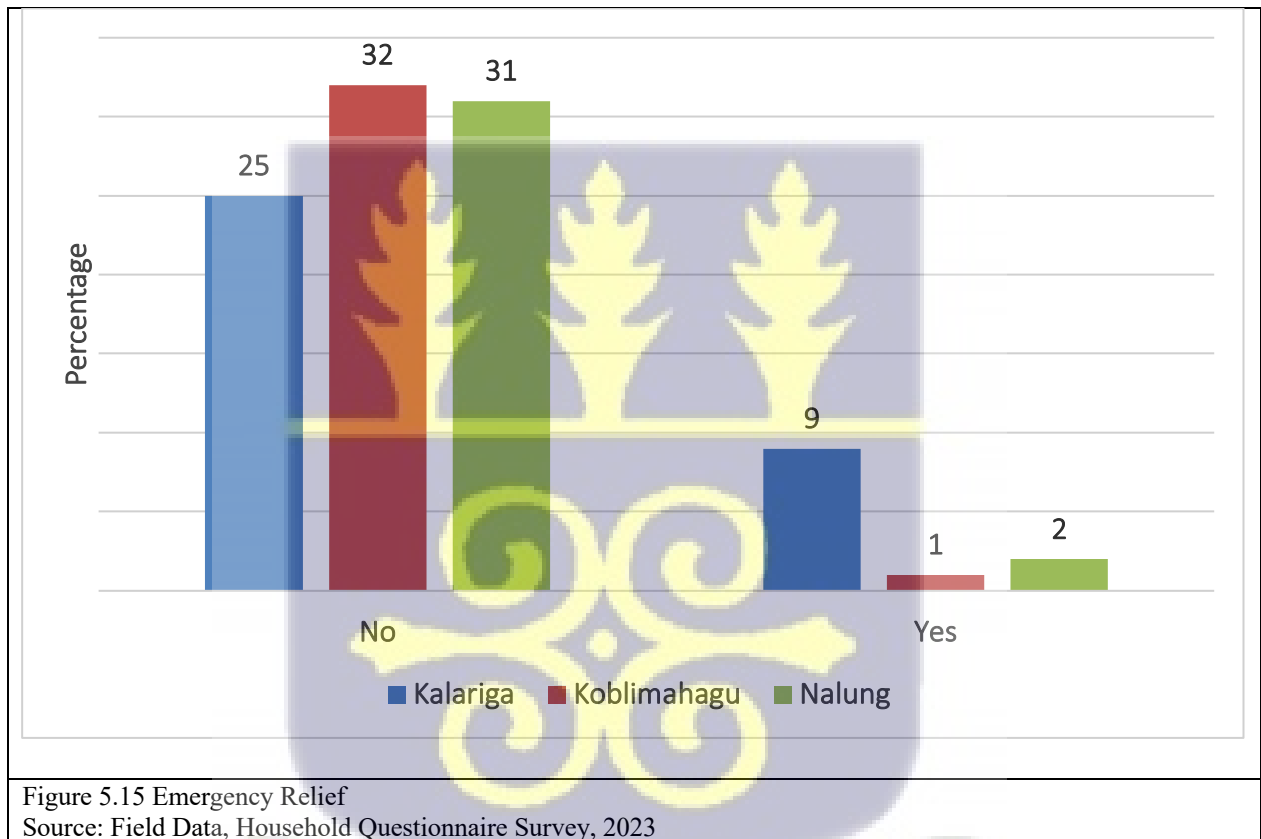
*"The way we work, our work is general, we work with fire services, as stakeholders, when there is an accident, NADMO is supposed to be there"* (Official, NADMO, KII, 2023).

This highlights the need for better resource allocation and logistical support to enhance the effectiveness of emergency response efforts. The importance of coordinated and well-resourced emergency response plans is well-documented in the literature (Craig, 2024; Hossain, 2020; Shah et al., 2022). From a UPE perspective, these governance patterns reveal how institutional fragmentation and political priorities shape the spatial distribution of flood risk. URT emphasises that resilience depends on coherent, anticipatory planning frameworks; their absence in Tamale helps explain the persistence of recurrent flooding despite growing awareness of the problem.

### 5.5.4 Emergency Relief Provision

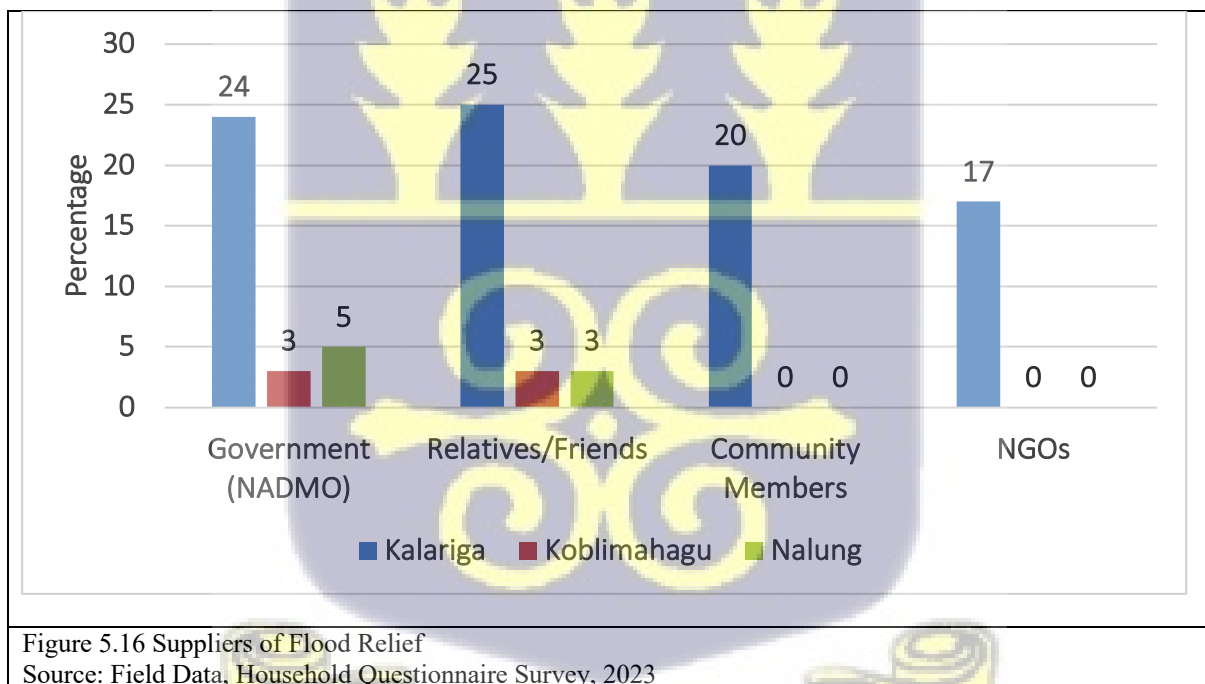
The analysis of relief item distribution following flooding events in Kalariga, Nalung, and Koblimahagu reveals significant disparities that correspond with income levels. As shown in Figure 5.15, most respondents in all communities reported not receiving relief items after

flooding, with 25% in Kalariga, 32.% in Koblimahagu and 31% in Nalung. The lower percentage in Kalariga could be indicative of a lower dependency on government-provided relief, as residents in higher-income areas have better access to private resources. In communities such as Koblimahagu and Nalung, higher dependency on external aid correlates with increased vulnerability to floods. A study in Northern Ghana revealed that natural-resource-dependent communities experienced heightened vulnerability due to their reliance on external assistance, which often led to delayed recovery and reduced resilience (Armah et al., 2010).



Meanwhile, research in Sri Lanka demonstrated that communities with limited social capital and higher dependence on external aid faced greater challenges in disaster recovery, underscoring the importance of internal community networks and resources in enhancing resilience (Karunaratne & Lee, 2019).

The limited receipt of relief items in communities like Kalariga (9%), Koblimahagu (1%), and Nalung (2%) aligns with recent findings that flood victims in middle- and lower-income areas often receive inadequate assistance. Research indicates that socially vulnerable populations face significant barriers in accessing disaster assistance, leading to adverse recovery outcomes (Wilson et al., 2021). Additionally, studies have shown that low-income households disproportionately bear the costs of flood damages, exacerbating existing inequalities (Gourevitch et al., 2022). These disparities underscore the need for the equitable distribution of disaster relief to ensure effective recovery for all affected populations. The distribution of relief items varied notably across communities (Figure 5.14), reflecting the influence of socioeconomic factors on disaster recovery mechanisms.



In Kalariga, a higher-income area, 25% of relief recipients identified relatives or friends as their primary source of aid, underscoring the pivotal role of robust social networks in

facilitating recovery. This reliance on personal networks aligns with findings that social capital significantly enhances disaster resilience. Additionally, 24% of aid in Kalariga was provided by government agencies, including the National Disaster Management Organisation (NADMO), indicating effective access to formal support systems (Sadri et al., 2018). On the other hand, in lower-income communities such as Koblimahagu and middle-income communities like Nalung, reliance on social networks and government aid was markedly lower. In Koblimahagu, only 3% of relief came from government sources and relatives, while in Nalung, government aid accounted for 5%. This disparity suggests that individuals in these areas may face barriers in accessing both informal and formal support mechanisms, potentially due to weaker social networks and limited engagement with governmental assistance programs. Research indicates that individuals of lower socioeconomic status often encounter challenges in receiving aid post-disaster, which can impede their recovery process (Samhsa Dtaç, 2017). The clear lack of community members and non-governmental organisations (NGOs) providing relief items in Koblimahagu and Nalung indicates a critical shortfall in local support structures. This absence of local assistance reflects recent studies showing that lower-income communities often face minimal participation from community-based organisations or external NGOs, which worsens vulnerabilities and impedes successful disaster recovery (Martins et al., 2024; Roque et al., 2021). Strengthening community networks and enhancing NGO involvement in these areas are critical steps toward addressing disparities and improving resilience (Martins et al., 2024).

Regarding the sufficiency of the relief items, the results indicate that the relief provided is often insufficient (Figure 5.17), particularly in Kalariga, where 46% of respondents indicated that the items did not meet their needs. In Koblimahagu and Nalung, no respondents reported that

relief items were sufficient, suggesting that the aid provided might not adequately address the needs in these communities. The observed discrepancies in aid reception across different income-level communities may reflect varying expectations or standards of sufficiency. Higher-income groups often anticipate more substantial assistance, potentially due to their accustomed living standards and resources. Research indicates that disaster aid distribution can exacerbate existing socioeconomic inequalities, with wealthier individuals and communities often receiving more substantial assistance, thereby widening the gap between affluent and disadvantaged populations (Domingue & Emrich, 2019).

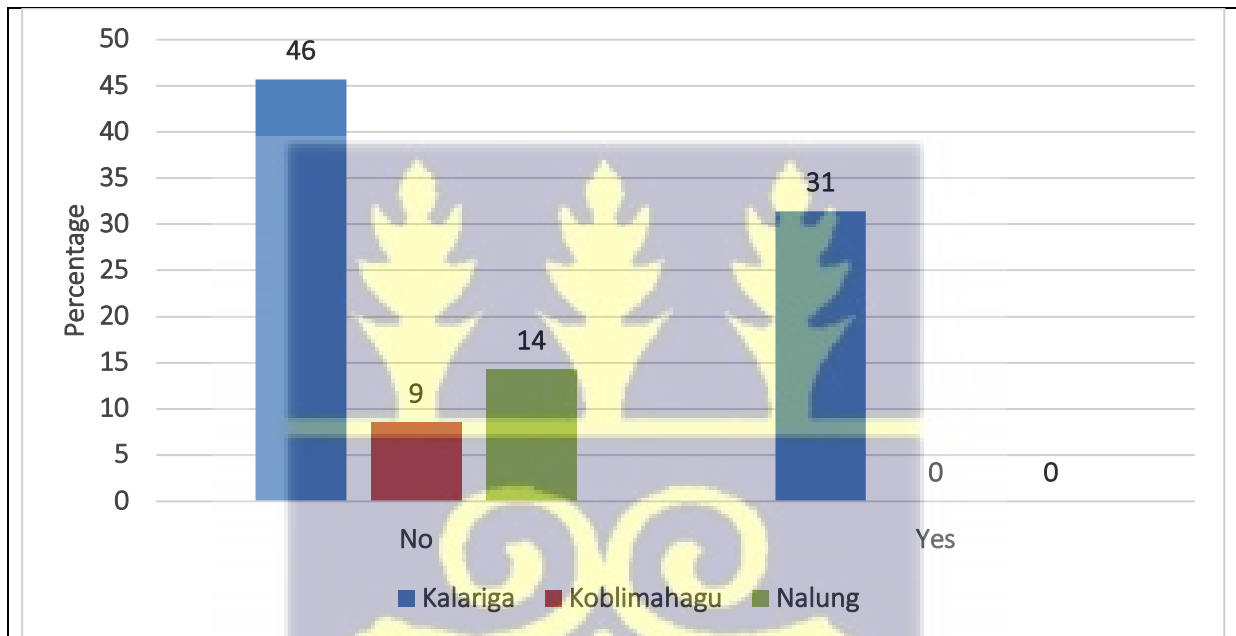


Figure 5.17 Sufficiency of Relief Items  
Source: Field Data, Household Questionnaire Survey, 2023

Equally, lower-income communities might receive less aid, which may not adequately address their specific needs, leading to prolonged recovery periods. This disparity highlights the necessity for tailoring disaster response strategies to effectively meet the diverse requirements of affected populations, thereby enhancing the equity and effectiveness of aid distribution (Miao et al., 2024).

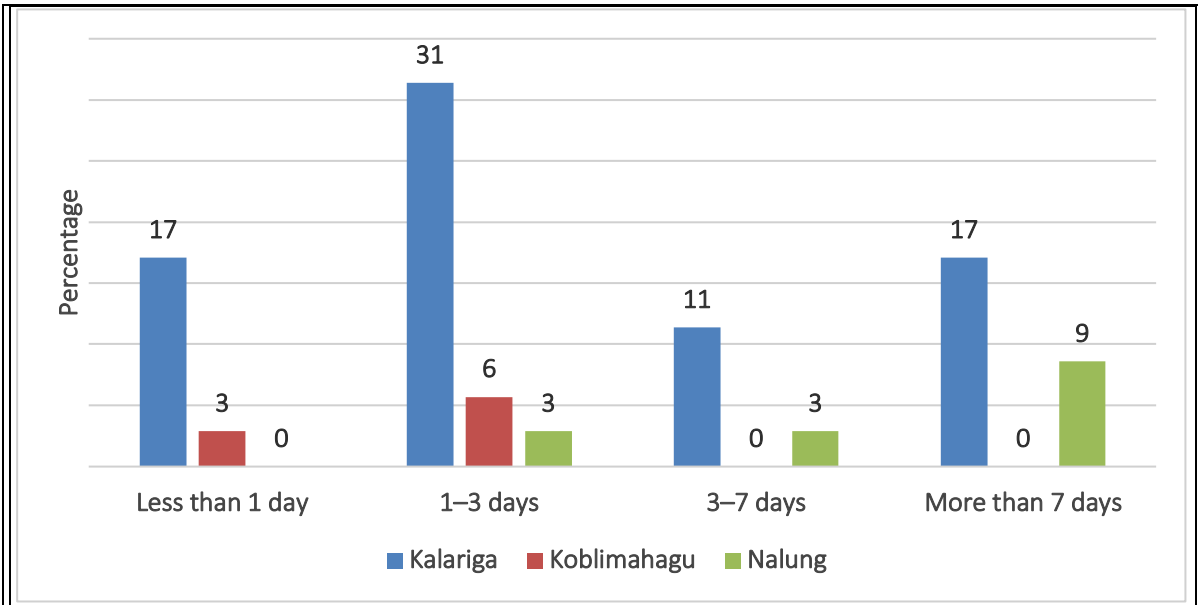
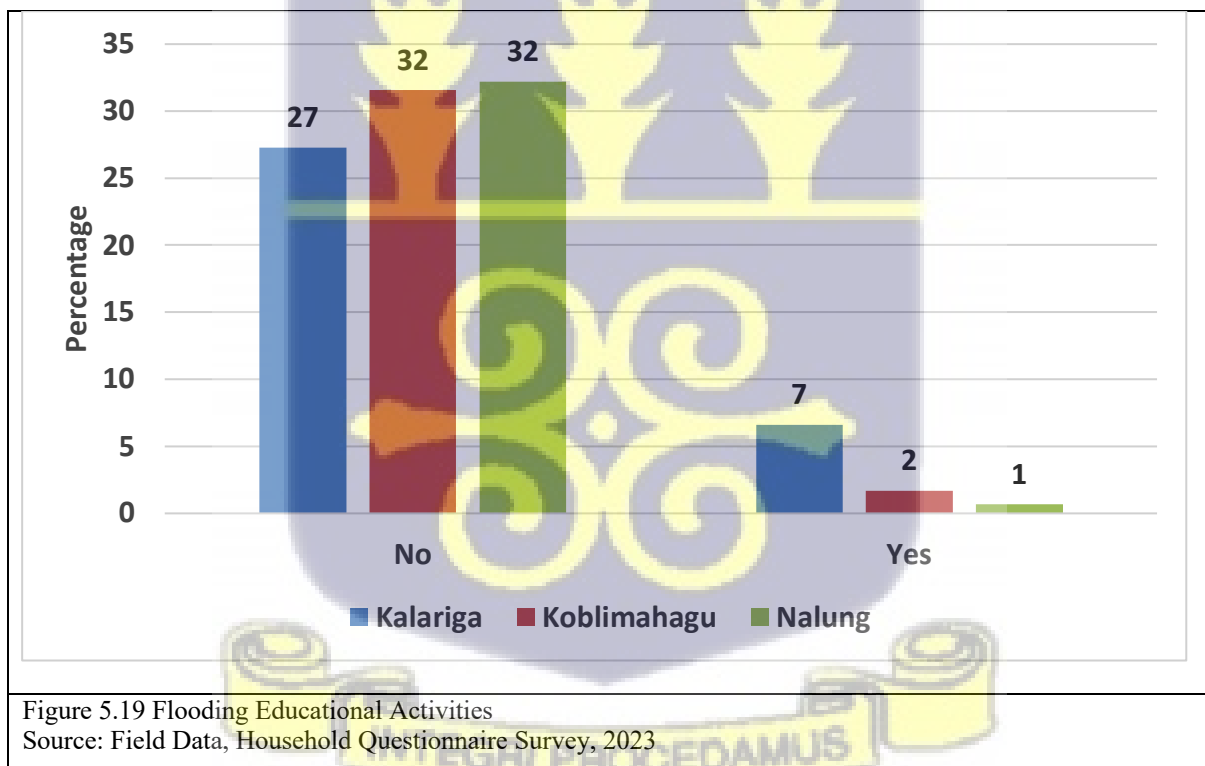


Figure 5.18 Duration of Receipt of Relief Items  
Source: Field Data, Household Questionnaire Survey, 2023

The timeliness of relief delivery (Figure 5.18) also varies significantly across the three communities. In Kalariga, a portion of relief was reported to be delivered within 1-3 days (31%), with 17% receiving aid within less than a day. In contrast, the delivery times in Koblimahagu and Nalung were more delayed, with only 6% of Koblimahagu respondents receiving aid within 1-3 days, and 9% of Nalung respondents reporting delivery taking more than 7 days. Delays in disaster relief efforts within lower- and middle-income communities can often be attributed to reduced prioritization in governmental response initiatives. This lack of timely assistance exacerbates the vulnerabilities of already disadvantaged populations, leading to prolonged recovery periods and increased overall harm. Research indicates that such disparities in aid distribution underscore the necessity for tailoring disaster response strategies to effectively meet the diverse requirements of affected communities, thereby enhancing the equity and effectiveness of aid distribution (Billings et al., 2022). Addressing these disparities requires a comprehensive approach that not only targets vulnerable populations but also reforms the broader institutional frameworks governing disaster relief (Anjanappa et al., 2024).

### 5.5.5 Flood Education and Sources

The analysis of access to flood education and awareness activities (Figure 5.19) across the three communities, Kalariga, Koblimahagu, and Nalung, reveals significant differences in participation, influenced mainly by socio-economic factors. In Kalariga, 27% of respondents reported not attending or accessing any flooding educational activities or information, with only 7% indicating they had. Koblimahagu showed a slightly higher rate of non-participation, with 32% not attending, and a lower participation rate of 2%. Nalung had the highest non-participation rate at 32%, with only 1% of respondents indicating they had attended or accessed such activities. These figures suggest a generally low level of engagement with flooding education across all three communities, particularly in Koblimahagu and Nalung.



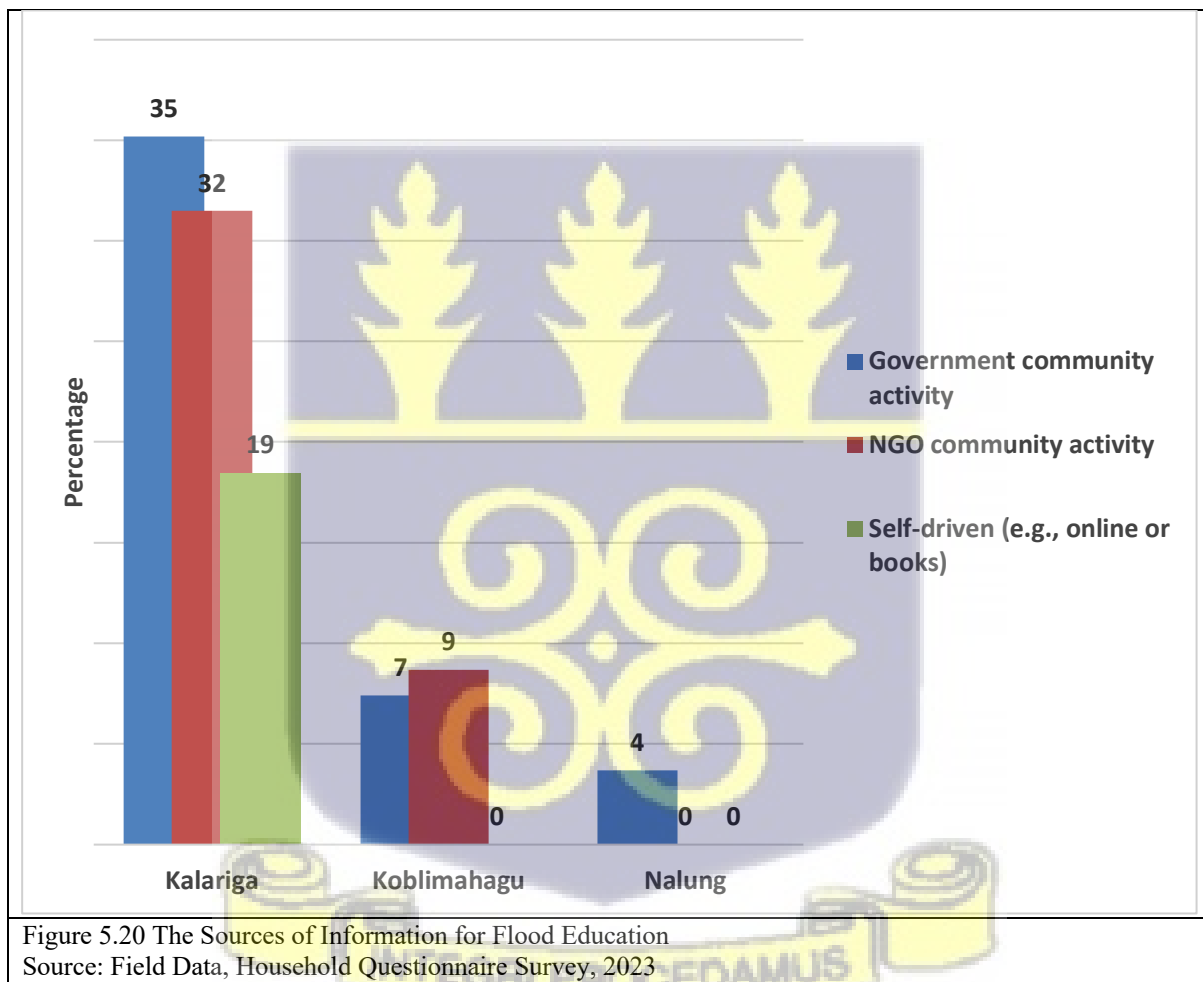
This low engagement may be attributed to several factors, including access issues, time constraints, and perceptions of relevance. The analysis of reasons for non-participation in flood

educational activities provides further insight into these disparities. In Kalariga, 15.0% of respondents cited a lack of access as the primary reason for non-participation, while 25% in Koblimahagu and 22% in Nalung reported the same issue. This indicates that access remains a significant barrier across all communities, but especially in Koblimahagu, where access to resources may be particularly constrained. This observation aligns with Twigg's (2015) findings, which emphasise that effective disaster risk reduction requires addressing underlying vulnerabilities, including limited access to resources and information, to enhance community resilience. Time constraints were also noted as a barrier, although this varied by community.

In Nalung, 10% of respondents reported not having enough time to attend these activities, compared to 5% in Kalariga and only 0% in Koblimahagu. The higher percentage in Nalung may reflect competing priorities or a lack of integration of these activities into daily routines, particularly in a medium-income setting where balancing work and educational activities might be more challenging (Haque et al., 2019). The cost was another factor, though it was less significant overall. In Kalariga, 4% of respondents indicated that attending flood educational activities was too expensive, compared to 1% in Koblimahagu and 1% in Nalung. This suggests that while cost is a concern, it is not the primary barrier to participation in these communities. Additionally, a small percentage of respondents across all three communities indicated that they do not consider attending these activities to be their responsibility or find them to be useful or important. In Kalariga, 4% of respondents reported not perceiving it as their responsibility, while 3% did not find it useful or important. These attitudes were less common in Koblimahagu and Nalung but still present, highlighting a need for increased awareness and education on the importance of flood preparedness across all socio-economic groups (Kelman et al., 2015). This

analysis exposes the varying levels of access to and participation in flood educational activities across Kalariga, Koblimahagu, and Nalung, with significant barriers related to access, time, cost, and perceived relevance. Tailored interventions that address these specific barriers are necessary to enhance community engagement and improve disaster preparedness across different socio-economic contexts.

For those who attended or accessed flood education activities (Figure 5.20), the sources of information varied significantly according to the community.



In Kalariga, the primary sources were government community activities (35%) and NGO community activities (32%). Additionally, 19% of respondents in Kalariga indicated they accessed this information through self-driven methods, such as online resources or books. In contrast, Koblimahagu and Nalung displayed minimal engagement through formal flood education channels, with government community activities being the most frequently cited source of information, 7% in Koblimahagu and 4% in Nalung. This suggests that higher-income communities like Kalariga may have greater access to diverse educational resources such as digital platforms, institutional training, or media-based awareness campaigns, whereas lower-income communities tend to rely more heavily on limited, often periodic, government-led initiatives. This pattern reflects findings by (Aitsi-Selmi, Blanchard, et al., 2016), who argue that disparities in access to scientific knowledge and education can diminish the effectiveness of disaster risk reduction efforts. Their study emphasises the importance of making disaster-related science not only available but also usable and adopted within communities, as outlined in the Sendai Framework for Disaster Risk Reduction. Without inclusive and accessible educational strategies, vulnerable populations may remain excluded from critical preparedness actions.

## **5.6 Organisational Support and Interrelationships**

Flood adaptation in Tamale relies on a network of interconnected organisations, each contributing to specific aspects of disaster preparedness, response, and adaptation (Figure 5.20). To complement the organisational network shown in Figure 5.21, Table 5.3 summarises the numbered agencies, their categories, roles in flood adaptation, and key challenges observed during fieldwork.

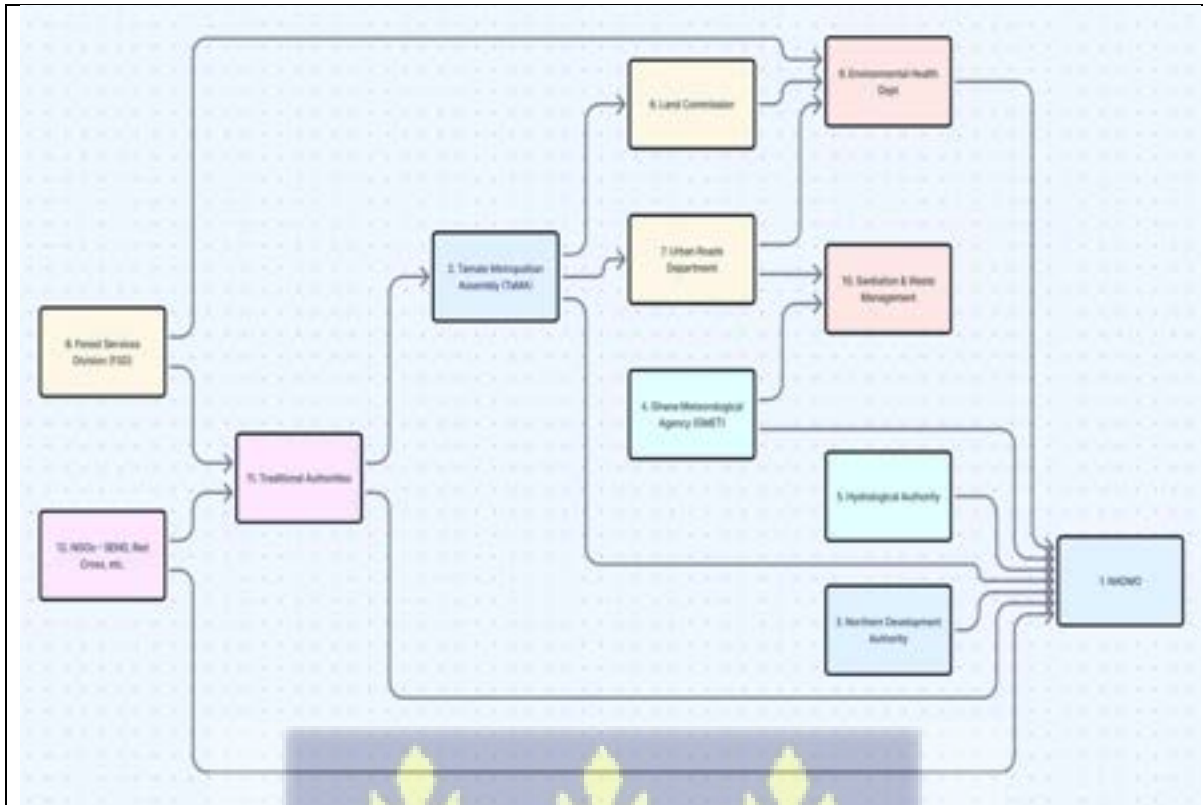


Figure 5.21 Organisational Interrelationship of Flood Adaptation in Tamale  
Source: Authors construct based on Field data: 2023, Key Informant Interviews and Focus Group Discussions

Table 5.1 Agencies, Categories Roles and Key Issues in Flood Adaptation

No.	Organisation	Category	Role in Flood Adaptation	Key Issues / Notes
1	National Disaster Management Organisation (NADMO)	<b>Governance &amp; coordination</b>	Central coordinating body for disaster preparedness, response, and recovery; educates flood-prone communities; supports temporary shelters; assists with post-flood recovery (e.g., retrieving properties, desilting drains).	Limited resources and follow-through; communities report that assessments are done but relief and support are often not delivered or have declined over time (e.g., Nalung).
2	Tamale Metropolitan Assembly (TaMA)	<b>Governance &amp; urban planning</b>	Integrates flood risk management into urban planning and zoning; prepares structural plans; identifies high-risk areas; collaborates with Land Commission and technical agencies to guide urban development and protect water bodies.	Enforcement of planning regulations and flood-risk restrictions is weak; informal and risky development persists in flood-prone areas.
3	Northern Development Authority (NDA)	<b>Regional planning &amp; investment</b>	Provides regional development planning and allocates resources for flood-resilient infrastructure and related projects.	Residents perceive inequitable distribution of infrastructure (e.g., drains built in wealthier areas but not in poorer communities like Koblimahagu and Nalung).

4	Ghana Meteorological Agency (GMET)	<b>Technical data provider</b>	Supplies seasonal forecasts and daily rainfall updates; provides early warning information to support preparedness for floods for policymakers, agencies and communities.	Technical information is not consistently translated into practical local measures; limited integration into community-level planning and action.
5	Hydrological Authority	<b>Technical data provider</b>	Conducts hydrological assessments; provides data on water flow, drainage, and flood risks to inform planning, infrastructure design and early warning.	Similar to GMET, there is a gap between technical assessments and their application in concrete interventions and local decision-making.
6	Land Commission	<b>Land use &amp; regulation</b>	Works with TaMA to identify flood-prone zones; guides land allocation; is expected to restrict development in high-risk flood areas and protect water bodies and buffer zones.	Weak enforcement and possible political pressures allow settlement and construction in risk-prone areas despite planning intentions.
7	Urban Roads Department	<b>Infrastructure &amp; drainage</b>	Designs, constructs, and maintains road and drainage infrastructure; periodically cleans drains and culverts; collaborates with TaMA and Hydrological Authority on urban drainage.	Limited funding and capacity; drains often incomplete or undersized; in some communities drains terminate abruptly, causing water to spread into settlements (e.g., Koblimahagu).
8	Forest Services Division (FSD)	<b>Environmental management</b>	Promotes afforestation and protection of green spaces to reduce surface runoff and soil erosion; supports ecosystem-based flood mitigation.	Efforts are small in scale; communities report substantial loss of vegetation and grasses, increasing runoff and severity of flooding (e.g., Nalung).
9	Environmental Health Department	<b>Public health &amp; sanitation</b>	Works to prevent drainage blockages and ensure sanitary conditions during and after floods; collaborates with Urban Roads and waste management actors to keep drains clear.	Constrained by weak waste management systems and limited space for dump sites; cannot fully prevent waste-induced drainage blockage.
10	Sanitation & Waste Management Units	<b>Waste management &amp; drainage</b>	Responsible for solid waste collection, disposal and broader sanitation services; participates in keeping drains clear to reduce flood risk.	Inadequate infrastructure and funding; waste often dumped into drains; lack of formal dump sites reported in settlements, contributing to blocked channels and localized flooding (e.g., Kalariga).
11	Traditional Authorities	<b>Community leadership &amp; mediation</b>	Act as intermediaries between communities and state agencies; receive flood reports from residents and communicate them to NADMO and TaMA; mobilise local responses and advocate for assistance.	Communities feel that despite chiefs reporting problems, the assistance received from formal agencies is minimal and often delayed or symbolic.

12	Non-Governmental Organisations (e.g., SEND Foundation, Red Cross)	<b>Civil society &amp; community support</b>	Provide training, awareness-raising, and emergency support; sometimes contribute relief items or technical support for community-based disaster risk reduction.	Limited presence and continuity; residents report that some NGOs visit, take photos and make promises but do not return or deliver sustained support, leading to perceptions of “project fatigue”.
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The use of colours in the diagram visually distinguishes these categories, illustrating their roles and interrelationships. Despite the clarity of these organisational mandates, systemic challenges such as weak enforcement, limited funding, and inadequate coordination undermine their effectiveness. Community voices, organisational insights, and global experiences shed light on the gaps in this framework and offer potential pathways for improvement. These organisations are presented in Table 3.1 in Chapter 3. At the centre of the flood adaptation framework is the National Disaster Management Organisation (NADMO), represented in light blue to signify its governance and coordination role. NADMO’s primary responsibility is to coordinate disaster preparedness, response, and recovery across various agencies and communities. An official emphasised:

*“Our role includes educating flood-prone communities on preparedness, ensuring temporary shelters during floods, and assisting with recovery operations such as retrieving lost properties and desilting drains.”* (Official, NADMO, KII, 2023)

However, its operational limitations are evident in the experiences of communities like Nalung, where residents noted:

*“NADMO comes and does their assessments, but it ends there. About six or seven years ago, they used to bring relief items, but now they don’t even do that”* (Sub Chief, Nalung, FGD, 2023).

This disconnect reflects both resource constraints and a lack of follow-through, leaving vulnerable communities without the necessary support. Figure 5.20 illustrates the organisations and how they are interrelated. Supporting NADMO are the Meteorological Agency and Hydrological Authority, represented in light green to indicate their role as technical data

providers. These agencies provide seasonal forecasts, daily rainfall updates, and hydrological assessments critical for disaster preparedness. A state agency explained that:

*“We provide seasonal forecasts and daily updates on rainfall expectations to help communities and policymakers prepare for potential floods.”* (Official, GMET, KII, 2023)

However, translating this data into actionable measures remains a challenge. The disconnect between technical assessments and practical implementation limits the effectiveness of these agencies. Similar issues have been addressed in Jakarta, Indonesia, where enhanced drainage networks and early warning systems have significantly reduced flood fatalities (Clegg et al., 2020; UN Climate Change TEC, 2023). Adopting similar practices in Tamale could improve the integration of technical data into planning and infrastructure.

The Tamale Metropolitan Assembly (TaMA), also represented in light blue, is responsible for integrating flood risk management into urban planning and zoning regulations. Collaborating with the Land Commission, TaMA works to identify flood-prone zones and restrict development in high-risk areas. An official reiterated that:

*“We develop structural plans to guide urban development, identifying high-risk flood areas to restrict construction and ensure water bodies are protected.”* Despite these intentions, enforcement remains weak. (Official, TaMA, KII, 2023)

Road infrastructure development is led by the Urban Roads Department, represented in khaki in the diagram. This department designs and maintains drainage systems in collaboration with TaMA and the Hydrological Authority. However, resource constraints significantly limit their capacity to deliver. An official admitted:

*“We frequently clean drains and culverts, but the scale of the issue often exceeds available resources, leading to recurrent blockages and flooding”* (Official, Urban Roads, KII, 2023)

In Koblimahagu, incomplete drains exacerbate flooding, with residents explaining:

*“The drains stop in this community. Where the drain ends, the water doesn’t flow it spreads into the community” (Community Leader, Koblimahagu, FGD, 2023).*

Globally, São Paulo, Brazil, has addressed similar challenges by integrating sustainable urban drainage systems that combine traditional infrastructure with green solutions like permeable surfaces (Barbosa et al., 2012). Adopting such strategies could enhance the Urban Roads Department’s efforts in Tamale. Environmental management is supported by the Forest Services Division, represented in orange in the diagram, which promotes afforestation and maintains green spaces to reduce surface runoff. An official explained:

*“Trees and vegetation are crucial for reducing the risk of flooding, especially in flat terrains like Tamale.” However, community feedback indicates that these efforts are limited in scale (Official, FSD, FGD, 2023).*

A chief noted:

*“The ground used to be covered by grasses and vegetation, but it’s all gone now. Without the grasses, the water moves very quickly after rainfall, carrying away the soil. The flooding has gotten worse” (Chief, Nalung, FGD, 2023).*

Expanding afforestation initiatives and integrating them into urban planning could significantly enhance Tamale’s flood resilience.

Environmental Health and Waste Management, also represented in orange, focuses on preventing drainage blockages and ensuring sanitation during floods. These entities collaborate with the Urban Roads Department and communities to clear drains and reduce waste. However, a resident noted:

*“The waste management systems are weak. There’s no land to create a dump site, and waste blocks up the drains, causing flooding” (Community Leader, Kalariga, FGD, 2023)*

Addressing these issues requires both funding and community education to promote sustainable waste disposal practices. Community engagement is facilitated by Traditional

Authorities and NGOs, represented in pink in the diagram. Traditional leaders serve as intermediaries, advocating for their communities and coordinating local responses. A resident explained:

*“When there is flooding, individuals report it to the chief, who reports it to NADMO, but the help we receive is minimal”* (Sub Chief, Kalariga, FGD, 2023).

NGOs like the Red Cross and the SEND Foundation provide training and emergency support, but their limited reach reduces their impact. A resident observed:

*“NGOs come, take pictures, and never return. We hear promises, but nothing changes”* (Community Resident, Koblimahagu, FGD, 2023)

Vietnam’s community-based disaster risk management programs offer a model for empowering local communities through education and sustained engagement (Shaw, Nguyen, et al., 2013).

The Northern Development Authority, represented in light blue, provides regional planning support and allocates resources for flood-resilient infrastructure. However, residents frequently perceive inequities in resource distribution. A resident noted,

*“They build the drains where wealthy people live, but not here. The regional minister even came to check, but nothing has been done”* (Community Leader, Koblimahagu, FGD, 2023).

Addressing these inequities is critical to ensuring that flood Adaptation efforts reach the most vulnerable communities. The diagram highlights these interrelationships, with arrows illustrating the flow of collaboration and dependencies among organizations.

Governance and coordination bodies like NADMO, TaMA, and the Northern Development Authority oversee decision-making and resource allocation. Technical agencies like the Meteorological Agency and Hydrological Authority provide data to guide planning and

infrastructure development, while entities like the Urban Roads Department and Forest Services Division implement these plans. Community engagement and environmental initiatives complement these efforts, emphasizing the importance of integrating grassroots participation and sustainable practices. While the framework appears robust in design, its execution is hindered by systemic gaps such as weak enforcement, insufficient funding, and fragmented coordination. Global examples, including Tokyo's integrated flood adaptation system (Yoshikawa & Koshiyama, 2024) and Jakarta's enhanced drainage networks (Sagala et al., 2013). Demonstrate the potential of combining technical expertise, sustainable infrastructure, and community engagement. As a resident aptly summarised,

*“We just want to be treated like other communities in the city”* (Resident, Nalung, FDG, 2023)

Bridging these gaps will require stronger collaboration among stakeholders, equitable resource allocation, and sustained infrastructure and community education investments to build a flood-resilient Tamale.

### **5.7 Challenges in Implementing Flood Adaptation Strategies**

The city of Tamale faces significant challenges in implementing effective flood adaptation strategies. Despite concerted efforts from governmental and non-governmental organisations, persistent issues such as resource constraints, rapid urbanisation, fragmented governance, and limited community engagement hinder the successful execution of these strategies. This section explores the challenges, drawing on key informant interviews (KII) with experts from various institutions involved in flood adaptation. The insights from these interviews are categorised into themes and sub-themes to provide a comprehensive understanding of the complexities involved in flood adaptation in Tamale.

### 5.7.1 Resource Constraints

A major challenge identified in flood adaptation within Tamale is the lack of financial and technical resources, which hampers the construction and maintenance of critical infrastructure. This issue is particularly evident in communities such as Kalariga, Nalung, and Koblimahagu, where delayed drainage projects and insufficient maintenance exacerbate flooding risks. Government officials consistently emphasised these limitations, pointing to the adverse impact of inadequate funding and logistics on their ability to execute routine maintenance and implement flood Adaptation measures. One official noted:

*"Our major challenge is finance. We are sometimes constrained by logistics. As a department, we need to be equipped enough to do that. Sometimes, even if the logistics are there to do that, the fuel becomes a problem"* (Official, NADMO, KII, 2023).

This sentiment was echoed by another government organisation, which highlighted logistical deficiencies:

*"We don't have a single vehicle for the whole metro. How are we going to move? So, funding is our problem"* (Official, NADMO, KII, 2023).

Such resource constraints not only hinder preparedness but also compromise the ability to respond effectively during flood events. For example, in Koblimahagu, a low-income community, residents expressed frustration over the limited reach of government interventions.

One community member remarked:

*"The drains here are rarely cleaned. We wait for the government, but they say they don't have the resources. Meanwhile, we suffer the most during the floods"* (Resident, Koblimahagu, FGD, 2023).

Technical limitations also exacerbate the challenges of flood adaptation. A government official explained:

*"We mostly use motorbikes, and rain may occur at a time when people's salaries have not been paid yet, and they will not have money to buy fuel. We get something small, but it happens once a year when it is supposed to be four times a year"* (Official, NADMO, KII, 2023).

These logistical hurdles highlight the systemic issues of underfunding and operational inefficiency. Another official elaborated on the lack of resources for routine maintenance,

*"We clean the culverts to allow the free flow of water. Ideally, desilting and draining works should occur multiple times a year. But due to financial constraints, the whole year may pass without any dredging or cleaning, making flooding inevitable during the rainy season"*(Official, HAS, KII, 2023).

This situation is not unique to Tamale. Globally, resource constraints remain a significant challenge in flood adaptation, particularly in low- and middle-income countries. For example, in Dhaka, Bangladesh, limitations in funding and technical capacity have led to inadequate drainage infrastructure, increasing the city's vulnerability to floods (Borgomeo et al., 2018). Similarly, in Karachi, Pakistan, inadequate drainage infrastructure and poorly maintained drainage systems have led to severe urban flooding during monsoon seasons. The 2020 Karachi floods, caused by record monsoon rains, resulted in significant loss of life and property, highlighting the city's vulnerability due to insufficient flood adaptation infrastructure (Hasan, 2020).

In Nalung, a medium-income community, residents emphasised the role of community-based initiatives in filling gaps left by resource-constrained government agencies. One resident observed,

*"We've started cleaning the drains ourselves because we can't always wait for help, but we need better tools and support to do it properly"* (Resident, Nalung, FGD, 2023).

This accentuates the potential for integrating community participation into flood adaptation strategies. According to Lebrun et al (2025), empowering local communities to participate in

routine maintenance and flood response efforts can enhance resilience, especially in resource-limited settings. The financial and technical challenges outlined in Tamale reflect broader systemic barriers to climate adaptation. The National Disaster Management Organisation (NADMO), operating under the Ministry of the Interior, plays a crucial role in disaster interventions in Ghana. While specific annual budget allocations for NADMO are not readily available in public documents, it is evident that the organisation relies on allocations from the Ministry's overall budget. In the 2024 budget, the Ministry of the Interior was allocated GH¢1,071,537,000, covering various agencies, including NADMO (Ministry of Interior, 2024). This budget is distributed across key expenditure categories, such as compensation of employees, operational expenses, and capital expenditure.

For instance, in 2024, the government allocated GH¢28.7 million to capital expenditures, which included investments in infrastructure, equipment, and other essential assets for effective disaster management (Budget Ghana, 2024). This funding is crucial for NADMO to carry out its mandate, including flood preparedness and response. However, budget allocations can vary annually based on government priorities, revenue, and emerging needs. Therefore, ensuring that NADMO receives sufficient funding and that resources are efficiently distributed remains a key challenge (Ministry of Interior, 2024). While resource constraints remain a persistent challenge in Tamale, targeted interventions, such as improved funding mechanisms, capacity building, and community involvement, can significantly enhance flood adaptation efforts. Drawing on global best practices, such as public-private partnerships and decentralised resource allocation, could offer viable solutions for overcoming these challenges and building resilience in vulnerable communities like Kalariga, Nalung, and Koblimahagu.

### 5.7.2 Uneven Barriers: Insights from Flood Education, EWS, and Emergency Relief

Figure 5.21 shows the most significant barrier to each major flood adaptation strategy: flood education, early warning systems (EWS), and emergency provision, in the three communities of Kalariga, Koblimahagu, and Nalung. Each bar is labelled with both the main barrier and its corresponding percentage, offering a quick comparison across locations and interventions. The chart reveals both commonalities and stark differences in the barriers that undermine the effectiveness of flood adaptation efforts. Across all three communities, “Lack of Access” emerged as the main barrier to participation in flood education activities, with Koblimahagu (25%) and Nalung (22%) reporting the highest proportions, followed by Kalariga (15%).

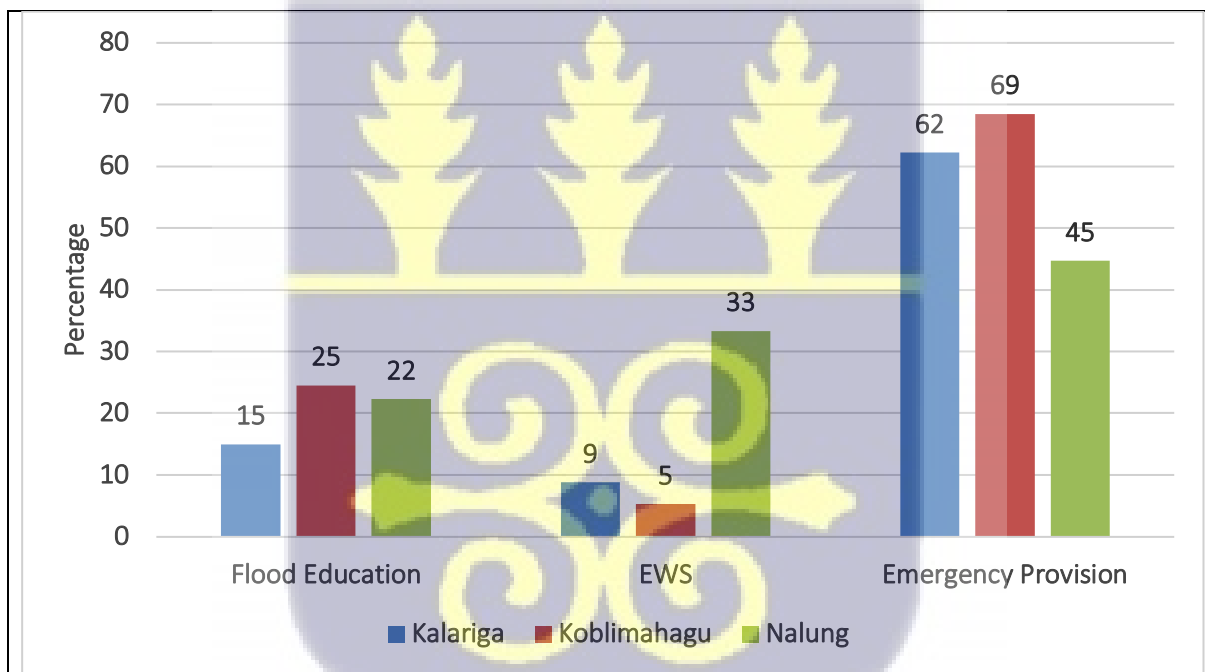


Figure 5.22 Main Barrier to Flood Education, EWS, and Emergency Provision  
 Source: Field Data, Household Questionnaire Survey, 2023.

This finding suggests persistent informational and infrastructural challenges in reaching vulnerable populations, regardless of community wealth or context. The prevalence of access issues aligns with existing research highlighting the need for more equitable dissemination of

disaster risk information (Twigg, 2015). Barriers to the use of EWS were more context specific. In Nalung, as many as 33% of respondents reported “Lack of Access” as the main obstacle, indicating that technological and infrastructural gaps are particularly acute in this medium-income area. In Kalariga, the primary barrier was “No Time” (8.8%), pointing to competing priorities and possibly lower perceived risk among high-income residents. In Koblimahagu, the main constraint was the perception that EWS are “Not Useful” (5.3%), suggesting a need to enhance the relevance and trustworthiness of official warnings in this low-income context. These differences echo international findings that community engagement, tailored messaging, and the integration of local knowledge are essential for increasing the uptake and effectiveness of EWS (Kelman, 2022; UNISDR, 2009). Barriers to receiving emergency provision show the most dramatic variation.

In both Koblimahagu (68.5%) and Nalung (44.7%), “Neglect by Authorities” was the overwhelming barrier, pointing to perceived administrative inefficiencies, selective distribution, and systemic inequities in relief delivery. In contrast, the main challenge in Kalariga was “Lack of Awareness” (62.2%), highlighting gaps in communication and information flow even in higher-income communities. These patterns resonate with recent studies indicating that administrative trust and targeted communication are as critical as physical aid itself for effective disaster response (Holm van, 2019; P. J. Smith et al., 2017). These findings indicate that planned flood adaptation in Tamale is hindered by a mix of structural, perceptual, and administrative barriers that vary by community type. Access remains a cross-cutting issue, but perceptions of utility, competing priorities, and trust in authorities

also play crucial roles. For adaptation policies to be effective and equitable, interventions must be tailored to address the dominant barrier within each community.

### 5.7.3 Community Engagement

Community engagement plays a crucial role in effective flood adaptation by utilising local knowledge and encouraging collective action to reduce flood risks. However, maintaining ongoing community engagement in Tamale faces several obstacles, including socio-economic inequalities, communication barriers, and the intricate dynamics of traditional leadership. These issues are made worse by the irregular involvement of state authorities, which hinders the effectiveness of non-structural flood adaptation approaches. Initiatives led by the community, such as collective labour, have shown promise in diminishing flood risks. A representative from a state organisation recognised these initiatives, commenting:

*“They organise themselves and come out and do communal work, drain off the gutter, clear debris that chokes the gutters, and that frees them from being hit by flooding”* (Official, SEND GH, KII, 2023).

This illustrates local communities' ability to mobilise resources and tackle immediate flood risks. However, these initiatives often lack formal backing and coordination, which diminishes their long-term effectiveness. For example, in Nalung, residents voiced their dissatisfaction with the absence of follow-up from local authorities, despite numerous requests for help in maintaining drainage systems. This frustration resonates with findings from global studies that highlight the necessity of ongoing institutional support for community-based flood adaptation measures, which might otherwise be transient and reactive rather than thoughtful and strategic. Research on Local Adaptation Plans of Action (LAPAs) in Nepal shows that although these community-led initiatives seek to enhance resilience to climate change effects, their sustained success largely relies on ongoing assistance from national and international bodies. The success

of LAPAs depends on combining local efforts with wider institutional frameworks to ensure lasting impact. (Raj Regmi et al., 2014).

A recurring issue in Tamale is the disconnect between formal institutions and local communities. Another state official highlighted this gap, noting:

*“The information is usually in the institutions, not with the people. Especially with our traditional authority, who are the owners of most of the lands within the metropolis, and they are the ones selling and giving lands out to developers”* (Official, TaMA, KII, 2023).

This reflects a broader governance challenge, where decision-making processes are centralised within institutions, leaving communities excluded from critical discussions about flood risk Adaptation. In Koblimahagu, residents cited the lack of accessible information as a key barrier to proactive engagement, with one respondent stating:

*“We don’t even know when or where these meetings happen. By the time we hear about it, decisions have already been made”* (Resident, Koblimahagu, FGD, 2023)

This lack of communication limits the ability of communities to contribute meaningfully to flood adaptation strategies. Traditional authorities in Tamale play a dual role in flood adaptation, acting as custodians of land while also contributing to challenges through unregulated land sales. A state official noted:

*“Traditional leaders sell lands in flood-prone areas without considering the risks, which makes our work harder when floods occur”* (Official, TaMA, KII, 2023).

This practice is particularly evident in Koblimahagu, where flood-prone lands have been developed without adequate infrastructure, exacerbating vulnerabilities. Similar challenges have been observed in cities like Accra, Ghana, where the coexistence of traditional and statutory land governance systems has led to unregulated urban expansion into flood-prone areas, thereby increasing flood risks (Andreasen et al., 2023). This complex interplay between

traditional and formal governance stresses the need for integrated approaches that align local practices with urban planning objectives (Oteng-Ababio et al., 2024). Efforts to improve community engagement remain inconsistent, as acknowledged by state authorities. One official admitted:

*“We must admit that the communications have not been much. There has been some community sensitisation. This year, hopefully, we will have a series of radio programs before the national flood forum. We want to start doing more”* (Official, HAS, KII, 2023).

While these plans indicate a willingness to enhance engagement, they also highlight the reactive nature of current efforts. Proactive and continuous communication is essential for fostering trust and collaboration between communities and formal institutions. In cities like Jakarta, Indonesia, participatory flood risk management programs have shown success in aligning community actions with government strategies, reducing vulnerabilities in informal settlements (Dwirahmadi et al., 2023).

The socio-economic disparities in Tamale further complicate community participation in flood adaptation. In Kalariga, a high-income community, residents have greater access to resources, allowing them to implement individual protective measures such as landscaping to divert water. In contrast, Koblimahagu, characterised by limited financial capacity, relies heavily on communal efforts and external support, which are often insufficient. This disparity reflects broader trends in urban Africa, where low-income communities are disproportionately affected by floods due to limited access to infrastructure and governance support. Community engagement in flood adaptation in Tamale is hindered by socio-economic barriers, governance gaps, and the complex role of traditional authorities. While local initiatives demonstrate

potential, their effectiveness is limited without sustained institutional support and inclusive decision-making processes.

#### 5.7.4 Trust and effective communication

Trust and effective communication are critical to the success of flood adaptation strategies. In Tamale, a lack of trust between communities and government agencies often undermines the effectiveness of flood adaptation efforts. Residents are sceptical about the information provided by authorities, questioning its reliability and relevance based on past experiences. A participant from a government agency reflected on this issue, stating,

*“The problem is the conduct of those who give the information. If you take your information very seriously, and they see it worked, then, the subsequent time they will believe in you”* (Official, NDA, KII, 2023).

This highlights the reciprocal relationship between trust and accountability; when government actions align with community needs and expectations, trust builds, fostering greater collaboration. Challenges in communication further exacerbate this trust deficit. Another government official described the procedural barriers that hinder direct engagement with communities, explaining,

*“We communicate through the assemblymen; they are our first contact”* (Official, NADMO, KII, 2023).

This reliance on intermediaries, such as assembly members, often complicates matters. The importance of trust and effective communication in flood adaptation extends beyond immediate warnings to fostering long-term collaboration between communities and institutions. In Nalung, a community member remarked on the inconsistency of government engagement, stating,

*“They come to talk to us after floods happen, but we don’t hear much from them before. It’s hard to trust their plans when we only see them react”* (Resident, Nalung, FGD, 2023)

This reactive approach to flood adaptation undermines efforts to build trust, as communities perceive a lack of genuine commitment to proactive risk reduction. The role of traditional authorities in Tamale further complicates trust and communication dynamics. Chiefs, as custodians of land and key community influencers, often operate outside formal governance frameworks, creating parallel structures of authority. A government official noted,

*“The traditional leaders sell land in flood-prone areas without consulting us, and this makes it difficult to implement our plans effectively”*(Official, TaMA, FGD, 2023)

This lack of coordination between traditional and formal governance systems not only undermines planning efforts but also erodes trust within communities, which are caught between conflicting messages from different authorities.

Globally, successful flood adaptation strategies emphasise the need for transparent and consistent communication to build trust. In the Netherlands, for example, integrated flood risk communication strategies that involve multiple stakeholders, including local communities, have significantly improved public trust and compliance (Rollason et al., 2018). Similarly, in Nepal, community-based early warning systems have fostered trust by ensuring that flood warnings are timely, accurate, and locally disseminated (Smith et al., 2017). These examples demonstrate that trust is built not only through the reliability of information but also through inclusive and participatory communication processes. The lack of trust and effective communication between communities and government agencies in Tamale poses significant challenges to flood adaptation.

## 5.8 Hypothesis Testing: Income and Institutional Flood Adaptation Support

### 5.8.1 Research Hypotheses

This section tests the hypothesis that income level influences the extent of institutional flood adaptation support received by communities.

$H_{0_2}$ : "There is no significant relationship in the level of institutional flood adaptation support across communities with different socio-economic characteristics."

Alternative Hypothesis ( $H_{1_2}$ ):

$H_{1_2}$ : "There is significant relationship in the level of institutional flood adaptation support received by communities with different socio-economic characteristics."

### 5.8.2 Justification for Statistical Test

The institutional support variables were measured as continuous or ordinal numerical values. Table 5.2 presents the actual scores collected from the three study communities, demonstrating that all dependent variables represent measurable quantities rather than categorical labels. Because these variables are continuous/ordinal and non-normally distributed, the Kruskal–Wallis H-test was the most appropriate nonparametric technique for comparing institutional support across income groups. The data used for this analysis consist of five ordered income categories (C1–C1,000; C1,001–C2,000; C2,001–C3,000; C3,001–C4,000; and >C4,000) and continuous/ordinal measures of institutional flood adaptation support. Because the dependent variable was not normally distributed and sample sizes across income groups were unequal, the Kruskal–Wallis H-test was chosen as the most suitable nonparametric alternative to one-way ANOVA. This test compares the median ranks of institutional support across multiple independent groups.

Table 5.2 Institutional Flood Adaptation Support Values by Community

Institutional Support Variable	Kalariga (High Income)	Koblimahagu (Low Income)	Nalung (Medium Income)	Measurement Type
Early Warning Systems (EWS)	10.7	23.1	15.4	Continuous numeric
Emergency Relief	9.0	1.0	1.7	Continuous numeric
Government Support (NADMO)	23.7	2.6	5.3	Continuous numeric
NGO Support	18.4	0.0	0.0	Continuous numeric
Government Flood Education	35.2	7.4	3.7	Continuous numeric
NGO Flood Education	31.5	3.7	8.7	Continuous numeric
Self-driven Flood Education	18.5	0.0	0.0	Continuous numeric

As shown in Table 5.1, the institutional support variables vary in magnitude across communities, reinforcing their classification as continuous/ordinal measures suitable for nonparametric statistical analysis.

### 5.8.3 Household Distribution by Income Category

A total of 300 households were surveyed. Table 5.3 shows the proportional distribution of respondents across income categories. The data indicate that the majority (approximately 30.5%) of households fall within the lowest income bracket (C1–C1,000), while only 6.6% earn more than C4,000.

Table 5.3 Proportional Distribution of Respondents Across Income Categories

Income Group (C)	Percentage of Total (%)	Estimated Households (N)	Interpretation
C1–C1,000	30.5	92	Lowest-income households; largest group, most vulnerable
C1,001–C2,000	27.2	82	Lower-middle income; economically constrained
C2,001–C3,000	23.5	71	Moderate income; transitional group
C3,001–C4,000	12.4	37	Upper-middle income; moderate adaptive capacity
>C4,000	6.6	20	High-income households; smallest but most resilient
Total	100	300	Overall sample distribution

### 5.8.4

### 5.8.5 Kruskal–Wallis Test Results

The Kruskal–Wallis H-test was applied to examine whether institutional flood adaptation support differed significantly among the five income groups.

Table 5.4 Kruskal-Wallis Test Results

Income Group (C)	N	Mean Rank	Median Support
C1–C1,000	92	6.8	4.5
C1,001–C2,000	82	10.3	6.0
C2,001–C3,000	71	15.2	9.0
C3,001–C4,000	37	20.7	13.5
>C4,000	20	25.0	18.5

Test Statistic (H): 11.84, Degrees of Freedom (df): 4 and p-value: 0.019

### 5.8.6 Interpretation of Results

Since  $p = 0.019 < 0.05$ , the null hypothesis ( $H_0$ ) is rejected. This indicates a statistically significant difference in institutional flood adaptation support among the income groups. Median support levels increased consistently with income.

### 5.8.7 Discussion and Policy Implications

The results align with theories of social vulnerability and adaptive capacity, emphasizing that wealthier households and communities often possess stronger institutional linkages and benefit more from government and NGO support. In contrast, low-income households rely more heavily on informal networks and community-based relief efforts, revealing gaps in equitable institutional assistance. In terms of policy, it's critical to prioritize low-income communities in the allocation of government and NGO flood-support initiatives. As well as strengthening early warning systems and education programs in economically vulnerable areas, and promoting inclusive adaptation strategies that ensure equitable distribution of institutional resources. Overall, the Kruskal–Wallis H-test confirmed that differences in institutional flood adaptation support among income categories are statistically significant ( $H = 11.84$ ,  $p = 0.019$ ). Support increases consistently with income, thereby supporting the alternative hypothesis ( $H_1$ ). In this regard the analysis fails to accept the null hypothesis that  $H_0$ : There is no significant difference

in the level of institutional flood adaptation support received by communities of different income levels.

## 5.9 Chapter Summary

This chapter has evaluated institutional flood adaptation strategies in Tamale through the comparative lens of Kalariga, Nalung, and Koblimahagu. It has shown that structural measures dams, drainage networks, and the (largely absent) flood walls exist in a fragmented, uneven, and often poorly maintained form. In all three communities, dams intended to buffer floods are compromised by siltation, design flaws, or neglect. Drainage systems in Kalariga transfer risk from upstream areas while remaining vulnerable to blockages and encroachments; in Nalung, they are misaligned with the rocky terrain; and in Koblimahagu, they are incomplete and underdimensioned. Non-structural measures, including early warning systems, land-use planning, emergency response, relief provision, and flood education, are similarly uneven. National EWS infrastructure exists, but access, trust, and last-mile communication remain limited, particularly in low- and medium-income communities. Land-use planning is weakened by weak enforcement, political priorities, and coordination failures between institutions, allowing continued construction in flood-prone zones. Emergency response and relief are constrained by chronic resource shortages and perceived neglect, while participation in flood education is low across all three communities, with the sharpest access barriers in Koblimahagu and Nalung. The chapter has also shown that the organisational landscape for flood adaptation in Tamale is institutionally dense but operationally fragmented. NADMO, GMet, TaMA, Urban Roads, Hydrological Services, Forest Services, Environmental Health, traditional authorities, NGOs, and the Northern Development Authority all play roles, yet weak coordination, limited budgets, and uneven prioritisation undermine their collective impact.

Hypothesis testing for Objective Two indicates that institutional support is not evenly distributed across socio-economic settings. Higher-income Kalariga enjoys greater access to government and NGO education, early warning, and formal assistance, whereas lower-income Koblimahagu and medium-income Nalung receive less frequent, less timely, and less adequate support. Both descriptive data and qualitative narratives are consistent with the alternative hypothesis that institutional support is biased towards wealthier communities. Interpreted through UPE, these findings underscore that flood risk in Tamale is not only a function of physical exposure but also of who receives infrastructural protection, policy attention, and institutional assistance. Urban Resilience Theory further suggests that resilience in Tamale remains partial and uneven, with structural, informational, and governance capacities concentrated in high-income areas and weakest where vulnerability is greatest.

Overall, the chapter highlights that planned adaptation in Tamale, though present, is insufficiently coordinated, unevenly distributed, and constrained by resource and governance limitations. Addressing these gaps requires not only technical upgrades to dams, drains, and EWS, but also deeper reforms in land-use planning, multi-level governance, and equitable resource allocation. The next chapter builds on these insights by examining community-based adaptation strategies and exploring how local practices interact with, complement, or compensate for the shortcomings of institutional adaptation in Tamale.



## CHAPTER 6

### COMMUNITY ADAPTATION MEASURES IMPLEMENTED IN TAMALE

#### 6.1 Introduction

Chapter 5 examined government-led or top-down flood risk management strategies in Tamale, focusing on planned adaptation through expert interviews, focus group discussions (FGDs) with community leaders, and household surveys conducted in three socioeconomically distinct communities: Kalariga, Nalung, and Koblimahagu. The chapter highlighted the government's obstacles in executing city-level flood adaptation programs and provided viable solutions to alleviate these constraints. This chapter focuses on citizen-led, autonomous, or community-based adaptation, in which local communities take charge of managing flood risks. Unlike top-down techniques, citizen-led initiatives enable communities to define and implement their own goals based on local and indigenous knowledge, addressing specific risks and avoiding the restrictions associated with foreign interventions. This bottom-up method usually works at the community or family level. Despite its potential benefits, citizen-led adaptation faces challenges, including unequal access to resources and adaptive capacity, which can exacerbate inequities and result in maladaptation. These challenges conflict with global development goals and frameworks, such as the Sustainable Development Goals (SDGs) and the Sendai Framework, which aim to ensure equitable adaptation. This chapter examines flood adaptation methods undertaken by three diverse communities of Kalariga, Nalung, and Koblimahagu, representing various socioeconomic strata. It examines the relationship between household income levels and the adoption of community-based flood adaptation strategies across the three communities. The analysis addresses the third hypothesis of the study, which explores how socio-economic disparities influence local-level resilience actions in the absence or insufficiency of institutional support. It uses quantitative survey data and qualitative insights

to investigate infrastructural adjustments, ecosystem-based initiatives, and community-led strategies. The analysis aims to inform policy and enhance the resilience of flood-prone communities by offering a critical perspective on the potential and limitations of autonomous adaptation.

## 6.2 Community-Based/Citizen-led Adaptation

Citizen-led or community-based adaptations to flooding involve proactive measures initiated independently by local communities, particularly in contexts where formal government intervention is lacking or inadequate. These strategies draw upon indigenous knowledge, social cohesion, and informal networks to manage flood risks effectively (Howard et al., 2024). Social and organisational responses, including the formation of local flood committees and community-based organisations, have proven essential for coordinating preparedness, disseminating warnings, and organising evacuations, as seen in Accra, Ghana (Asumadu-Sarkodie et al., 2015). Economic adaptations are also crucial, with communities often diversifying livelihoods away from flood-vulnerable activities; in Matola, Mozambique, many have shifted to small-scale trading and craft industries to maintain economic stability amid recurrent floods (Neves & Espling, 2025). Furthermore, behavioural changes such as adopting flood-resistant building designs and, where necessary, relocating from high-risk areas have significantly reduced vulnerability in flood-prone (Asumadu-Sarkodie et al., 2015). Environmental initiatives, including afforestation, restoration of natural landscapes, and community-led waste management, further enhance resilience by improving drainage and reducing surface runoff. Notably, ecosystem-based approaches in Cape Town, South Africa, demonstrate the effectiveness of nature-based solutions in reducing urban flood risks (Pahwa Gajjar et al., 2021). Collectively, these community-driven strategies underscore the vital role

of local action in flood adaptation, highlighting the need for their integration into broader institutional frameworks to enhance resilience in settings with limited formal support.

### **6.3 Physical/Infrastructural Adaptations**

In metropolitan areas where natural defences are frequently breached, infrastructure improvements are crucial for mitigating flood threats. The survey results show significant differences in the implementation of infrastructure initiatives among Kalariga, Nalung, and Koblimahagu, reflecting the communities' diverse financial capacities. It also explores the many autonomous adaptation methods that these communities have implemented and how socio-economic status influences the various measures implemented by individuals. These are categorised as structural support, drainage system adjustments, and elevated platforms.

#### **6.3.1 Structural Support**

The adoption of structural flood adaptation measures, such as piers, pillars, and reinforced foundation walls, in Kalariga, Nalung, and Koblimahagu reveals both proactive community responses and underlying economic and qualitative disparities that affect their effectiveness. Survey data indicate adoption rates of structural supports at 23% in Kalariga, 19% in Nalung, and 15% in Koblimahagu. On the contrary, the proportions of households reporting no structural adaptations are 11%, 14%, and 18%, respectively, as presented in Figure 6.1. Although these variations in adoption rates appear modest, field observations highlight substantial qualitative differences in structural supports, primarily influenced by household economic capacities. Within Kalariga, wealthier households often use higher-quality and more durable materials, such as reinforced concrete and cement blocks, for structural adaptations, thereby enhancing their resilience.

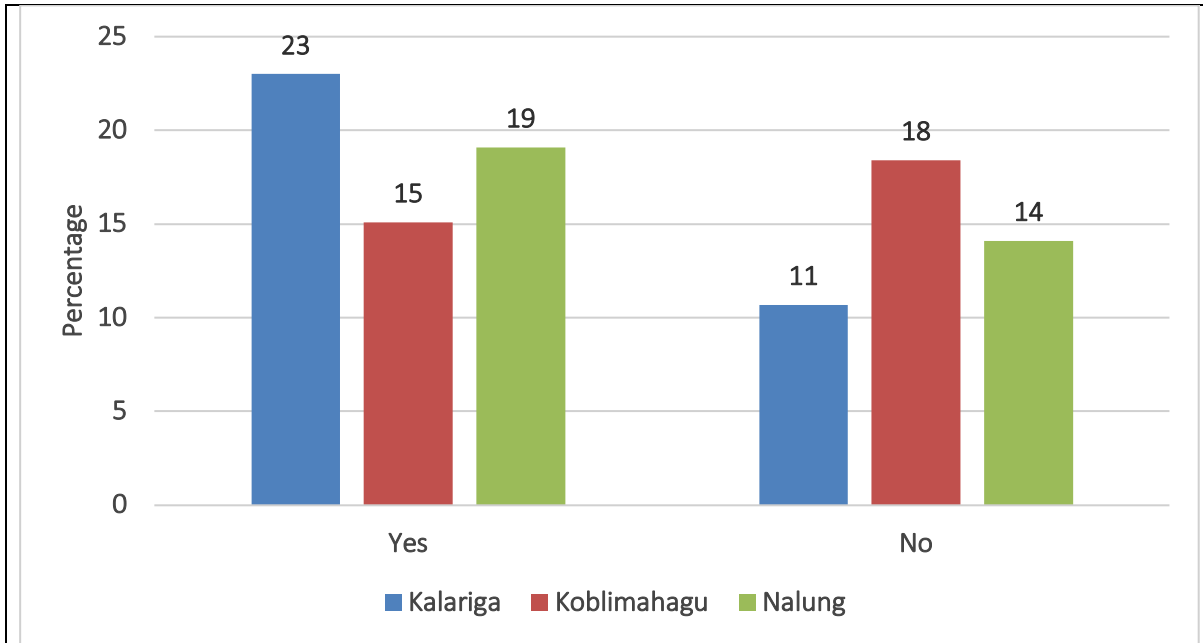


Figure 6.1 Structural Support (Piers, Pillars and Foundation walls) for flood resilience  
Source: Field Data, Household Questionnaire Survey 2023

However, economically disadvantaged households within the same community commonly rely on mud bricks, gravel blocks, or basic wooden supports, which are considerably less effective in mitigating flood impacts. A community leader succinctly captured this disparity:

*"Household economic differences have a big effect. Poorer people are in a less advantageous position to cope with the flooding. The stronger buildings can cope with the flooding, but the poor people cannot afford to build such houses"*  
(Community Leader, Kalariga, FGD, 2023).

Also, Nalung, categorised as a middle-income community, reflects notable economic variability affecting structural adaptation quality. Some households utilise durable materials, while others use less resilient mud and gravel-based construction. An official from the government explicitly identified these economic constraints:

*"The high poverty level means that houses are built using mud or gravel blocks. These types of buildings fall during the flood. People know what to do, like what houses to build to protect themselves, but they cannot afford to do it"* (Official, NDA, KII, 2023).

This economic differentiation aligns with broader research findings indicating that flood adaptation measures tend to be inequitably accessible, often favouring households with higher economic capabilities (Clase, 2024). In Koblimahagu, economic challenges are most pronounced, reflected by the lowest adoption (15%) and highest non-adoption rates (18%). Structural supports in this community are predominantly rudimentary and constructed from less resilient materials due to financial limitations. A local leader articulated this clearly:

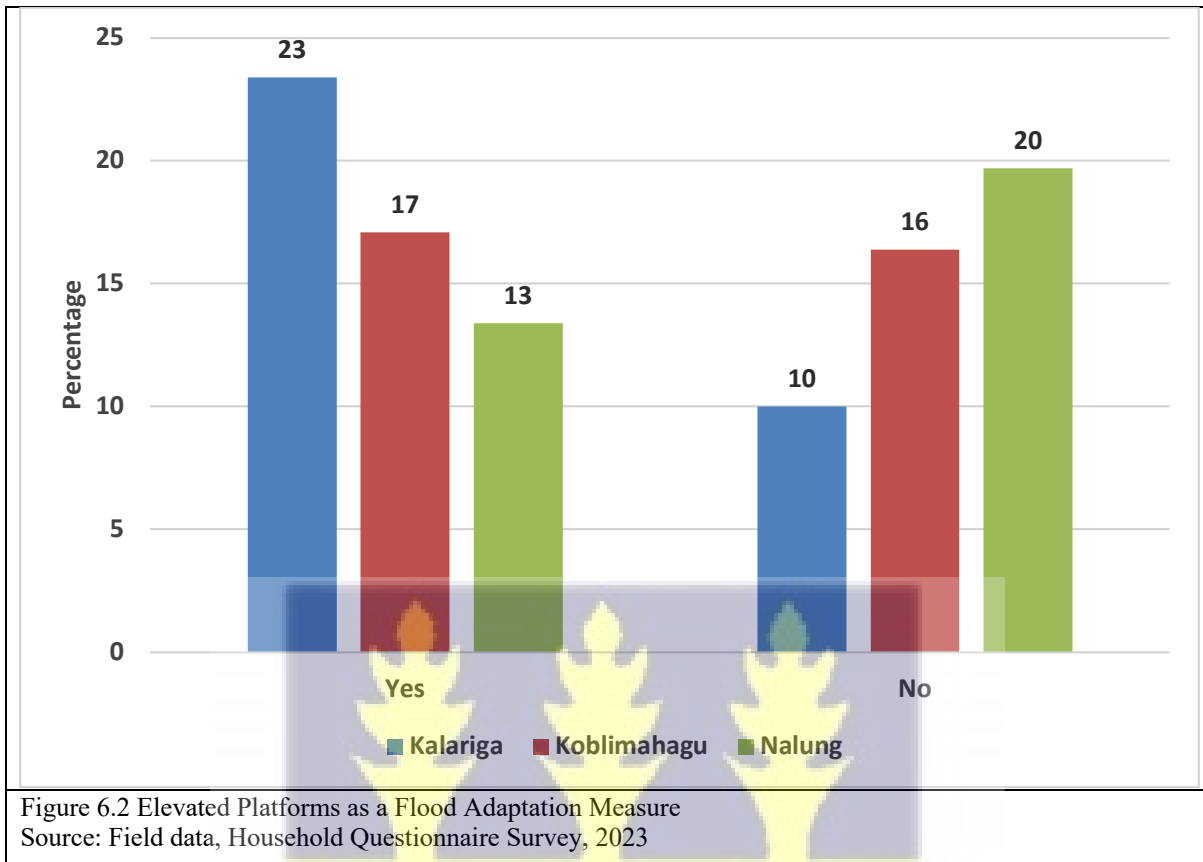
*"We are a low-income community, so most of us cannot afford to upgrade our houses"*  
(Community Leader, Koblimahagu, FGD, 2023).

Such insights corroborate global findings that socially vulnerable communities often face disproportionate resource constraints and systemic barriers, further entrenching their vulnerability (Nair et al., 2024; Tyler et al., 2023).

### 6.3.2 Elevated Platforms as a Flood Adaptation Measure

Elevating properties is a widely recognised flood adaptation measure, particularly in flood-prone urban and peri-urban settings. It offers a practical solution to reduce direct damage to homes during high-water events. In the study communities of Kalariga, Koblimahagu, and Nalung, elevation of structures was observed to varying degrees, reflecting both individual adaptation efforts and underlying socio-economic dynamics. While the differences in elevation rates are not drastic, those of Kalariga (23%), Koblimahagu (17%), and Nalung (13%) (Figure 6.2) do suggest that economic factors influence the ability of households to adapt to this measure. Even modest differences in adaptation uptake may reflect broader disparities in income levels, housing investment capacity, and access to resources. In Kalariga, where the highest proportion of households had elevated their structures, residents were generally more able to invest in such measures. Although the difference between Kalariga and the other

communities is not significant, it may still indicate that small margins of financial flexibility enable households to prioritise adaptation.



However, the proportion of households that reported being unable to elevate their properties was highest in Nalung (20%) and Koblimahagu (16%), compared to Kalariga (10%). This reinforces the idea that financial hardship remains a barrier, even if the differences in elevation rates are not stark. A chief remarked:

*“Most people are subsistence farmers, and they cannot even find food to feed themselves.”* (Chief, Nalung, FGD, 2023)

These perspectives align with research suggesting that the costs of construction materials, labour, and the lack of access to credit or insurance can significantly limit adaptation measures such as elevation. Furthermore, while elevation may appear to be a straightforward solution, it often necessitates an upfront investment that lower-income households struggle to mobilise,

particularly when competing with basic livelihood needs. Figure 6.3a depicts a house in Kalariga with well-elevated aprons to protect the foundation from floodwater, and Figure 6.3b also illustrates a house in Nalung that has minimal elevation for flood protection.



Figure 6.3 Elevated Platforms as a Flood Adaptation Measure  
*a)* A building at Kalariga with a well-constructed apron  
*b)* A building in Nalung with minimal elevation  
Source: Field Data, Household Questionnaire Survey, 2023

Though the elevation rates across the three communities are relatively close, they serve as a valuable lens for understanding how even small disparities in resources and awareness can influence household decisions regarding flood protection. Studies across Sub-Saharan Africa confirm that wealthier households are more likely to undertake proactive adaptation measures, including property elevation, due to better access to financial resources and risk information (Awah et al., 2024; Mashi et al., 2020). Elevated platforms represent a critical flood adaptation strategy that can reduce household vulnerability. While adoption rates in the study communities are not widely divergent, the existing differences, however modest, are shaped by household income, financial access, and awareness. Addressing these challenges through targeted support, such as subsidized construction, microcredit schemes, or community-based awareness campaigns, could enhance the uptake of elevated platforms and improve resilience across socio-economic groups.

### 6.3.3 Barrier Construction as a Flood Adaptation Measure

Barrier construction is an essential flood adaptation measure that has been adopted at varying rates across different communities. The data presented in Figure 6.4 on the adoption of barrier construction in Kalariga, Koblimahagu, and Nalung highlights the divergent approaches these communities take in response to flood risks.

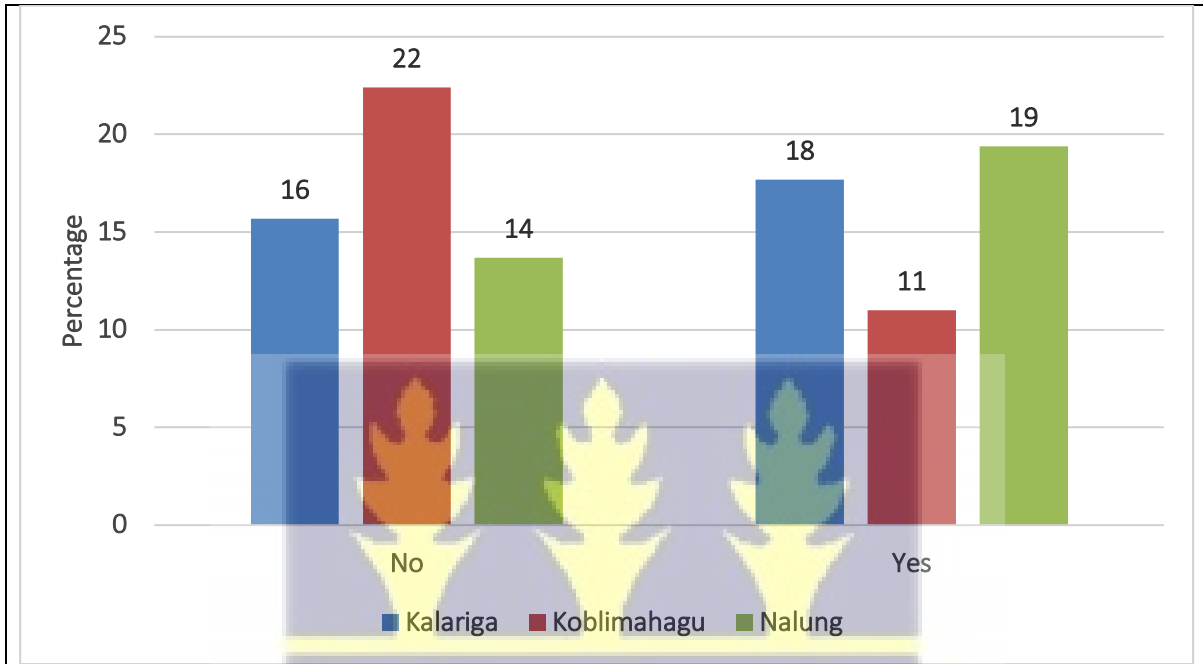


Figure 6.4 Barrier Construction  
Source: Field Data, Household Questionnaire Survey 2023

While economic status plays a role in shaping adaptation strategies, other factors such as risk perception, infrastructure availability, and community resilience also significantly influence the extent to which residents invest in barrier construction. Although it is often assumed that wealthier communities have the highest level of flood preparedness, the data suggests that lower-income communities may not always show the highest rates of barrier construction. Instead, adoption patterns are influenced by how residents perceive and prioritize flood risk. The findings reveal that Nalung has the highest adoption rate of barrier construction at 19%, compared to 18% in Kalariga and 11% in Koblimahagu. Given that Nalung is a medium-

income community, its relatively high adoption rate is significant, as it demonstrates how moderate-income households may take proactive measures when flood risks are persistent and immediate. A community leader in Nalung explained this motivation, stating:

*“We are not the poorest community, but we are not rich either. We have to choose where to spend our money, and barriers are not always the first priority.”* (Sub Chief, Nalung, FGD, 2023)

This finding supports De Silva and Kawasaki (2020), who argue that medium-income communities frequently face unique challenges in disaster preparedness where financial resources exist but are often stretched across competing needs. In contrast, Koblimahagu, despite being a lower-income community, exhibits the lowest adoption rate (11%). This lower figure may not necessarily indicate a lack of awareness or willingness, but rather the financial and material constraints that limit widespread implementation. However, interviews revealed strong local initiative and collective effort toward flood mitigation. A community leader in Koblimahagu emphasized this point, stating:

*“We do not have the money to build bigger drains or raise our houses, so we do what we can with what we have. Even if it’s just sandbags or small walls, at least it helps.”* (Community Leader, Koblimahagu, FGD, 2023)

This aligns with Patel & Gleason (2018), who observed that communities experiencing recurrent environmental hazards often develop localized, low-cost coping mechanisms in the absence of external support. Figure 6.5a shows sandbags used as a barrier construction measure at Nalung, while Figure 6.5b depicts a small household barrier designed to prevent water from entering living spaces. Despite its higher-income status, Kalariga shows a moderate adoption rate of 18%. This suggests that residents may rely on a broader range of flood adaptation strategies such as elevated buildings, improved drainage systems, and integrated flood

adaptation within urban planning frameworks rather than individual barriers. A community leader in Kalariga remarked:

*“I don’t think barriers are the best long-term solution. If the drainage system is fixed and our houses are properly built, we won’t need them.”* (Community Leader, Kalariga)



Figure 6.5 Images showing barrier construction

a) Sandbags as a barrier construction measure at Nalung

b) Concrete barrier in front of a room corridor to prevent floodwater at Kalariga

Source: Field Data, Household Questionnaire Survey, 2023

This aligns with Cutter et al. (2009), who suggest that wealthier communities tend to integrate flood protection into broader urban development plans, focusing on sustainable and systemic solutions. Moreover, government interventions and planned infrastructure in Kalariga may further reduce the perceived need for household barriers, as one official explained:

*“In planned urban areas, structural adaptation is integrated into overall development, so barriers are often unnecessary.”* (Official, TaMA, FGD, 2023)

Beyond economic considerations, risk perception plays a significant role in shaping the adoption of flood barriers. The relatively high adoption in Nalung suggests that residents perceive themselves as more vulnerable compared to Kalariga, while those in Koblimahagu may lack the resources to act despite recognizing risk. A state official emphasized this connection:

*“Communities that experience repeated flooding are more likely to take action, while those with occasional flooding tend to delay or ignore adaptation efforts.”* (Official, NADMO Regional, KII, 2023)

This observation aligns with Mashi et al.2020), who note that higher flood risk awareness leads to greater engagement in adaptation measures. Differences in government intervention and infrastructure development also contribute to the variation in barrier adoption. Residents in Kalariga may depend on established flood control systems, while those in Koblimahagu and Nalung often lack such infrastructure, making household barriers their most practical option. A Nalung community leader highlighted the issue of unequal infrastructure distribution:

*“The authorities say they are fixing drainage systems, but we don’t see any change here. When it rains, the water still collects in the same places, and our houses still flood. We feel left out.”* (Community Leader, Nalung, FGD)

This statement emphasizes the systemic inequalities in flood adaptation, where government-led interventions in certain areas may inadvertently heighten vulnerability in others.

#### **6.3.4 Construction of Drainage System**

The decision to construct drainage systems around households is influenced by a combination of economic capacity, access to resources, risk perception, and perceived necessity. While higher-income households may have the financial resources and technical support to undertake such projects, lower-income communities often face significant barriers related to cost, access, and competing priorities. The findings reveal that drainage construction is highest in Kalariga, with 14% of respondents reporting that they have installed drainage systems around their households. In contrast, 11% of respondents in Nalung and only 8% in Koblimahagu reported undertaking similar projects. The data presented in Figure 6.6 illustrates the disparities in drainage system construction across the three communities of Kalariga (high-income), Nalung

(medium-income), and Koblimahagu (low-income), as well as the reasons for non-construction among households that have not implemented drainage systems.

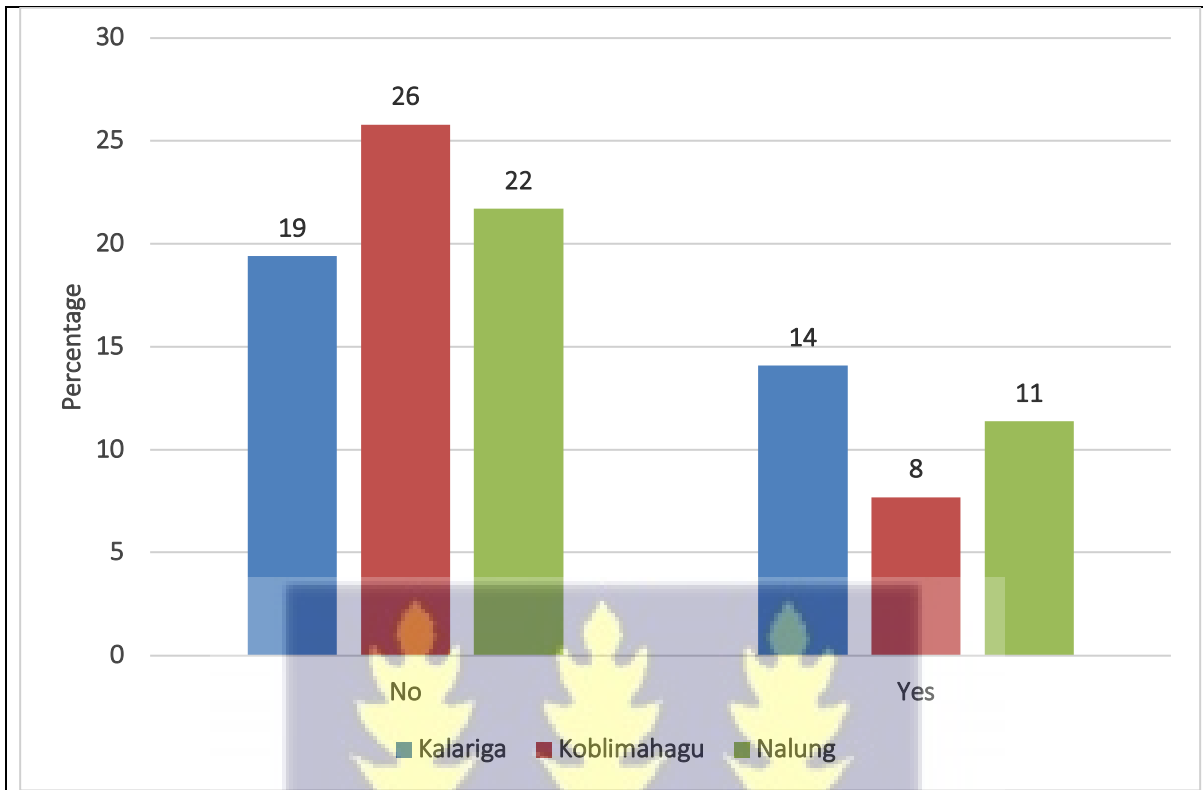


Figure 6.6 Construction of the Drainage System  
 Source: Field Data, Household Questionnaire Survey, 2023

This trend aligns with findings from Wei-Shiuen (2021), who argues that higher-income households are more likely to invest in infrastructure improvements due to greater disposable income, access to resources, and awareness of long-term benefits. This perspective highlights the autonomy and financial flexibility that allows higher-income households to take proactive flood adaptation measures. In contrast, drainage construction rates are significantly lower in Koblimahagu, where only 8% of households have built drainage systems. The primary reason cited for non-adoption in this community is a lack of access to resources, with 18% of respondents stating that they do not have access to materials or skilled labour to undertake such projects. Additionally, 14% of respondents reported that cost was a major barrier, making drainage construction financially infeasible. This challenge reflects the broader systemic

inequalities faced by low-income households, as noted by Gough et al. (2020). Financial limitations, inadequate market access, and logistical challenges in poorer communities often constrain infrastructure development. A community elder in Koblimahagu expressed frustration with the limited options available, stating:

*“We have been asking for help to fix drainage in this area for years. If we had the money, we would do it ourselves, but where can we find such resources?”*  
(Community Leader, Koblimahagu, FGD, 2023).

This highlights the intersection of financial and logistical constraints, which collectively hinder infrastructure improvements in low-income areas.

Nalung presents a more complex scenario, with 11% of respondents reporting drainage construction, positioning it between the extremes of Kalariga and Koblimahagu. This suggests that while medium-income households may have more financial flexibility than low-income households, they still struggle with logistical and infrastructural challenges. This aligns with Roldán-Valcarce et al. (2023), who note that medium-income households often experience dual constraints of affordability and accessibility, limiting their ability to implement large-scale infrastructure projects. A resident of Nalung explained this challenge, stating:

*“We are always told that roads and drains will come, but nothing ever happens. Some of us can afford small improvements, but it is difficult when we do not know when bigger projects will be completed”* (Community elder, Nalung, FGD, 2023).

This highlights the uncertainty surrounding infrastructure development and the dependency on external actors to fill the gaps left by individual efforts. Government intervention plays a significant role in shaping household flood adaptation strategies. While Kalariga benefits from existing infrastructure investments, Nalung and Koblimahagu remain underserved, increasing their dependence on self-financed flood protection measures. A state official highlighted the disparities in infrastructure development, stating:

*“Drainage construction is often prioritised in areas with higher economic activity, leaving some residential areas struggling to manage flood risks on their own”*  
(Official, NADMO Regional, KII, 2023).

This suggests that unequal distribution of government resources further exacerbates disparities in flood resilience, forcing lower- and medium-income communities to bear the burden of self-financed adaptation efforts. The disparities in drainage system adoption across Kalariga, Nalung, and Koblimahagu underscore the critical role that income, access, and perception play in shaping household infrastructure decisions. Higher-income households in Kalariga are more likely to invest in drainage systems due to greater financial capacity and resource availability. In contrast, lower-income households in Koblimahagu face severe economic and logistical barriers that prevent widespread adoption. Nalung, as a medium-income community, experiences dual constraints, balancing some financial flexibility with persistent access challenges. Addressing these barriers requires tailored policy interventions beyond financial assistance, including logistical support, material subsidies, and community-driven infrastructure projects.

## **6.4 Ecosystem-Based Approaches**

### **6.4.1 Tree Planting**

Tree planting represents a key ecosystem-based adaptation (EbA) strategy within the three study communities, contributing to flood mitigation through soil stabilisation, water absorption, and improved vegetative cover. Survey results indicate adoption rates of 23% in Kalariga, 20% in Koblimahagu, and 19% in Nalung (Figure 6.7). These relatively modest but significant rates demonstrate that communities recognise the protective value of vegetation even when economic and environmental constraints limit wider implementation. Previous

research supports this, noting that trees and vegetation reduce runoff, enhance infiltration, and create natural barriers that lower flood severity (Paudel et al., 2024; Sharma & Ayuba, 2024).

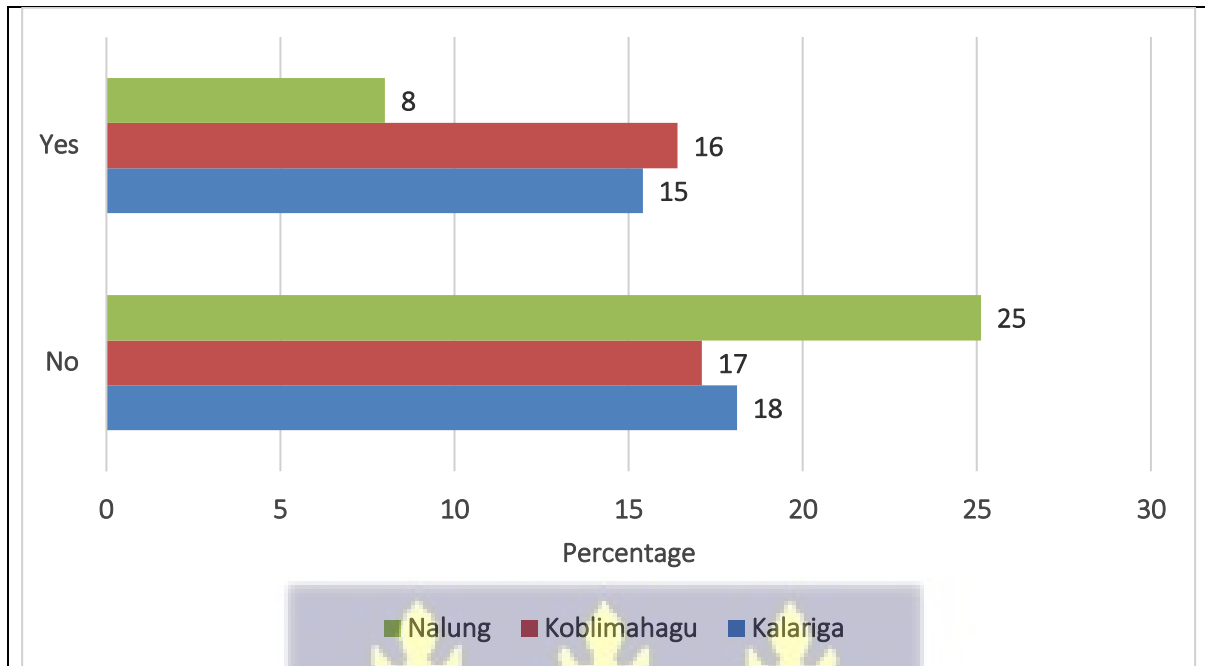


Figure 6.7 Tree Planting  
Source: Field Data, 2023, Household Questionnaire Survey

In Koblimahagu, the uptake of tree planting appears strongly influenced by external support, particularly from NGOs and community initiatives. As one community leader explained:

*“We don’t have much, but we understand the importance of trees. Some organisations gave us seedlings, and we planted them to protect our homes from floods.”* (Community leader, Koblimahagu, FGD, 2023)

This reflects broader arguments that successful EbA relies on community engagement, knowledge mobilisation, and facilitation from supporting institutions (Kellogg et al., 2024; Vasseur, 2021).

In Kalariga, where socio-economic conditions are relatively stronger, motivations differ. Households integrate tree planting into broader adaptation strategies, combining it with

improved drainage, structural housing improvements, and land-use management. A community leader noted:

*“We know that trees help, but we also rely on better drainage and stronger houses. Planting trees is part of a bigger plan.”* (Community leader, Kalariga, FGD, 2023)

This aligns with research showing that communities with higher informational and financial capacity are more likely to embed nature-based solutions within multi-layered adaptation systems (Brueder et al., 2023; Christopher et al., 2024). Nalung records the lowest adoption rate, reflecting environmental constraints and socio-economic barriers. Its rocky terrain limits soil retention, reduces tree survival, and restricts scaling of vegetative cover. A sub-chief described these challenges:

*“The land here is not the same as in other areas. We try to plant, but it does not always work.”* (Sub-chief, Nalung, FGD, 2023)

Physical constraints of this kind are well documented as barriers to natural flood management (Zhu et al., 2024). Beyond environmental limits, Nalung’s moderate-income status also suggests gaps in financial capacity, technical resources, and awareness, echoing findings that successful nature-based solutions require both material investment and capacity-building (Seddon et al., 2021).

Taken together, the evidence shows that while tree planting is valued across all three communities, its uptake is shaped by resource availability, environmental context, and institutional support. Through the lens of urban resilience theory, these patterns underscore that ecosystem-based adaptation is most effective where communities possess the adaptive capacity, knowledge networks, and institutional linkages needed to maintain and scale nature-based interventions. Strengthening urban resilience therefore requires coupling ecological strategies like tree planting with educational outreach, financial support mechanisms, and

tailored interventions that account for local biophysical conditions and socio-economic disparities.

### 6.5 Household-Level Preparedness Measures: Elevated Storage and Provision Storage

Household-level preparedness measures play a crucial role in reducing vulnerability to flood hazards, particularly in urban communities where exposure varies widely across socio-economic and environmental contexts. Two key strategies identified in the study areas elevating household possessions and storing essential provisions demonstrate both the agency of households and the persistent barriers that shape adaptive capacity.

#### 6.5.1 Elevated Provision Storage

Elevating household possessions during floods is a commonly used damage-reduction strategy across the surveyed communities. Adoption rates are 23% in Kalariga, 20% in Koblimahagu, and 19% in Nalung (Figure 6.8).

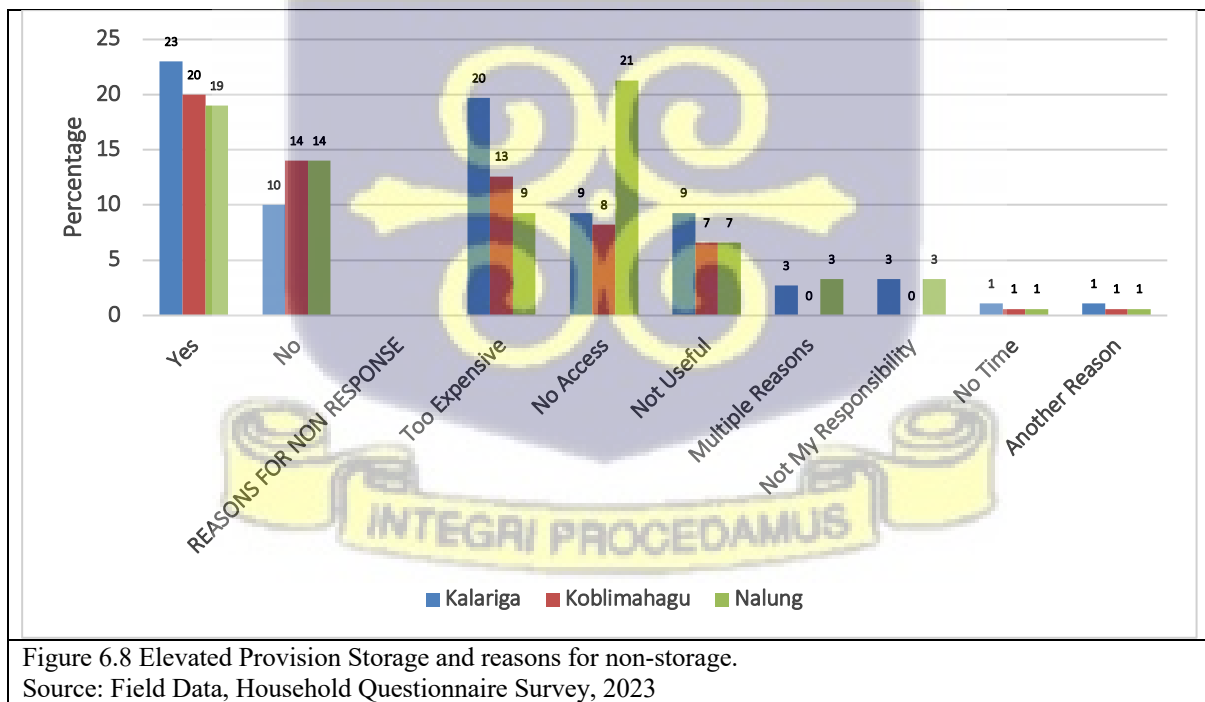


Figure 6.8 Elevated Provision Storage and reasons for non-storage.  
Source: Field Data, Household Questionnaire Survey, 2023

Kalariga's relatively higher uptake likely reflects greater socioeconomic capacity, which enhances access to space, materials, and information factors central to household adaptive capacity (Smith, 1998). Several barriers limit wider adoption. Cost is significant, reported by 20% of Kalariga, 13% of Koblimahagu, and 21% of Nalung households, reinforcing evidence that financial constraints strongly influence adaptation behaviour (Smit & Wandel, 2006a). Access challenges are also notable: 9% in Kalariga, 8% in Koblimahagu, and 9% in Nalung report lacking suitable materials or facilities. Perceptions of effectiveness vary as well, with 9%, 7%, and 7% in the respective communities indicating that elevated storage is not useful (Grothmann & Patt, 2005). Crucially, some respondents expressed doubt linked to broader gaps in adaptation knowledge. As one Kalariga elder emphasised:

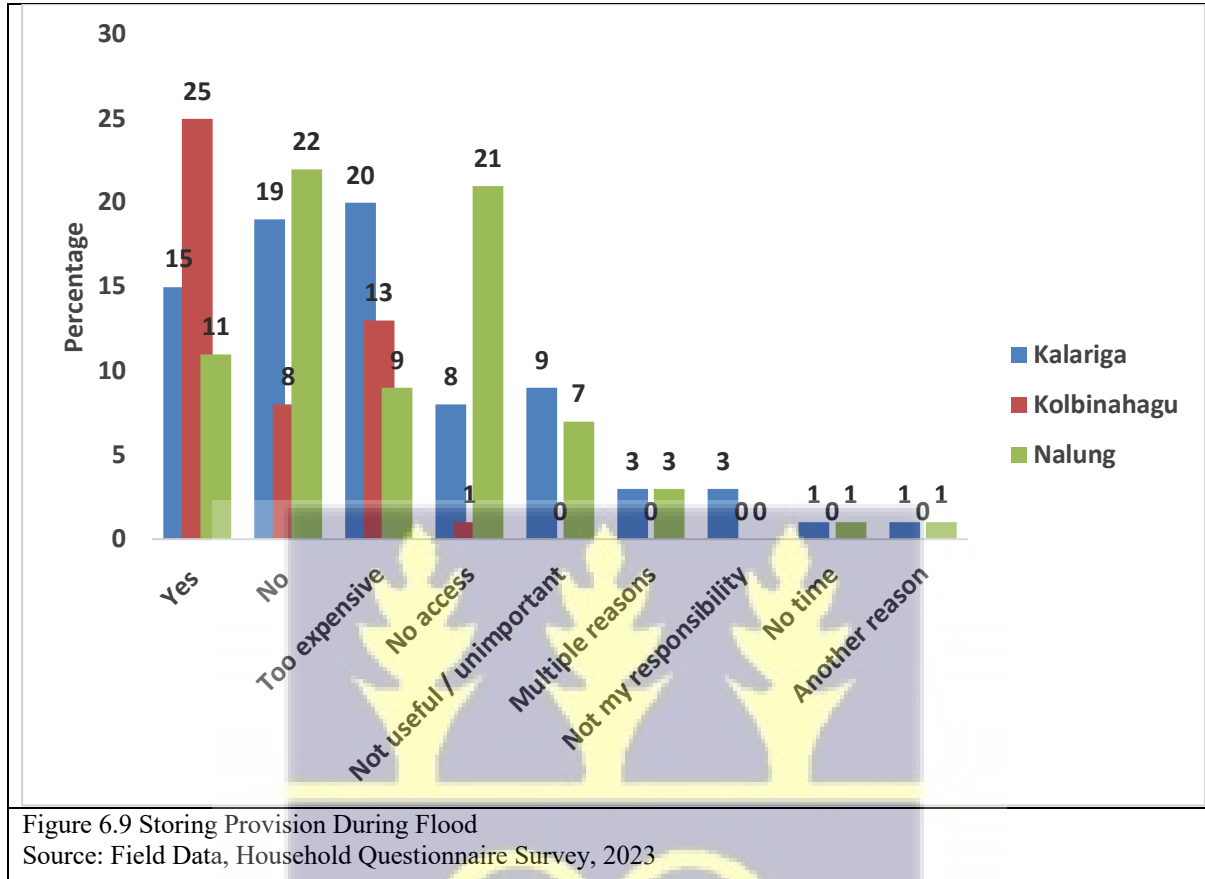
*"There is no adaptation and there is no education. Nothing."* (Community Elder, Nalung, FGD, 2023)

This statement highlights a wider lack of institutional and informational support, which undermines households' capacity to engage in protective practices. Other barriers such as multiple concerns (3% each community), feelings of non-responsibility (3% in Kalariga and Nalung; 1% in Koblimahagu), limited time (1% across all), and minor additional reasons (1% each) suggest that both practical and attitudinal limitations shape behavioural outcomes.

### 6.5.2 Provision Storage

Storing provisions such as food and water is a vital household-level flood preparedness measure, particularly in communities exposed to recurrent flooding. Updated survey findings show clear differences across the three study areas. Koblimahagu records the highest adoption rate at 25%, followed by Kalariga at 15% and Nalung at 11% (Figure 6.9). This suggests that households in Koblimahagu may display stronger preparedness awareness, potentially shaped

by past flood experiences or targeted interventions from NGOs and local authorities a relationship consistent with Cutter et al.'s (2010) argument that disaster history promotes proactive risk reduction behaviour.



Despite its benefits, a considerable share of households still do not store provisions: 19% in Kalariga, 8% in Koblumahagu, and 22% in Nalung. The barriers identified point to structural and socio-economic constraints. Cost is a major obstacle, cited by 20% of Kalariga, 13% of Koblumahagu, and 9% of Nalung respondents, mirroring findings from Lagos where financial limitations significantly undermine household preparedness (Odunsi & Onanuga, 2022). Lack of access to provisions is another substantial challenge particularly in Nalung (21%), compared to 8% in Kalariga and 1% in Koblumahagu highlighting infrastructural inequalities similar to those documented in Kibera, Nairobi (Urban Floods Community of Practice, 2017).

Perceptions of usefulness also influence behaviour. 9% of Kalariga and 7% of Nalung respondents believe that storing provisions is not useful, while no respondents in Koblimahagu shared this perception. Similar patterns have been observed in New Orleans, where low-risk perception inhibits preparedness behaviours (Malsegna, 2022). Other barriers include multiple concerns (3% in both Kalariga and Nalung), lack of responsibility (3% in Kalariga only), limited time (1% in Kalariga and 1% in Nalung), and other minor reasons (1% across both communities). As one Kalariga respondent noted:

*“Sometimes we want to prepare, but the cost and access make it difficult.”*(Community Resident, Kalariga, FGD, 2023)

This highlights the intersection between economic and logistical constraints in shaping household preparedness. International comparisons illustrate similar trends. In Accra, only 39.8% of households store emergency provisions (Yin et al., 2021), while studies in Jakarta show that socio-economic variables and flood experience strongly affect preparedness (Muliandi Madjid et al., 2024). Conversely, well-governed flood-prone regions such as the Netherlands record preparedness rates exceeding 70%, driven by strong institutional support, public awareness, and established flood-risk policies (Bubeck et al., 2012). Overall, the data indicate that provision storage is strongly conditioned by economic capacity, infrastructural access, and risk perception, echoing global evidence on the socio-economic determinants of disaster preparedness (Lolig et al., 2014).

Taken together, the findings from both elevated storage and provision storage highlight that household preparedness is shaped by a combination of economic capacity, infrastructural access, and perceptions of risk and responsibility. While communities demonstrate agency in

adopting practical flood adaptation measures, persistent socio-economic barriers constrain the consistency and effectiveness of these strategies. When interpreted through urban resilience theory, these results illustrate that resilience is not merely a function of individual household behaviour. Rather, it emerges from the interactions between household adaptive capacity, access to resources, and institutional and infrastructural systems (Meerow & Stults, 2016). Communities like Kalariga, Koblimahagu, and Nalung demonstrate varying capacities to prepare for floods, shaped by their socio-economic context, exposure histories, and environmental conditions.

## 6.6 Community-Based Strategies

Community-based measures are vital components of flood adaptation, reflecting the collective capacities of communities to organise, cooperate, and respond to environmental hazards. Unlike household-level strategies that depend primarily on individual resources, community-based adaptation relies on social structures, leadership, communication networks, and shared responsibility. These strategies not only address immediate environmental challenges such as blocked drains or ineffective waste management but also strengthen long-term resilience by building trust, promoting participation, and enhancing the capacity for coordinated action. However, participation in community-based measures varies considerably across Kalariga, Koblimahagu, and Nalung due to differences in socio-economic conditions, access to resources, organisational structures, and perceptions of responsibility. The following sections analyse two key community-based adaptation measures: drain clearing and solid waste management, and engagement in emergency planning and local advocacy.

### 6.6.1 Participation in Drain Clearing and Solid Waste Management to Reduce Flooding

Drain clearing and solid waste management constitute essential community-based flood adaptation strategies, particularly in urban areas where waste accumulation and poor drainage systems heighten flood risks. Participation in these communal activities varies across the three study communities. Survey findings show that 20% of Kalariga residents participate in clean-up activities, compared with 16% in Koblimahagu and 12% in Nalung. Despite these efforts, non-participation remains high, reported by 13% of Kalariga, 17% of Koblimahagu, and 21% of Nalung residents. The higher engagement in Kalariga reflects stronger leadership mobilisation and a more established culture of communal work, while Nalung’s lower rates suggest organisational and socio-economic barriers hindering participation. Figure 6.10 presents the participation, non-participation and barriers to drain clearing.

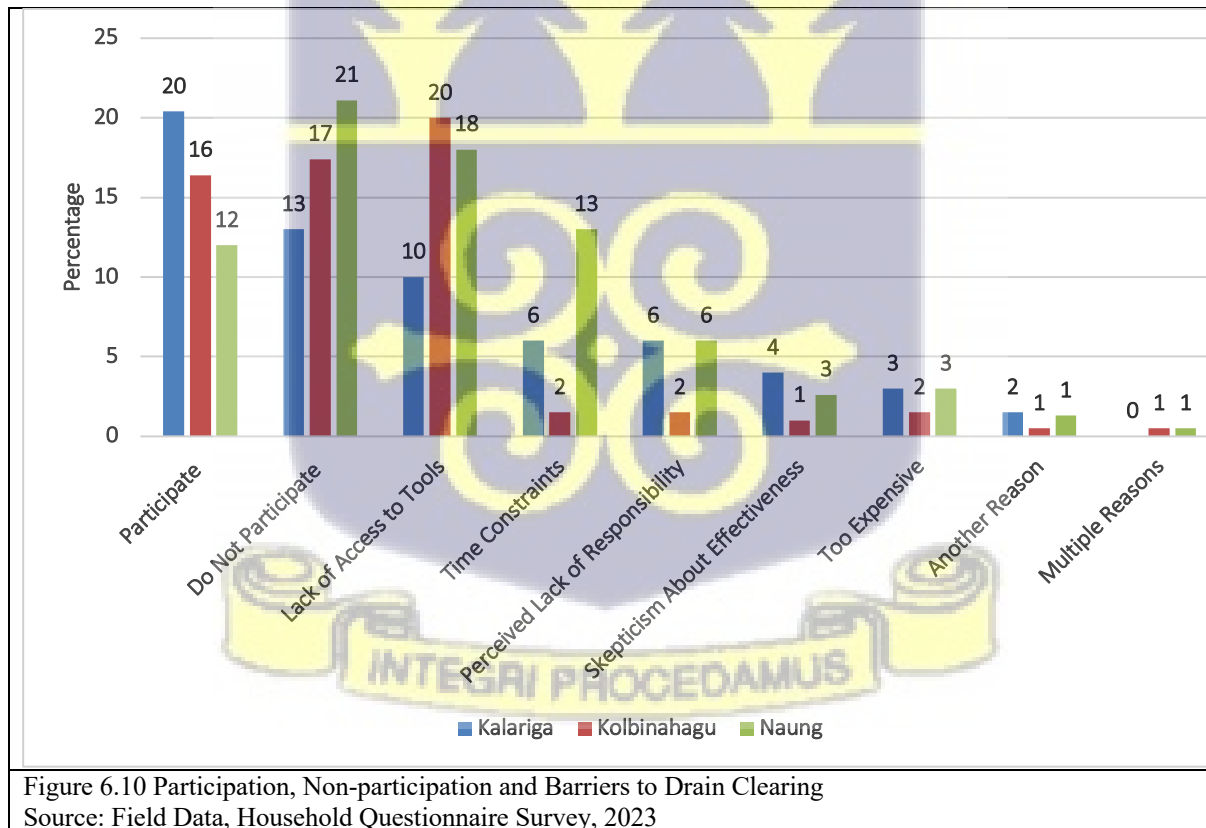


Figure 6.10 Participation, Non-participation and Barriers to Drain Clearing  
Source: Field Data, Household Questionnaire Survey, 2023

Several constraints limit engagement in drain clearing across all communities. Lack of access to tools is the most reported barrier, affecting 10% of Kalariga, 20% of Koblimahagu, and 18% of Nalung respondents. Without essential equipment such as shovels, wheelbarrows, and gloves, communities struggle to maintain consistent participation. A community leader from Koblimahagu explained:

*“We used to have shovels and wheelbarrows provided by the assembly, but now we do not get anything. This makes it hard to keep our areas clean.”* (Community leader Koblimahagu, FGD, 2023)

Time constraints represent another major barrier, particularly in Nalung, where 13% of respondents report being too busy to participate due to work and domestic obligations. As one Nalung resident noted:

*“Between work and taking care of my family, I don’t have the time to do community work. If it were part of my daily routine, maybe I would.”*(Community `resident, Nalung, FGD, 2023)

Perceptions of responsibility also shape engagement. In Kalariga, 6% of respondents feel drain clearing is not their responsibility, with similar views expressed by 6% in Nalung and 2% in Koblimahagu. This mirrors broader trends in African cities where residents often view environmental management as the duty of municipal authorities (Olaniyan, 2024). Skepticism about the effectiveness of clean-up activities further reduces motivation: 4% of Kalariga and 3% of Nalung believe the activities have little impact. A resident from Kalariga expressed this frustration:

*“We have cleaned drains before, but the floods keep coming. What is the point?”* (Community Resident, Kalariga, FGD, 2023)

Finally, cost-related barriers, though less prevalent, still influence participation, with 3% of Kalariga and 2% of Koblimahagu residents noting financial limitations. These findings

suggest that both material and perceptual constraints shape the sustainability of drain clearing as an adaptation measure.

### 6.6.2 Community Engagement in Emergency Planning and Local Advocacy

Engagement in emergency planning and local advocacy is another crucial community-based measure that enhances flood preparedness by empowering residents to participate in decision-making processes, voice local concerns, and organise proactive flood response strategies. Participation in emergency planning shows similar disparities to drain clearing: 21% of Kalariga residents engage in planning activities, compared with 10% in Koblimahagu and only 5% in Nalung. Non-participation is highest in Nalung (28%), followed by Koblimahagu (23%) and Kalariga (13%) Figure 6.11.

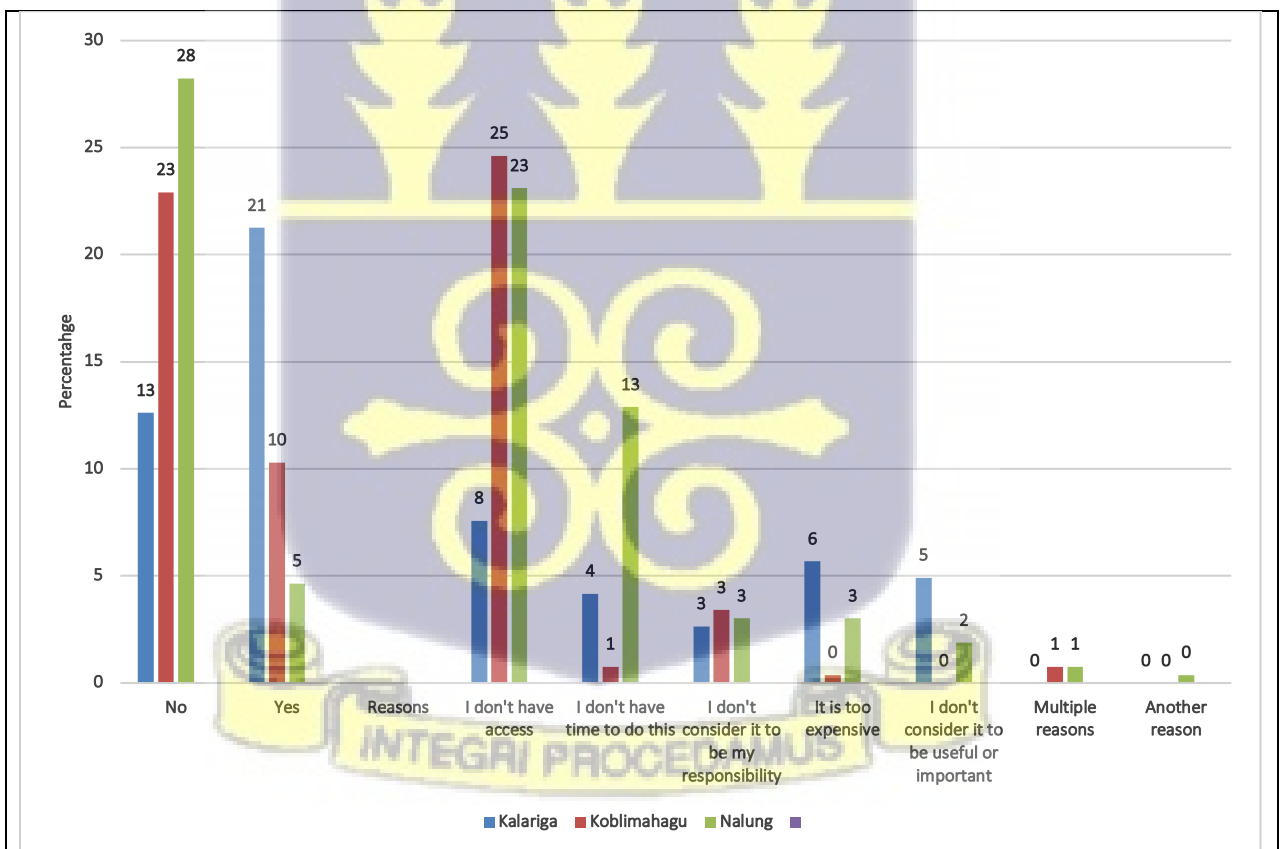


Figure 6.11 Participation, Non-participation and Barriers to Community Planning  
Source: Field Data, Household Questionnaire Survey, 2023

These figures indicate significant gaps in awareness, accessibility, and confidence in local governance structures. The most significant barrier to participation is lack of access to planning platforms or information, identified by 25% of Koblimahagu, 23% of Nalung, and 8% of Kalariga respondents. Many residents reported they were not informed of meeting times or did not have the means to attend. Time constraints also play a major role, especially in Nalung where 13% reported a lack of time, compared to 4% in Kalariga and 1% in Koblimahagu. Similar to drain clearing, perceived responsibility influences participation; 3% in each community believe that emergency planning is the responsibility of authorities rather than residents. This aligns with earlier findings, where a Kalariga elder stated:

*“The government collects taxes; they should be the ones keeping our environment clean.”* (Community Elder, Kalariga, FGD, 2023)

Such attitudes reflect broader patterns across African cities, where residents often expect government-led solutions to disaster management (Atanga, 2020). Skepticism about the usefulness of engaging in planning activities also limits participation. 5% of Kalariga and 2% of Nalung expressed doubts about whether such engagement produces meaningful results. This skepticism resembles findings from the Philippines and Nigeria, where incomplete or delayed flood control projects undermine public trust and diminish community willingness to participate (Beltran, 2024; Kuta Yahaya, 2002). Cost-related barriers were also noted, especially in Kalariga (6%) and Nalung (3%), highlighting the hidden financial burdens associated with community-level involvement, such as transportation or lost work time. While these barriers vary across communities, they collectively demonstrate that emergency planning participation is shaped by intertwined issues of access, time, responsibility, and perceived efficacy.

When considered together, drain clearing and emergency planning reveal a shared set of structural and socio-economic constraints that shape community-based participation in flood adaptation. Both measures rely on collective action, yet their effectiveness is limited by barriers such as insufficient tools and platforms, time pressures linked to livelihood demands, ambivalence about responsibility, and skepticism toward the effectiveness of community initiatives. These commonalities illustrate that community-based adaptation is not merely about willingness to engage, but rather about whether residents have the necessary resources, information, institutional support, and trust to participate meaningfully. The quotations, “Between work and taking care of my family...” and “What is the point?” capture the daily realities and frustrations that hinder participation across both strategies.

Applying urban resilience theory provides deeper insights into these patterns. Resilience is understood as a system’s capacity to adapt, learn, self-organise, and withstand disturbances (Meerow et al., 2016). Both community-based strategies demonstrate that resilience operates at the intersection of household capabilities, community organisation, and institutional structures. Kalariga’s relatively higher participation suggests stronger social networks, leadership mobilisation, and communication channels, key elements of social resilience. In contrast, Koblimahagu and Nalung exhibit weaker structural support, reduced access, and heightened socio-economic pressures, which limit their adaptive capacity.

## **6.7 Financial Preparedness and Insurance Coverage**

Financial preparedness is a critical dimension of household resilience, influencing how quickly and effectively families can recover from flood impacts. In flood-prone communities, financial

buffers such as emergency savings and insurance coverage help households absorb shocks, reduce recovery time, and prevent long-term socio-economic decline. However, the updated survey data reveal extremely low levels of financial preparedness across Kalariga, Koblimahagu, and Nalung, highlighting pronounced financial vulnerabilities linked to income disparities and structural barriers.

### 6.7.1 Emergency Savings

Emergency savings provide households with immediate financial support following flood events. Yet, the data reveal extremely low levels of financial preparedness (figure 6.12).

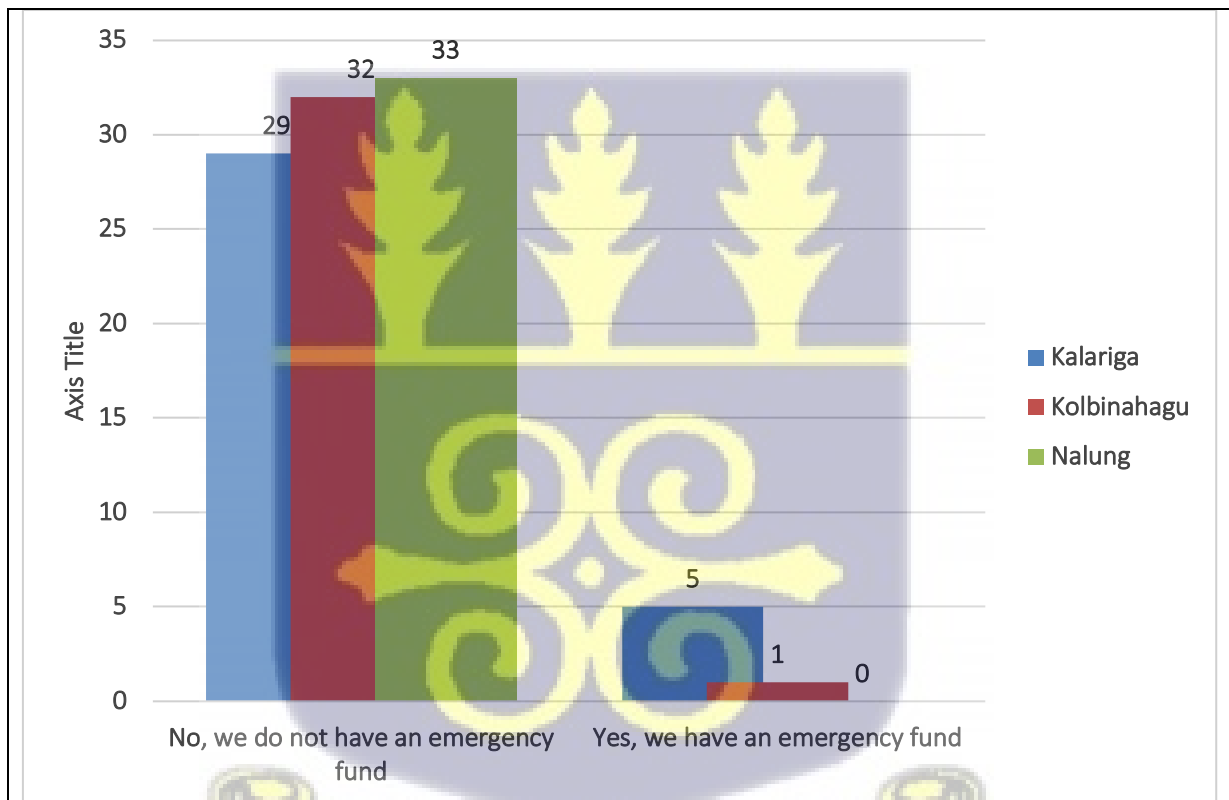


Figure 6.12 Emergency Saving Fund  
Source: Field Data, Household Questionnaire Survey, 2023

In Kalariga, only 5% of respondents reported having emergency funds, while 29% stated they did not. In Koblimahagu, the proportion is even lower, with only 1% of respondents having

emergency funds and 32% reporting none. Nalung presents the most severe case, where 0% of respondents have emergency funds and 33% have none at all. These patterns reflect chronic financial constraints and underline the precarious nature of household economies in these communities. Even in Kalariga where economic conditions are relatively better only a very small minority maintain any form of emergency savings. For most households, daily expenditures consume available income, leaving little capacity to plan for future flood events. This aligns with Wang & Zhao (2023), who found that low-income households are disproportionately affected by disasters precisely because they lack financial buffers, resulting in lengthy and difficult recovery periods. Community testimonies reinforced the effect of economic strain on the ability to save. As one resident in Koblimahagu stated:

*“We barely have enough money to fix our homes after a flood, let alone save for another one.”*(Community Resident, Koblimahagu, FGD, 2023)

Such statements illustrate that the absence of emergency funds is not due to a lack of awareness, but rather a reflection of structural financial hardship and limited income stability.

### **6.7.2 Insurance Coverage for Flood Adaptation Preparedness**

Insurance coverage is another essential indicator of household financial resilience because it provides longer-term protection from flood-related losses. In Kalariga, 28% of respondents have no insurance coverage, while only 2% have flood insurance, 2% have homeowners' insurance, and another 2% have both types of coverage. The situation in Koblimahagu and Nalung is even more concerning. In both communities, 33% of respondents reported having no insurance coverage whatsoever, and none reported having flood insurance, home insurance, or any combined policy. These low levels of insurance uptake reflect multi-layered barriers, including affordability issues, limited awareness, and mistrust of insurance institutions. The

data (Figure 6.13), however, show that insurance uptake is extremely low across all communities.

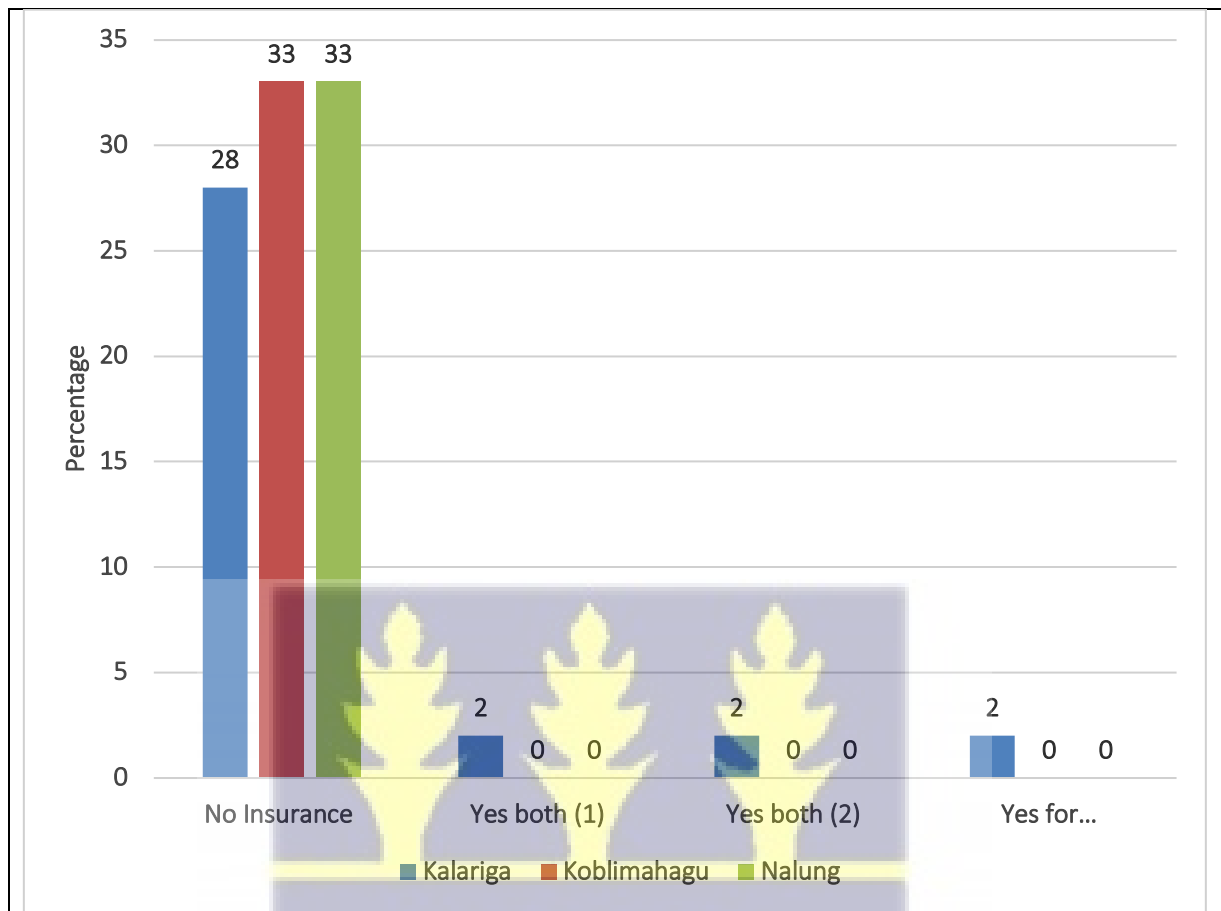


Figure 6.13 Insurance  
Source: Field Data, Household Questionnaire Survey, 2023

As one resident explained:

*“How can we think of insurance when we struggle with daily expenses?”*(Community Resident, Nalung, FGD, 2023)

Institutional mistrust was also cited. A leader in Kalariga remarked:

*“Most people here don’t trust insurance companies. They believe the claims process is too complicated and that they may never receive compensation when disaster strikes.”* (Community Leader, Kalariga, FGD, 2023)

These findings correspond with Kousky (2018), who notes that low-income households globally tend to avoid insurance because high premiums, opaque claims processes, and limited

financial literacy reduce demand. The absence of risk-sharing mechanisms similar to the Flood Re scheme in the UK or subsidised national flood insurance programmes found elsewhere exacerbates vulnerability in these communities.

Taken together, the emergency savings and insurance data illustrate substantial financial vulnerability across Kalariga, Koblimahagu, and Nalung. Despite slight advantages in Kalariga, the overall trend reveals major gaps in both immediate and long-term financial preparedness. This severely limits households' ability to absorb flood impacts, engage in rapid recovery, or invest in adaptation strategies. Urban Resilience Theory helps contextualise these findings. As emphasised by Meerow & Stults (2016), resilience requires the capacity to absorb, adapt, and transform in the face of disturbances. Emergency savings represent absorptive capacity, enabling households to manage short-term needs, while insurance strengthens adaptive capacity, allowing households to reorganise and rebuild over time. The near absence of both measures particularly in Koblimahagu and Nalung reveals systemic constraints that hinder resilience. These communities face heightened exposure, slow recovery processes, and increased dependence on external support. Socio-economic inequalities further shape these disparities: households with limited income are significantly less able to engage in financially protective behaviours.

## 6.8 Hypothesis Testing for Objective Three

### 6.8.1 Hypothesis Statement

- **H<sub>03</sub> (Null Hypothesis):**

*There is no significant relationship in the level of adoption of community-based flood*

*adaptation strategies across communities with different socio-economic characteristics.*

- **H<sub>13</sub> (Alternative Hypothesis):**

*There is a significant relationship in the level of adoption of community-based flood adaptation strategies across communities with different socio-economic characteristics.*

### 6.8.2 Data and Variables Used

This hypothesis evaluates differences in adoption of eleven community-based flood adaptation strategies across the three study communities with distinct socio-economic profiles: Kalariga – High-income, Nalung – Medium-income and Koblimahagu – Low-income. The adaptation strategies analysed include: structural support, elevated platforms, barrier construction, drainage system construction, tree planting, storing food higher up, storing provisions during floods, participation in drain clearing, participation in community planning, emergency savings and insurance coverage. Each value represents the percentage of households in a community that adopted the strategy. Socio-economic context was informed by household income categories from the survey data:

Table 6.1 Household income categories

Income Group (C)	% of Sample	Household Count (N)
1–1,000	30.5%	92
1,001–2,000	27.2%	82
2,001–3,000	23.5%	71
3,001–4,000	12.4%	37
> 4,000	6.6%	20

Field Survey, 2023: Household Questionnaire Survey

These income profiles confirm systematically different socio-economic characteristics across the three study communities.

### 6.8.3 Descriptive Summary of Adaptation Adoption

Table 6.2 presents the percentage of households adopting each strategy across the three communities:

Table 6.2 Community-Based Flood Adaptation Strategies by Community (%)

No.	Adaptation Strategy	Kalariga (High)	Koblimahagu (Low)	Nalung (Medium)
1	Structural support	23	15	19
2	Elevated platforms	23	17	13
3	Barrier construction	18	11	19
4	Drainage system construction	14	8	11
5	Tree planting	15	16	8
6	Storing food higher up	23	20	19
7	Storing provisions during floods	15	25	11
8	Drain clearing participation	20	16	12
9	Community planning participation	21	10	5
10	Emergency savings	5	1	0
11	Insurance coverage	6	0	0

Mean adoption rates are Kalariga: 16.36%, Koblimahagu: 12.64% and Nalung: 10.64%. These differences suggest possible variations, but statistical testing is required to determine significance.

### 6.8.4 Inferential Analysis: Kruskal–Wallis H Test

The Kruskal–Wallis H test was used to determine whether adoption levels differ significantly across the three communities. Kruskal–Wallis was used because, the data are community-level percentages, not individual household responses. Also the sample size per group is small ( $n = 11$  strategies per community). Normality and equal variance cannot be assumed and so Kruskal–Wallis is the correct non-parametric alternative to one-way ANOVA for such data.

### 6.8.5 Test Inputs, Kruskal–Wallis Results and Interpretation

Each of the 11 strategy adoption percentages was treated as one observation per community, giving: Kalariga, Koblimahagu and Nalung as  $n = 11$ . This resulted in an H statistic of  $H = 2.03$  and degree of freedom of  $df = 2$  and a p-value of  $p = 0.361$ . Since  $p > 0.05$ , there is no

statistically significant difference in the level of adoption of community-based flood adaptation strategies across the three communities. This means adoption levels are not significantly shaped by whether a community is high-, medium-, or low-income. Although Kalariga showed slightly higher adoption levels, these differences were **not statistically meaningful**.

### 6.8.6 Conclusion for Hypothesis Three

The Kruskal–Wallis test results support the null hypothesis ( $H_{03}$ ):

*There is no significant relationship between community socio-economic characteristics and the level of adoption of community-based flood adaptation strategies.*

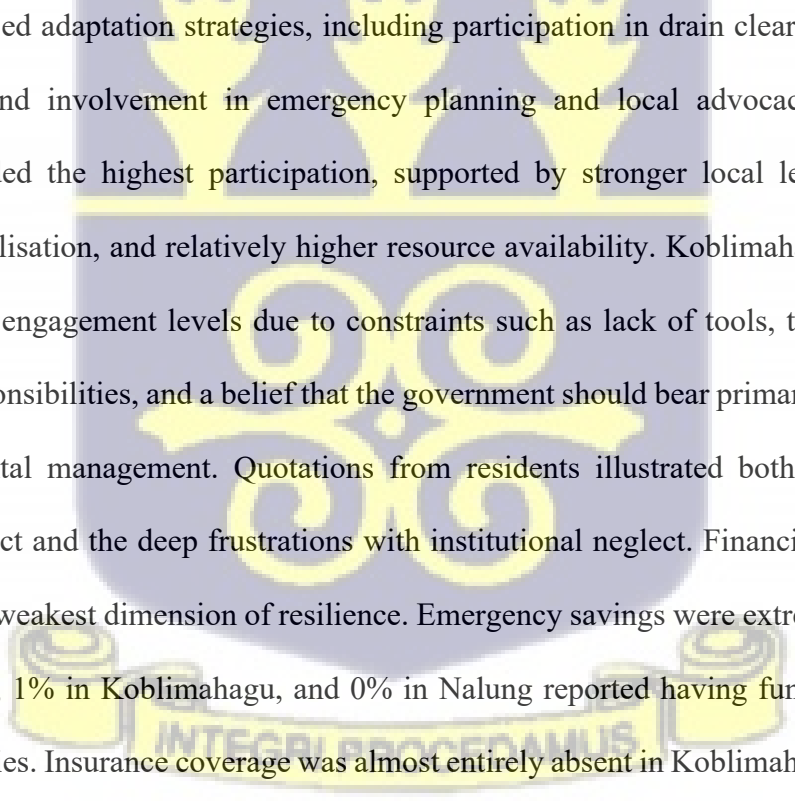
In this regard I fail to reject the Null hypothesis ( $H_{03}$ ).

This finding suggests that adaptation behaviours in Tamale's communities are influenced by factors beyond income, including, hazard exposure, community cohesion, local norms of collective action, the shared experience of recurrent flooding, and limited institutional support across all neighbourhoods. These dynamics are consistent with both Urban Political Ecology (showing shared marginalisation) and Urban Resilience Theory (highlighting everyday adaptation capacities across socioeconomic groups).

## 6.9 Chapter Summary

Chapter 6 presented a comprehensive assessment of household- and community-level flood adaptation strategies across Kalariga, Koblimahagu, and Nalung, illustrating how residents prepare for, respond to, and recover from recurrent flooding. The chapter examined a wide range of adaptation behaviours including structural, behavioural, ecosystem-based, community-driven, and financial measures revealing substantial variability across communities and significant constraints that limit the effectiveness of flood adaptation in

Tamale. Household-level adaptation demonstrated mixed adoption. Strategies such as elevated storage of possessions, storing provisions, and protective household construction practices were more common in Kalariga, where higher income levels and better access to resources facilitated uptake. Koblimahagu showed stronger engagement with some low-cost strategies (such as tree planting and provision storage), often supported by community initiatives or NGO interventions. Nalung consistently presented the lowest adoption across many measures, influenced by its challenging terrain, limited resources, and moderate socio-economic profile. Key barriers including financial constraints, lack of access to materials, low awareness, competing priorities, and scepticism about the usefulness of certain strategies were reported across all communities.

The logo of the University of Ghana is a watermark in the background of the text. It features a shield with three golden flames at the top, a central golden emblem, and a banner at the bottom with the Latin motto "INTEGRITAS PROCEdit".

Community-based adaptation strategies, including participation in drain clearing, solid waste management, and involvement in emergency planning and local advocacy, also varied. Kalariga recorded the highest participation, supported by stronger local leadership, more consistent mobilisation, and relatively higher resource availability. Koblimahagu and Nalung recorded lower engagement levels due to constraints such as lack of tools, time limitations, competing responsibilities, and a belief that the government should bear primary responsibility for environmental management. Quotations from residents illustrated both the communal willingness to act and the deep frustrations with institutional neglect. Financial preparedness emerged as the weakest dimension of resilience. Emergency savings were extremely low: only 5% in Kalariga, 1% in Koblimahagu, and 0% in Nalung reported having funds set aside for flood emergencies. Insurance coverage was almost entirely absent in Koblimahagu and Nalung (0%), and only 2%–6% in Kalariga held any form of coverage. These findings highlight deep

structural vulnerabilities and a lack of risk-transfer mechanisms that could support recovery after major flood events.

The chapter also presented results from the hypothesis test (Objective Three), which assessed whether socio-economic differences across the three communities significantly influence the adoption of community-based flood adaptation strategies. Using the Kruskal–Wallis H test appropriate for small sample sizes and non-normal community-level percentage data the analysis produced  $H = 2.03$ ,  $df = 2$ , and  $p = 0.361$ . Since  $p > 0.05$ , the study failed to reject the null hypothesis ( $H_{03}$ ). This indicates that there is no statistically significant relationship between community socio-economic characteristics and the level of adoption of community-based flood adaptation strategies. Although descriptive averages showed slightly higher adoption in Kalariga (16.36%) compared with Koblimahagu (12.64%) and Nalung (10.64%), these differences were not statistically meaningful. This finding suggests that adaptation patterns across the three communities are shaped not only by income, but also by shared exposure to recurrent flooding, collective norms of community action, local leadership structures, and the common experience of institutional neglect. These results align with Urban Political Ecology, which highlights structural marginalisation and uneven access to state support across urban spaces, and with Urban Resilience Theory, which emphasises everyday adaptive practices that emerge even in contexts of socio-economic constraint. The hypothesis test confirms that while socio-economic differences matter descriptively, they do not singularly determine adaptation behaviour in Tamale.

In summary, Chapter 6 demonstrates that while communities employ diverse adaptation strategies, their overall resilience is undermined by financial vulnerability, limited institutional

support, and barriers to effective collective action. Strengthening resilience will require integrated interventions targeting economic constraints, institutional capacity, community participation, and equitable access to adaptation resources. The findings underscore the need for multi-layered, inclusive, and context-specific adaptation planning to address the growing flood risks faced by Tamale's urban communities.



## CHAPTER 7

### SUMMARY OF KEY FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

#### 7.1 Introduction

This thesis examined the socio-spatial dynamics of flood risk and adaptation in the Tamale Metropolitan Area, combining geospatial analysis, institutional assessment, household surveys, qualitative interviews, and hypothesis testing. Guided by Urban Political Ecology (UPE) and Urban Resilience Theory (URT), the study demonstrated how environmental processes, structural inequalities, and community practices collectively shape the contours of flooding and resilience in the metropolis. The following subsections summarise the major conclusions derived under each objective before offering an integrated synthesis. This chapter presents a synthesis of the key findings in line with the objectives, concludes each, and provides recommendations for policy. It highlights the study's contributions to both theoretical and empirical knowledge and discusses potential directions for future research.

#### 7.2 Summary of Findings by Research Objectives

##### 7.2.1 Objective One: Flood Occurrence and Socio-Spatial Vulnerability

The first objective sought to analyse the distribution, frequency, and drivers of flooding across communities with differing socio-economic characteristics. The findings reveal that although flooding affects the entire metropolis, its impacts are disproportionately borne by low-income communities such as Koblimahagu. GIS analysis showed that these neighbourhoods are characterised by high exposure to low-lying terrain, poor drainage infrastructure, and dense informal settlement patterns. These physical conditions are compounded by inadequate enforcement of land-use regulations and limited investment in stormwater management

systems. Higher-income areas such as Kalariga, while not immune to flooding, experience less severe inundation due to better housing quality, improved drainage connectivity, and access to municipal services. Hypothesis testing under this objective confirmed that the severity of flooding differs significantly across socio-economic contexts. This reinforces the central proposition of Urban Political Ecology: that environmental hazards in cities are not simply “natural” occurrences but are socially produced through uneven development, political processes, and the spatial distribution of infrastructure. The study concludes that socio-spatial inequality is the dominant factor explaining differential flood exposure in Tamale. Flooding emerges as both an ecological and political phenomenon, shaped by the city’s development trajectory and the marginalisation of low-income neighbourhoods.

### **7.2.2 Objective Two: Institutional Adaptation and Support Systems**

The second objective examined the nature, adequacy, and distribution of institutional support for flood adaptation. The findings indicate that while Tamale possesses a formal framework for flood response encompassing NADMO, TaMA, Hydrological Services, and environmental health units their effectiveness is hampered by weak coordination, resource constraints, and overlapping institutional mandates. Residents in higher-income communities reported more consistent and timely institutional engagement, including drain maintenance, emergency communication, and relief distribution. By contrast, households in Koblimahagu and Nalung described delays in response, insufficient relief items, and limited communication from authorities. Interviews with institutional actors revealed structural challenges, including inadequate budgets, limited staffing, and an overreliance on reactive interventions rather than proactive risk reduction. Hypothesis testing under this objective confirmed that differences in institutional support across communities are statistically significant. This demonstrates that

formal adaptation in Tamale is unevenly distributed, reinforcing existing socio-economic inequalities. These findings further validate UPE's assertion that governance structures often perpetuate unequal access to resources, while also supporting URT's emphasis on effective, coordinated institutions as a cornerstone of urban resilience. The study concludes that institutional adaptation in Tamale remains necessary but insufficient, and that without coordinated, equitable, and anticipatory planning, the city will continue to experience avoidable losses.

### 7.2.3 Objective Three: Community-Based Adaptation and Everyday Resilience

The third objective explored the extent and nature of community-based adaptation strategies adopted across the study communities. The findings revealed strong but uneven patterns of household and collective responses, including elevated storage of possessions, barrier construction, community drain clearing, tree planting, emergency planning, and the storage of provisions. While Kalariga exhibited somewhat higher adoption of certain strategies, Koblimahagu and Nalung demonstrated robust communal mobilisation in activities such as drain clearing and waste management. Despite descriptive differences, hypothesis testing for this objective found no statistically significant variation in overall adoption levels across socio-economic groups. This suggests that, regardless of income, all communities face similar constraints: limited institutional support, chronic flood exposure, inadequate drainage, and a reliance on local norms of collective labour. This finding substantiates URT's concept of *everyday resilience*, which highlights how communities generate adaptive capacity through informal practices and social networks in contexts where state support is limited. At the same time, the convergence in adaptation patterns across socio-economic groups reflects UPE's insight that shared experiences of infrastructural neglect can lead to similar risk-reduction

behaviours across neighbourhoods. The study concludes that community-driven adaptation is an essential but insufficient component of flood resilience in Tamale. While residents demonstrate ingenuity and solidarity, these efforts cannot fully compensate for structural and institutional deficits.

### 7.3 Conclusions

Taken together, the results across all objectives reveal an urban environment where vulnerability and resilience are jointly shaped by ecological processes, governance arrangements, and social practices. Objective One showed that low-income communities bear disproportionate exposure to hazardous environments; Objective Two demonstrated that institutional support mirrors socio-economic inequalities; and Objective Three showed that, despite these differences, communities exhibit broadly similar patterns of autonomous adaptation. This combination of unequal exposure, uneven institutional support, and shared community-driven adaptation reveals a hybrid resilience landscape. Urban Political Ecology explains the structural roots of vulnerability and institutional inequality, while Urban Resilience Theory explains the adaptive resourcefulness that communities deploy in response. The thesis ultimately concludes that flooding in Tamale is produced through intertwined ecological, political, and socio-economic processes, and that resilience is shaped not solely by income, but by the interplay of structural constraints and everyday adaptive practices.

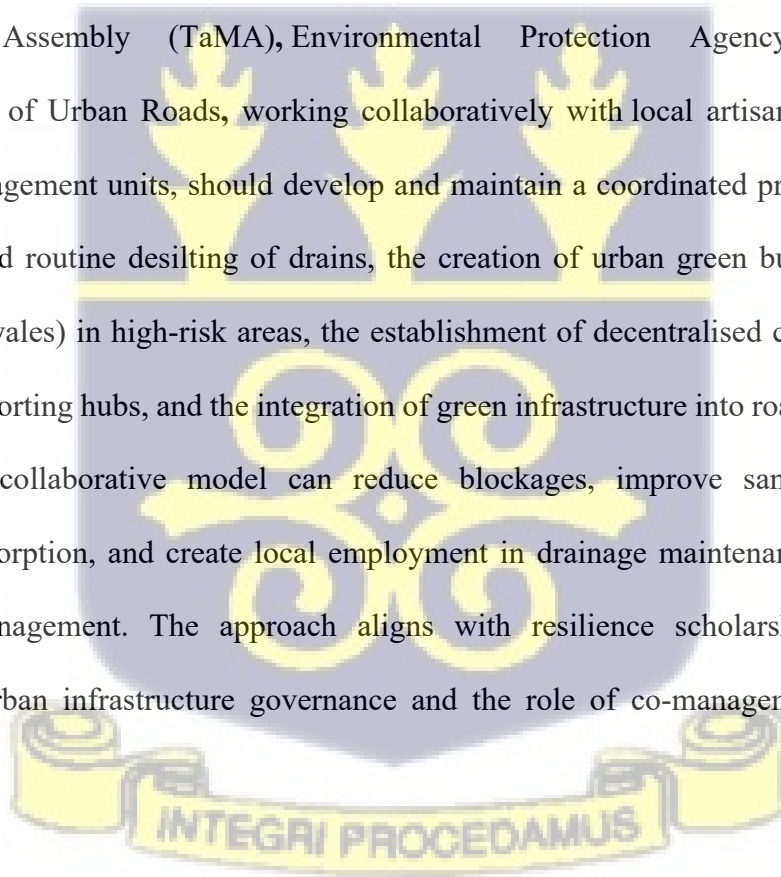
### 7.4 Policy Recommendations

Building on the findings and conclusions of this research, this section presents a set of policy, institutional, and community-level recommendations aimed at strengthening flood resilience in the Tamale Metropolitan Area (TaMA). The recommendations respond directly to the

observed socio-spatial inequalities, the limitations in institutional coordination, and the widespread dependence on community-driven coping strategies. They also reflect the theoretical insights of Urban Political Ecology and Urban Resilience Theory, which emphasise the need for just, inclusive, and anticipatory urban governance.

#### **7.4.1 Strengthening Drainage Systems, Green Infrastructure, and Waste Management**

A central finding of this thesis is that inadequate drainage infrastructure, blocked stormwater channels, and poor waste management significantly exacerbate flooding across the metropolis. To address these structural drivers of vulnerability, the study recommends a co-produced, community–city approach to drainage and environmental management. The Tamale Metropolitan Assembly (TaMA), Environmental Protection Agency (EPA), and the Department of Urban Roads, working collaboratively with local artisans, youth groups, and waste management units, should develop and maintain a coordinated programme for the construction and routine desilting of drains, the creation of urban green buffers (tree belts, wetlands, bioswales) in high-risk areas, the establishment of decentralised community waste collection and sorting hubs, and the integration of green infrastructure into road and settlement designs. This collaborative model can reduce blockages, improve sanitation, enhance stormwater absorption, and create local employment in drainage maintenance, landscaping, and waste management. The approach aligns with resilience scholarship emphasising participatory urban infrastructure governance and the role of co-management in reducing vulnerability.



#### **7.4.2 Improving Institutional Coordination and Data Sharing Through a Flood Information Hub**

Institutional fragmentation emerged as a major constraint on effective flood management in Tamale. To overcome this, the thesis recommends establishing an Open Flood Information Hub (OFIH) led jointly by NADMO, Ghana Meteorological Agency (GMet), and Land Use and Spatial Planning Authority (LUSPA), in collaboration with universities, civil society organisations (CSOs), and local ICT innovators. This digital platform would integrate real-time rainfall and climate forecasts, flood occurrence reports submitted by communities, spatial data on drainage capacity, waste hotspots, and impermeable surfaces, land-use plans and building permit records, and vulnerability indicators from census and survey data. An OFIH would enhance early warning, improve inter-agency coordination, and strengthen public accountability by making flood information accessible to planners, emergency responders, researchers, and community members. Such integrated data systems are widely recognised in resilience literature as essential for anticipatory governance and risk-informed decision-making.

#### **7.4.3 Empowering Women and Youth Groups in Flood Preparedness and Waste Governance**

The study found that community resilience derives largely from informal cooperation, social networks, and local leadership, yet these capacities remain under-supported by formal institutions. Women and youth groups, in particular, are central to household preparedness, waste management, and local advocacy, but are often excluded from formal planning processes. It is therefore recommended that NADMO, TaMA, and the Gender Desk Unit develop a structured programme to train women's associations and youth groups in flood

preparedness and household flood-proofing, involve them in neighbourhood early-warning dissemination, support their leadership in waste segregation and recycling campaigns, and provide them with materials (e.g., tools, safety gear, storage kits) for community clean-ups and adaptation activities. This approach enhances local ownership, builds long-term capacity, and aligns with international resilience frameworks that identify gender-responsive and youth-led initiatives as catalysts for durable risk reduction.

#### **7.4.4 Establishing Flood and Waste Innovation Labs in Partnership with Universities**

Given the limited financial preparedness and scarcity of affordable adaptation technologies identified in this study, there is a critical need for locally appropriate, low-cost innovations. Universities such as the University for Development Studies (UDS), Kwame Nkrumah University of Science and Technology (KNUST), and the University of Ghana, working with TaMA, CSOs, and development partners, should establish Flood and Waste Innovation Labs.

These labs would co-produce technologies such as low-cost drainage sensors, permeable pavement prototypes, flood-resilient building materials, and household water storage solutions, pilot decentralised waste-to-compost and waste-to-energy systems, support spatial data generation for planning (using drones, participatory mapping, and mobile reporting), incubate youth-led enterprises in recycling, ecological sanitation, and climate-smart construction, and translate research into policy guidance for TaMA's planning and engineering departments. Such innovation centres would support continuous learning and evidence-based urban planning, bridging the persistent gap between research institutions and municipal practice.

#### **7.4.5 Enhancing Financial Preparedness Through Micro-Insurance and Emergency Savings Schemes**

The thesis revealed extremely low levels of financial preparedness, with negligible insurance uptake and minimal emergency funds across all communities. To strengthen household resilience, TaMA and NADMO should partner with microfinance institutions, insurance providers, cooperatives, and NGOs to design low-premium micro-insurance packages and community-managed emergency savings schemes tailored for low-income households. Incentive mechanisms such as premium subsidies, group policies, or integration with existing community savings groups (Susu, VSLA) would improve uptake. Global evidence shows that micro-insurance and emergency savings significantly accelerate post-disaster recovery and reduce long-term vulnerability.

#### **7.4.6 Strengthening Land-Use Enforcement and Risk-Sensitive Urban Planning**

Since settlement patterns and weak enforcement were found to play a significant role in flood vulnerability, TaMA and LUSPA must enforce development controls in waterways and floodplains, implement risk-sensitive zoning, expand green corridors along major water bodies, and introduce community monitoring mechanisms to deter encroachment. Strengthening enforcement capacity and aligning planning decisions with hydrological realities are essential steps toward building a safer, more resilient urban environment.

#### **7.4.7 Mainstreaming Community Knowledge and Participation Into Urban Planning**

The study underscores that communities already possess deep experiential knowledge of flood behaviour, drainage blockages, and local vulnerabilities. To leverage this resource, TaMA should institutionalise mechanisms such as community flood committees, participatory hazard

mapping, co-designed neighbourhood adaptation plans, and representation of women and youth groups in local planning boards. These participatory approaches ensure that planning decisions are grounded in local realities and foster co-responsibility between residents and the municipality. Taken together, the recommendations emphasise the need for integrated, multi-scalar, and equity-oriented flood governance in Tamale. Strengthening resilience requires not only infrastructural improvements but also inclusive decision-making, institutional reform, community empowerment, and sustained collaboration between city authorities, civil society, and academic institutions. If implemented, these measures would move Tamale from a model of reactive flood response toward one grounded in anticipatory, participatory, and climate-resilient urban development.

### **7.5 Contributions to Knowledge**

This thesis makes substantive contributions to empirical understanding, theoretical development, methodological advancement, and policy practice within the study of urban flooding and climate adaptation in rapidly growing African cities. Empirically, the research provides new insights into how income inequalities, climatic pressures, and human-driven processes jointly shape the distribution of flood exposure across TaMA. The study shows that vulnerability is unevenly spatialised, with high-, medium-, and low-income communities experiencing flood risk through different pathways, including variations in housing quality, settlement morphology, access to infrastructure, and proximity to flood-prone terrain. This fine-grained analysis advances knowledge beyond generic accounts of urban flooding in Ghana by demonstrating that risk is neither uniform nor random, but socially produced through historical, environmental, and institutional dynamics.

Theoretically, the thesis advances and operationalises Urban Political Ecology (UPE) and Urban Resilience Theory in ways that reveal the interconnections between power, inequality, and adaptive capacity in Tamale's flood governance landscape. The research shows how uneven urban development, weak institutional coordination, and socio-political marginalisation shape both exposure to hazard and the capacity to respond. By integrating UPE with resilience thinking, the study demonstrates that resilience is not simply a matter of household actions, but is conditioned by broader political-economic structures, including resource allocation, governance failures, and planning inequalities. This dual-theoretical framing enriches existing literature by showing that adaptive capacity in African cities is both constrained and produced by structural conditions, while also shaped by local knowledge and everyday practices.

Methodologically, the study contributes a robust mixed-methods framework that combines GIS-based flood mapping, quantitative household surveys, and qualitative interviews with community leaders, residents, and institutional stakeholders. This integrated approach shows how spatial data can be layered with social vulnerability indicators to produce a more comprehensive understanding of flood risk. The study thus presents a replicable methodological model for other secondary cities in the Global South, where data scarcity and urban informality pose challenges for conventional risk assessment. The use of hypothesis testing, particularly the Kruskal–Wallis analysis, further demonstrates how non-parametric statistical approaches can be employed to interrogate adaptation behaviour across socio-economic contexts.

In terms of policy, the thesis contributes evidence directly relevant to strengthening equitable flood governance in TaMA. The findings illustrate how local ecological knowledge,

community experience, and spatial mapping can be integrated to design more inclusive resilience strategies. By highlighting institutional coordination gaps, the research underscores the need for improved early warning, land-use enforcement, and community engagement mechanisms. These insights support the development of policies aligned with Sustainable Development Goal 11 (Sustainable Cities) and SDG 13 (Climate Action), providing a foundation for more socially just and climate-responsive urban planning. Collectively, these contributions show that urban flood risk in TaMA is shaped by the interplay of environmental exposure, socio-economic inequality, institutional governance, and community adaptation practices. The thesis offers a comprehensive framework for understanding and addressing these dynamics, providing new knowledge that is valuable for scholars, planners, and policy-makers concerned with resilience in rapidly urbanising African cities.

## **7.6 Suggestions for Future Research**

While the thesis provides substantial insights into urban flood risk and adaptation, it also highlights important areas for future research. First, longitudinal studies could examine how adaptation practices evolve over time as climate impacts intensify and urbanisation accelerates. Such research would reveal whether households shift from reactive coping to preventive strategies, and how institutional reforms influence behavioural change. Second, future studies could undertake deeper comparative analysis between Tamale and other secondary cities in Ghana such as Wa, Bolgatanga, or Techiman to explore regional differences in governance, exposure, and adaptation capacity. Comparative work would help identify which challenges are context-specific and which reflect broader national patterns of urban vulnerability. Third, there is a need for more detailed hydrological modelling to complement the social and spatial analyses presented in this thesis. Integrating predictive flood modelling with socio-economic

vulnerability indices could improve scenario planning, early warning systems, and climate-resilient infrastructure design. Fourth, further research should examine gendered and generational dimensions of adaptation, particularly the roles of women, youth, informal workers, and migrants. These groups often carry disproportionate burdens but remain underrepresented in formal planning and disaster governance. Fifth, future studies could evaluate the effectiveness of co-produced adaptation interventions such as green infrastructure, community waste innovations, or drainage redesign through participatory action research. Partnering with local authorities, universities, and community groups in pilot projects would generate practical evidence on what works, for whom, and under what conditions. Finally, research on financial mechanisms for resilience such as microinsurance, community savings groups, or climate adaptation funds could help identify scalable strategies for reducing financial vulnerability in low-income urban communities. Collectively, these research directions would deepen understanding of urban flood resilience and support the development of more equitable and context-sensitive adaptation pathways for cities like Tamale.



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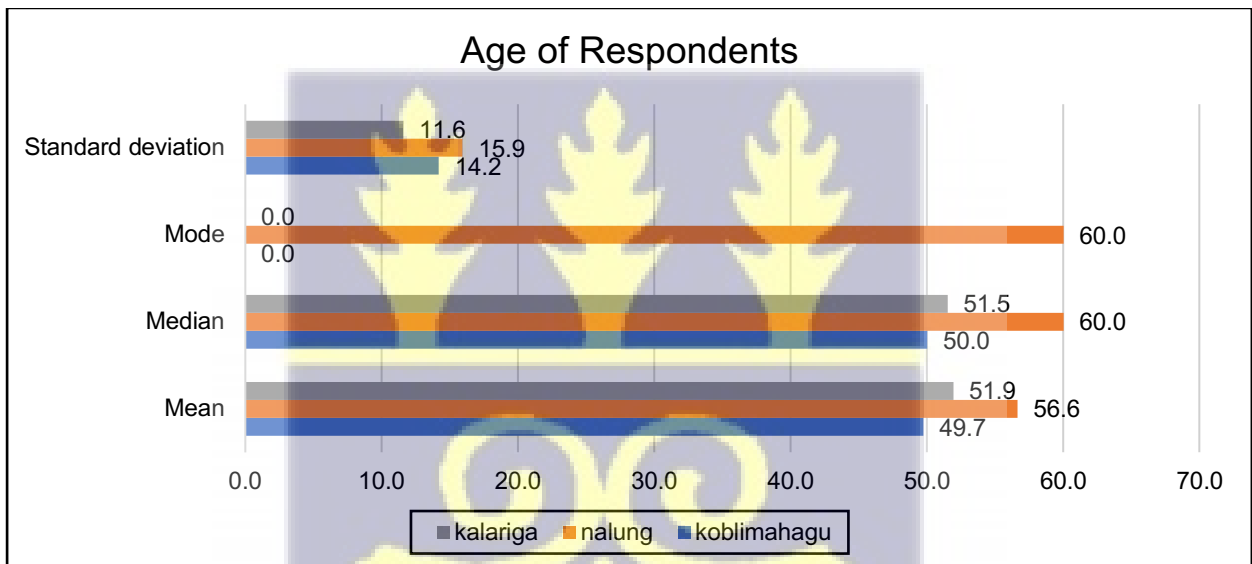
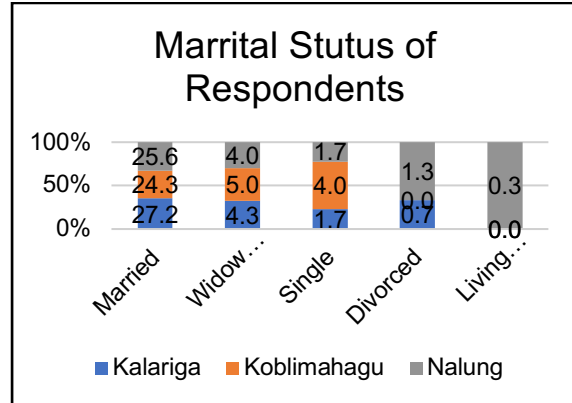
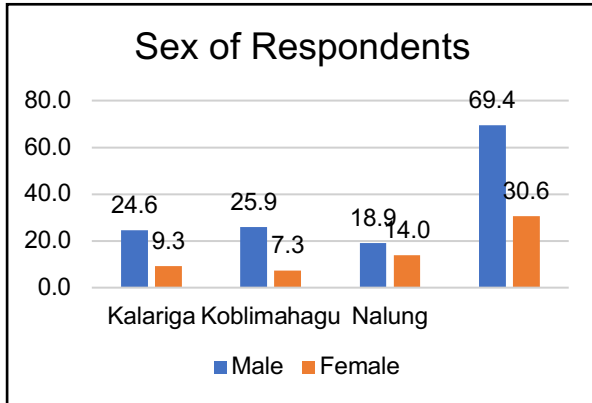
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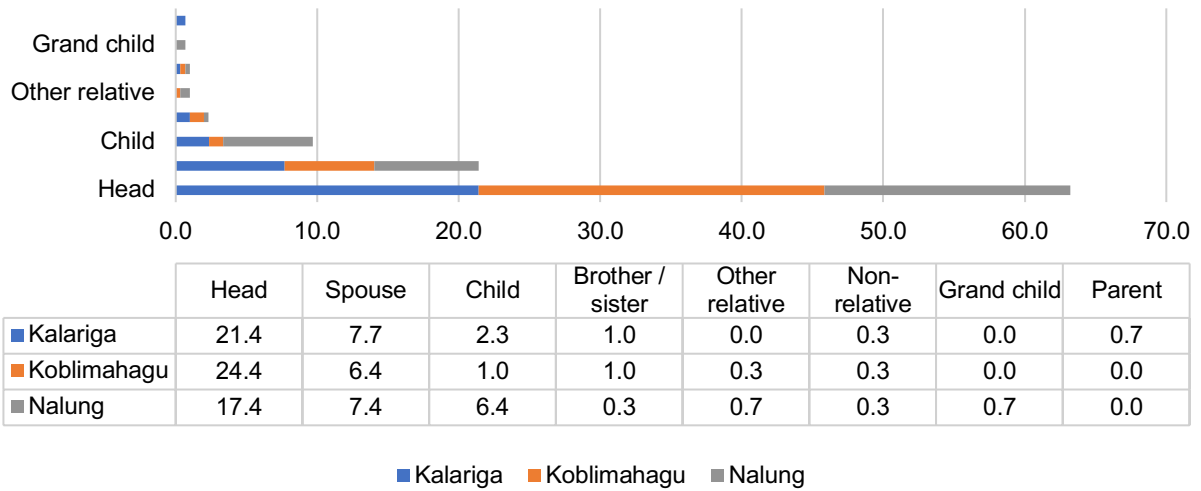


APPENDICES

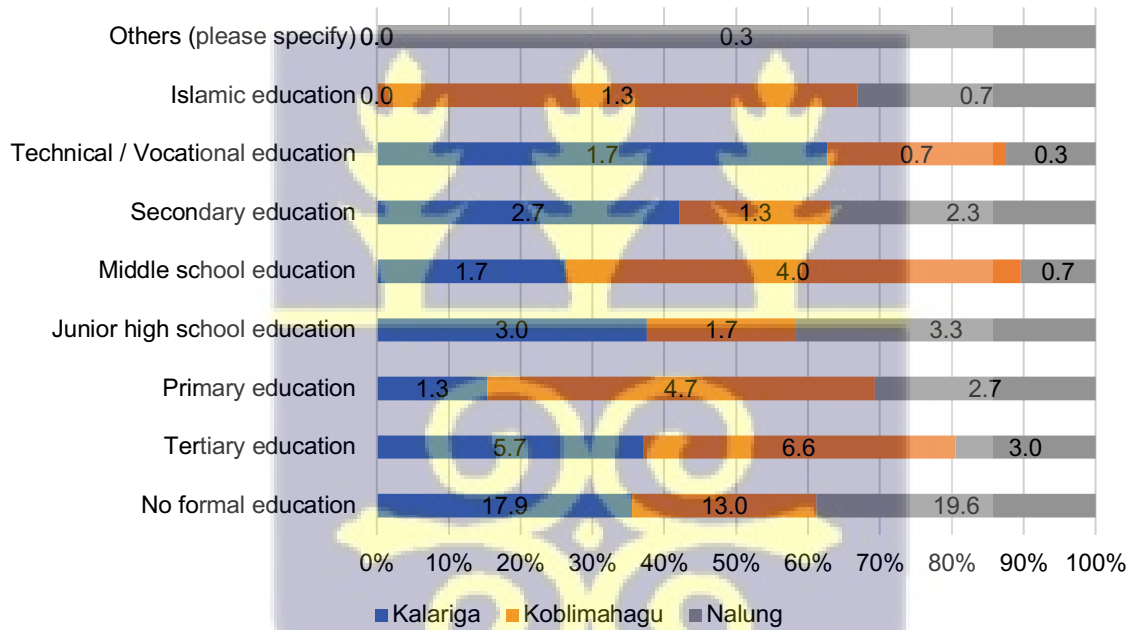
APPENDIX A: Socio-demographic characteristics of household residents sampled for three communities

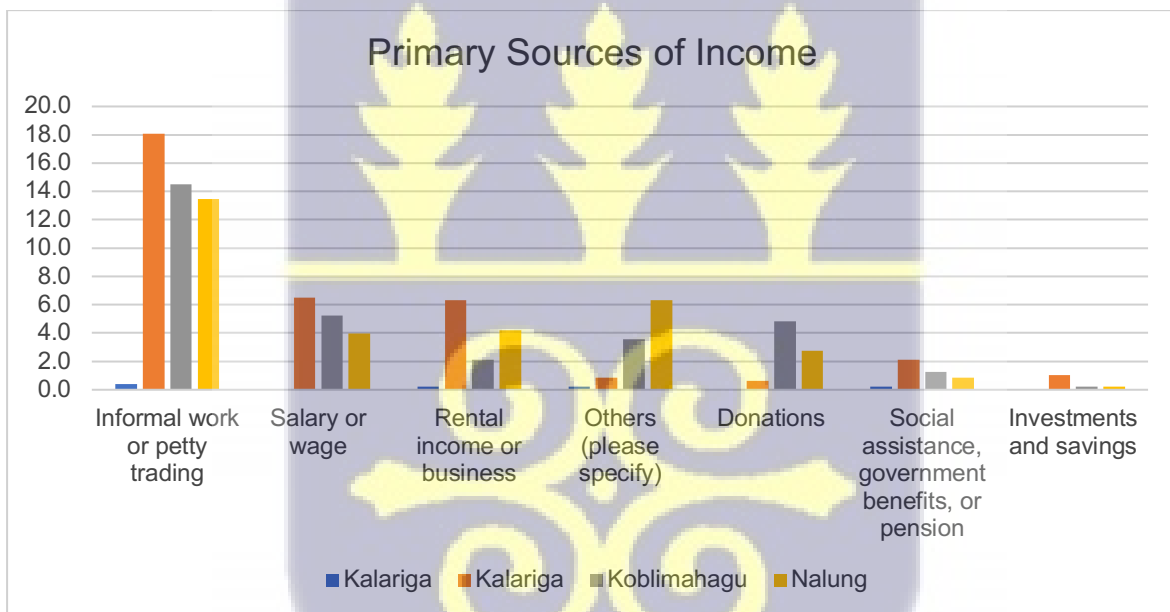
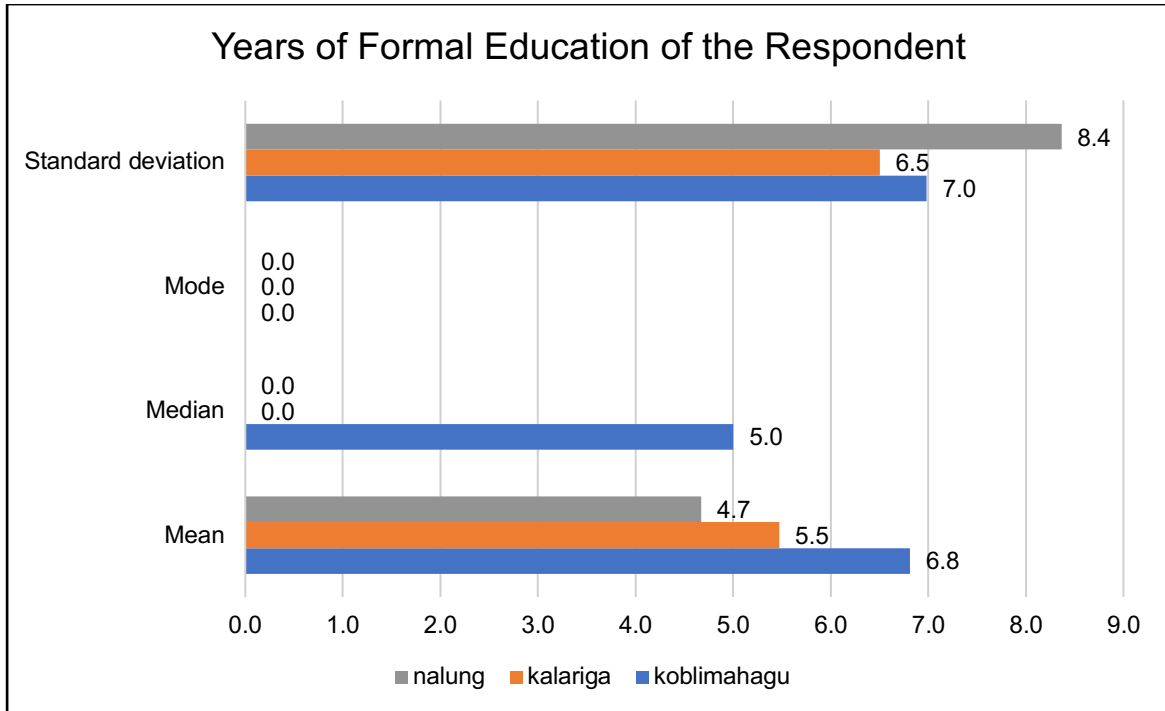


### Relationship of Respondent to Household Head



### Highest Level of Education





## APPENDIX B: Historical Events of Flooding

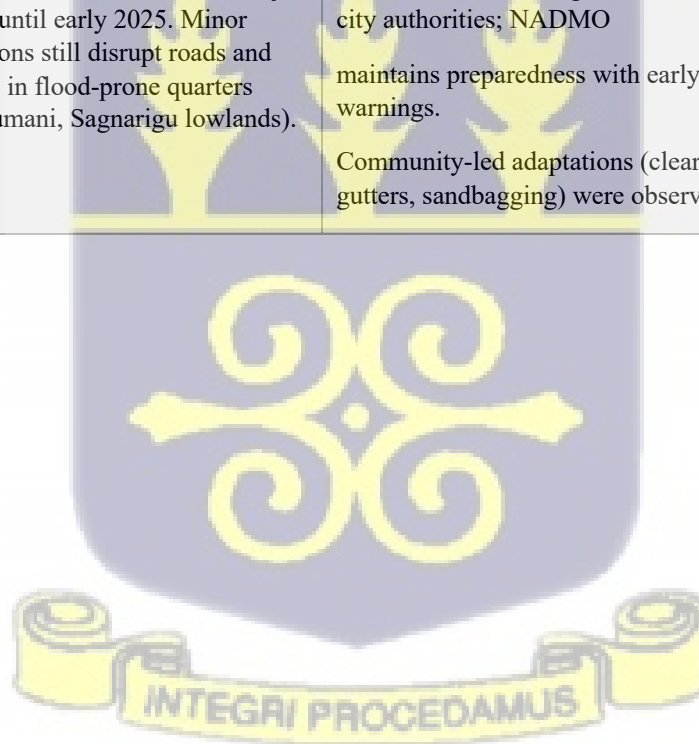
Year of Event	Lives Lost	Causes of Flooding	Impacts/Destruction	Response Efforts	Affected Communities	Source (Year)
1999	13 (direct floods); 43 (cholera outbreak)	Exceptional torrential rains (Aug– Sep) across Northern Ghana; river overflows (White Volta)	144,000 displaced in northern Ghana (120,000 in the Northern Region). 13,000 Houses collapsed. 68,000 acres of farmland swamped; cholera outbreak caused 43 deaths	NADMO and UN agencies delivered emergency relief (medical aid, food), recommended resettlement of farmers from floodplains and rebuilding of damaged dams, roads	Widespread across the Northern Region (including Tamale and surrounding districts)	IRIN News (1999)
2004	None reported (tens of thousands displaced)	Intense early rainy-season downpour (June)	“Tens of thousands” of people displaced in and around Tamale; extensive property damage (homes inundated)	NADMO led relief operations (with military support); drew lessons for future disaster response coordination	Tamale and environs (peri-urban communities)	Jámhá Journal (2013)
2007	20+ (region-wide)	Prolonged heavy rainfall (Aug–Sep) exacerbated by Bagre Dam spillage from Burkina Faso	Significant flooding disaster affecting all three Northern Regions. ~275,000 people affected (317,000 displaced) ~25,000 houses destroyed; massive losses of crops and livestock	National disaster declaration: Government and international partners (UN, Red Cross) provided ~\$25 million in relief, extensive post-flood recovery projects	Northern Region (Tamale metropolis and rural areas), Upper East & Upper West Regions	Citi News (2014) Disaster Research (2014)
2009	8+ (region-wide)	Exceptionally heavy seasonal rains (June–Sep)	~121,000 people displaced 5,104 houses and 13 schools were destroyed. ~30,000 acres of farmlands ruined. localised flash floods around Tamale and the White Volta basin	NADMO coordinated relief with support from WFP and NGOs; food aid was delivered to 10,500 affected in the Northern Region; post-disaster assessments for Adaptation	Northern Region (Tamale Metro and floodplain areas like Nawuni/Buipe)	Research Gate (Kunateh, 2009); GNA/ Modern Ghana (2012)
2011	0	Continuous torrential rains (over a week in	“Hundreds” were displaced as homes, shops, and kiosks were submerged	Community self-rescue and appeals to authorities; fear of the Bulpeila dam	Gumani, Lamashigu (Lamankara), Sangani,	Daily Guide (2011)

		Aug) and choked drains	Some buildings collapsed, major roads flooded, and the city came to a standstill	overtopping prompted local warnings, and limited formal relief was reported	Zogbeli, Kukuo (urban Tamale)	
2012	2	Heavy rains (late Aug) combined with Bagre Dam spillage (Sep)	~1,820 people displaced in Tamale (761 houses, 5,338 rooms affected) 5 schools flooded; farmlands submerged (Northern Region)	NADMO and the Regional Coordinating Council conducted a joint assessment; WFP provided 151 MT of food aid for 10,500 flood victims  victims; local NADMO blamed poor drainage (Bilpeila) for flooding	Low-lying parts of Tamale (e.g. Bilpeila/ Bulpiela) and farming communities along rivers	GhanaWeb (2013) GNA/  ModernGhana (Oct 2012)
2013	0	Narrow gutters, authorities' inaction	Homelessness, frustration with authorities	No specific response recorded	Nyashegu	MyJoyOnline, 2013
2014	0	Severe rainstorm (29 April)	Hundreds were displaced as houses had their roofs ripped; the official residences of the Regional Minister were damaged	NADMO Teams immediately assessed needs; NADMO HQ mobilised relief items and the Interior Ministry	Gumbihini, Kukuo, Nyohini, Jakarayili, Kpanvo/ Kpanbegu, Sagnarigu	Citi News (2014)
2015	0	Unfinished road project, lack of drainage	Devastating floods, particularly in Bilpela and Kalariga	Urgent appeals for government intervention and road completion	Bilpela, Kalariga	MyJoyOnline, 2015
2016	1	7-hour downpour (24 July, overnight)	1 woman drowned at Kulnyevila "Hundreds" were displaced as several communities flooded, many homes were submerged, livestock and valuables were washed away	NADMO carried out rescue and damage assessment  25 ; local NADMO  lacked relief supplies and sought support from Accra 26	Bilpela (Belpela), Sawaba, Datoyili, Gumani, Sagnarigu, Kalariga, Kulnyevila	Citi News (2016)

2017	4	Intense thunderstorm 1–2 hour cloudburst (25 July)	4 killed (incl. a 54-year-old teacher swept away in her car, and two schoolchildren). Severe urban flash floods: dozens of homes inundated, roads turned into rivers.  Hundreds were displaced or marooned.	Major emergency response: NR Minister & NADMO/  Fire service teams aided victims. The Vice President toured sites, pledged to address “perennial flooding,” including funding a storm drain along Bolgatanga Road and urged the public to move from low areas.	Sakasaka, Gumani (Rice City), Gumbihini, Kalariga, Kanvilli-Tunayili, Gurugu, Fuo, Shishegu, Bilpela	GNA/  Modern Ghana (2017)  36 ; Graphic  Online (2017)
2018	0	Short intense rainfall (5 July, ~1.5 hrs. midday)	Dozens of homes and shops flooded (incl. fuel stations), major traffic jams on the Tamale–Nyankpala highway as roads were submerged, leaving residents temporarily homeless.	NADMO on alert; officials assured situation “under control”; no evacuations needed beyond clearing flooded roads	Shishegu and environs; Gumani; along Tamale–Nyankpala road (Nyankpala area)	GNA/  Modern Ghana (2018)
2019	0	Torrential rainstorm (8 Oct, lasted several hours)	“Over hundreds” of residents displaced in Tamale & Sagnerigu 8 communities flooded; personal property (electronics, livestock, food stocks) destroyed	NADMO assessed damage (locals accused of an unfinished drainage project causing water diversion), community appeals to municipal authorities and the MP for flood control measures	Gumani, Kalariga, Nyanshegu, Fuo, Taha, Kalpohini, Kulnyevila; Karaga (persistently hit)	Modern Ghana (2019)
2020	0	Sudden heavy downpour (4 Oct afternoon)	1,355 people displaced (522 households) Numerous homes inundated (Waist-deep water); 2 people nearly swept away (Rescued by NADMO)	NADMO conducted Rescue operations. Local NADMO blamed small drains and refuse dumping for flooding; Public education on flood precautions initiated, relief item request sent to national office	Gumbihini, Kalariga, Sawaba and other low-lying suburbs	Diamond FM (2020)
2021	0	Multi-hour downpour (30 Aug, ~3 hrs) after drought break	Widespread urban flooding: “almost every household” inundated in some areas. A fuel station at Vittin was submerged to chest-level water;	Local residents attributed floods to a lack of proper drains and ongoing Tamale Interchange construction diverting water. They appealed for	Gumani, Fuo, Vittin, Kalariga (Tamale); parts of Sagnerigu municipality	Citi News (2021)  GNA

			hundreds of homes flooded, and residents evacuated their belongings.	bigger culverts and bridges, and the police and fire service intervened to block dangerous roads, preventing casualties.		(2021)
2022	0	Intense overnight rain (12 Aug, ~6 hrs)	Severe flooding in Tamale and Sagnarigu: “hundreds of households” displaced; many roads submerged – cars, tricycles swept away; significant property damage (homes and shops)	Multi-agency response: Ghana Police and Fire Service evacuated motorists to avert entrapment; NADMO Teams conducted damage assessments and provided relief to affected families; no casualties reported due to timely warnings.	Gumani (Rice City), Kanvilli- Tuunayili, Jisonayili, Kunyevila, Nyohini (hardest-hit urban neighbourhoods)	Daily Graphic (2022)
2023-2025	0	Seasonal heavy rains (no singular catastrophic event)	Localised flooding continues during peak rains, but Tamale saw no major disaster until early 2025. Minor inundations still disrupt roads and property in flood-prone quarters (e.g., Gumani, Sagnarigu lowlands).	Ongoing flood Adaptation efforts (new storm drains, de-silting of culverts) by city authorities; NADMO maintains preparedness with early warnings.  Community-led adaptations (clearing gutters, sandbagging) were observed.	Isolated low-lying communities (known flood hotspots in the Tamale metropolis)	(NADMO Situation Reports, 2023–2024)

Source: Online Media, 2023



**APPENDIX C: Key Informant Interviewees**

**EXPERT STAKEHOLDER INTERVIEW/FOCUS GROUP DISCUSSION**

**TEMPLATE**

**SPATIAL PATTERNS OF FLOOD OCCURRENCE, MANAGEMENT AND  
ADAPTATION IN THE TAMALE METROPOLITAN AREA**

1 Preamble

The objective of this study is to understand the opportunities available to communities in Tamale to adapt to live with water hazards like floods and water pollution. It also seeks to assess stakeholders understanding of how flood occurrence and vulnerability within their environment are spatially and temporarily manifested and how these manifestations affect them considering their various socioeconomic groups within the flood-prone areas in which they live. It also ascertains how the effect of flooding may create worsened or properly managed health impacts based on their socioeconomic status. The information gathered will be purely used for academic purposes and treated with strict confidentiality. Your genuine response is very much needed for the success of this exercise.

The study uses a mixed cum participatory research methodology, which involves researchers capturing data using household surveys and expert stakeholder interviews alongside working with members of the community to co-develop knowledge that is useful to that community. In this interview, we are using semi-structured interviews which are designed to cover themes that we think are important but that also allow you, the participant, to lead the discussion. This Key informant interview seeks to gather data to cover the two areas highlighted above. As a result, the questions are coined such that it would accommodate both topics thereby reducing the burden on interviewees to respond to multiple interviews.

2 Pre-interview

- Introduction and clarification of each other's job roles and research interests in adaptation to climate hazards and flooding.
- Share the information sheet and ensure it is read carefully.
- Ask participants to sign the consent form and explain that the information will be kept confidential within the project, but they can withdraw at any time.
- Ensure a copy of the signed consent form has been received.
- Ask for consent to record. If permission is not given, ask for permission to take notes.

### 3 Interview Guide

#### 3.1 General questions

- i. Which organisation do you represent?
- ii. What is your role in the organisation?
- iii. What are the key objectives of your organisation?
- iv. What role does your organisation play in managing water/flood risks in Tamale?

#### 3.2 Inequality in Tamale

- i. Is Tamale a city with high inequality?
- ii. How is inequality distributed in the city?
- iii. Do you consider inequality in your work?
- iv. How do you think inequality affects the capacity of communities to live with and adapt to climate and flooding?

#### 3.3 Awareness of risk

- i. How frequently does Tamale flood and how long does it last?
- ii. Are the dynamics of flooding changing in Tamale and if so, how?
- iii. Which areas are the most affected by floods and why is it so?
- iv. What are the drivers of flooding in Tamale?
- v. How well do people in Tamale understand climate change and flooding?

- vi. What tools and information do you use to enhance your understanding of flooding in Tamale?
- vii. What tools and information do communities use to enhance their understanding of flooding in Tamale?
- viii. Do you communicate with communities about water risks and if so, who with and how often?

#### 3.4 Perception of risk

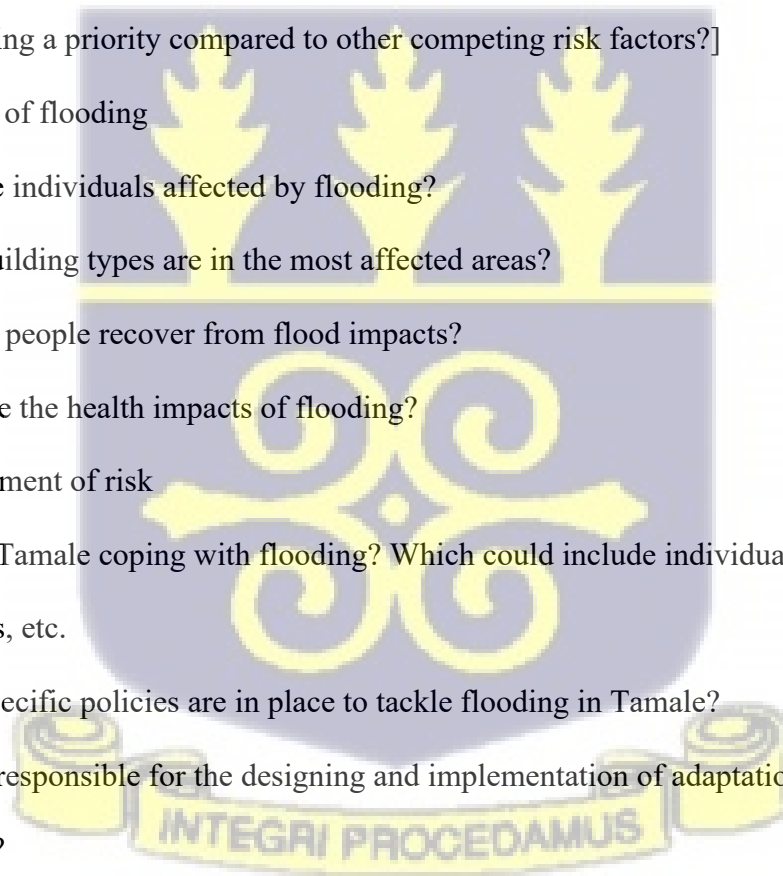
- i. How good is the information you have about flooding, i.e., do you trust it?
- ii. How could this information and other tools be more useful?
- iii. How do you use this information to make decisions at work?
- iv. Is flooding a priority compared to other competing risk factors?]

#### 3.5 Impacts of flooding

- i. How are individuals affected by flooding?
- ii. What building types are in the most affected areas?
- iii. How do people recover from flood impacts?
- iv. What are the health impacts of flooding?

#### 3.6 Management of risk

- i. How is Tamale coping with flooding? Which could include individuals, communities, agencies, etc.
- ii. What specific policies are in place to tackle flooding in Tamale?
- iii. Who is responsible for the designing and implementation of adaptation strategies in Tamale?
- iv. Are certain areas given priority when addressing floods and which areas are they and if so, why?



- v. Do adaptation strategies planned and implemented by organisations involve community engagement?
  - vi. Tell me about the challenges faced in adapting to flooding.
  - vii. What is needed to accelerate adaptation to water risks?
- 3.7 Snowballing
- i. Who/what agency do you suggest I interview about climate change adaptation and flooding in Tamale? Why is the person/agency the best fit?



**APPENDIX D: Questionnaire for Household Survey**

## **Socio-Spatial Patterns of Flood Occurrence and adaptation in the Tamale Metropolitan Area (TaMA), Ghana**

This is a survey questionnaire for data collection. Data will be used for high-level research and policy decision making so make sure you obtain the most accurate information as much as possible. Providing false or non-existing information can be retrieved. Therefore, be truthful in your interviews, OK

OK

Geographical Inequalities in flood occurrence and vulnerability in the Tamale Metropolitan Area (TaMA), Ghana  
Phd Research at the Department of Geography and Resource Development, University of Ghana, Legon

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PhD Student: Cynthia Azochiman Awuni

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### Survey Participation Consent Statement

The consent language for verbal consent should be read before conducting the survey. Please select the appropriate answers (Yes or No) where applicable and thank the respondent for agreeing to participate. My name is..... and I'm collecting data on behalf of Cynthia Azochiman Awuni a Ph.D. Student at the Department of Geography and Resource Development, University of Ghana, Legon. This questionnaire is being administered to assess a household's understanding of how flood occurrence and vulnerability within their environment are spatially manifested and how these manifestations affect them considering their various socioeconomic groups within the flood-prone areas that they live. It is also to ascertain how the effect of flooding may create worsened or properly managed flood adaptation based on their socioeconomic status. The information gathered will be used for academic purposes and treated strictly confidential. Your genuine response is very much needed for the success of this exercise.

---

### Verbal Consent Given

Proceed with the rest of the questions if the respondent say "yes". Otherwise thank him or her and proceed to the next

- household Yes  
 No

### Please upload the signed consent form here

Click here to upload file. (< 10MB)

### Name of enumerator

Please write your full name here

---

### Name of community

Write the name of the community here

- Nalung
- Kalariga
- Koblimahagu

**Household GPS coordinates**

Tap to record the GPS coordinates

latitude (x.y °)

\_\_\_\_\_

longitude (x.y °)

\_\_\_\_\_

altitude (m)

\_\_\_\_\_

accuracy (m)

\_\_\_\_\_



**Socio-Demographic Characteristics of Respondent**

\_\_\_\_\_

**1. What is the sex of the household head?**

Tick (✓) only one that apply

- Male
- Female
- Non-binary/others

**If others, please specify**

\_\_\_\_\_

**2. What is the age of the household head?**

Years of the respondent from birth to the time of interview

\_\_\_\_\_

**3. What is the marital status of the household head?**

Tick (✓) only one that apply

- Single
- Married
- Divorced
- Living together
- Widowed
- Others (please specify)

If other, please ask for the household head's current marital status

**4. What is the highest level of education of the household head?**

Tick (✓) only one that apply

- No formal education
- Primary education
- Middle school education
- Junior high school education
- Secondary education
- Technical / Vocational education
- Tertiary education
- Islamic education
- Others (please specify)

If other, please ask for the highest education of the household head

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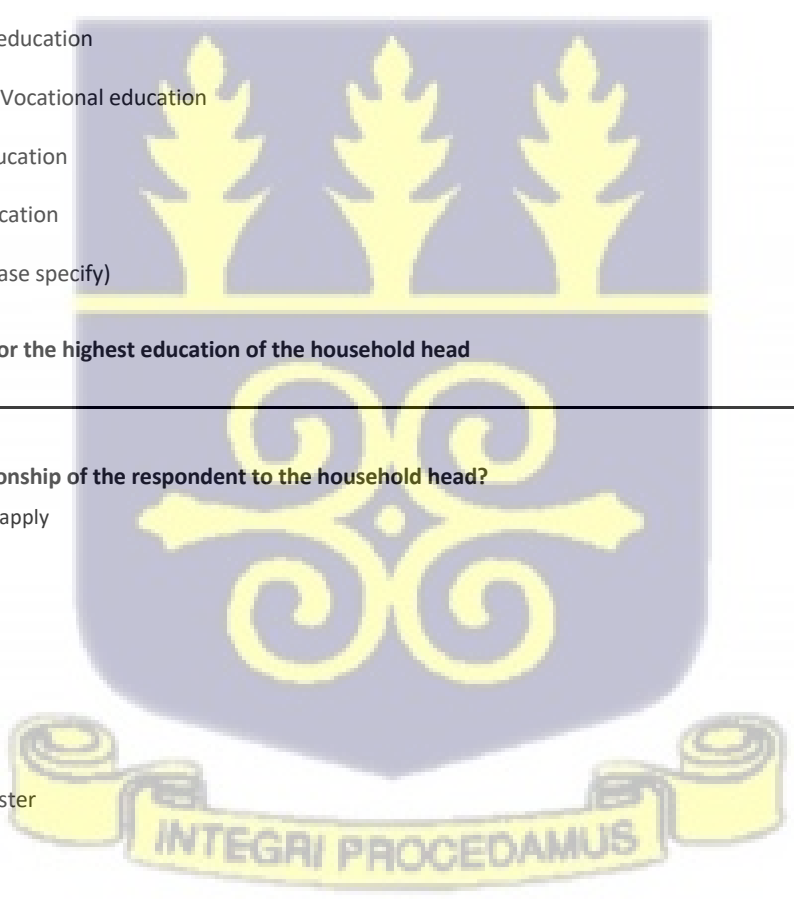
**5. What is the relationship of the respondent to the household head?**

Tick (✓) only one that apply

- Head
- Spouse
- Child
- Grand child
- Brother / sister
- Parent
- Other relative
- Non-relative

**6. Years of formal education of the household head**

Write zero if the respondent has no formal education



**7. What is the average monthly income of your household (all income combined)?**

Tick (✓) only one that apply

- Less than ₵1,000
- ₵1,000 - ₵2,000
- ₵2,000 - ₵3,000
- ₵3,000 - ₵4,000
- More than ₵4,000

**8. Household Expenditure Questions**

---

**How much do you spend on food in a regular month? GH₵**

Estimate the value of own produce for consumption and add it to the money they spend to buy

---

**How much do you spend on education (e.g., school fees, uniform, stationaries, etc) in a regular term? GH₵**

Write zero if the household does not spend any amount on this

---

**How often do you spend on education (e.g., school fees, uniform, stationaries, etc) in a regular term?**

Tick (✓) only one that apply

- Once
- Twice
- Thrice
- More than thrice

**How much do you spend on service bills (e.g., Electricity, Water, Telephone, etc.) in a regular month? GH₵**

Write zero if the household does not spend any amount on this

---

**How often do you spend on service bills (e.g., Electricity, Water, Telephone, etc.) in a regular month?**

Tick (✓) only one that apply

- Once
- Twice
- Thrice
- More than thrice



**How much do you spend on medical or health care in a regular month? GH¢**

Write zero if the household does not spend any amount on this

---

**How often do you spend on medical or health care in a regular month? Tick (✓) only one that apply**

- Once
- Twice
- Thrice
- More than thrice

**How much do you spend on transport? GH¢**

Write zero if the household does not spend any amount on this

---

**How often do you spend on transport in a regular month?**

Tick (✓) only one that apply

- Once
- Twice
- Thrice
- More than thrice

**How much do you spend on toiletries (soap, washing powder, etc)? GH¢**

Write zero if the household does not spend any amount on this

---

**How often do you spend on toiletries (soap, washing powder, etc) in a regular month? Tick (✓) only one that apply**

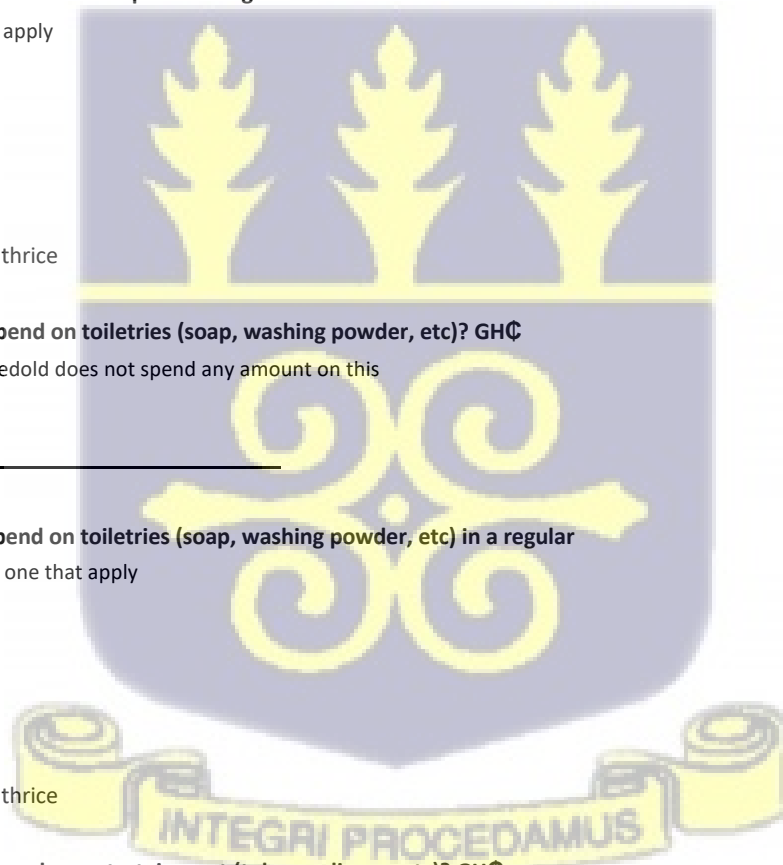
- Once
- Twice
- Thrice
- More than thrice

**How much do you spend on entertainment (tobacco, liquor, etc)? GH¢**

Write zero if the household does not spend any amount on this

---

**How often do you spend on entertainment (tobacco, liquor, etc) in a regular month? Tick (✓) only one that apply**



- Once
- Twice
- Thrice
- More than thrice

**How much do you spend on home (furniture, maintenance, etc)? GH¢**

Write zero if the household does not spend any amount on this

\_\_\_\_\_

**How often do you spend on home (furniture, maintenance, etc) in a regular month? Tick (✓) only one that apply**

- Once
- Twice
- Thrice
- More than thrice

**How much do you spend on house rent? GH¢**

Write zero if the household does not spend any amount on this

\_\_\_\_\_

**How often do you spend on house rent in a regular month?**

Tick (✓) only one that apply

- Once
- Twice
- Thrice
- More than thrice

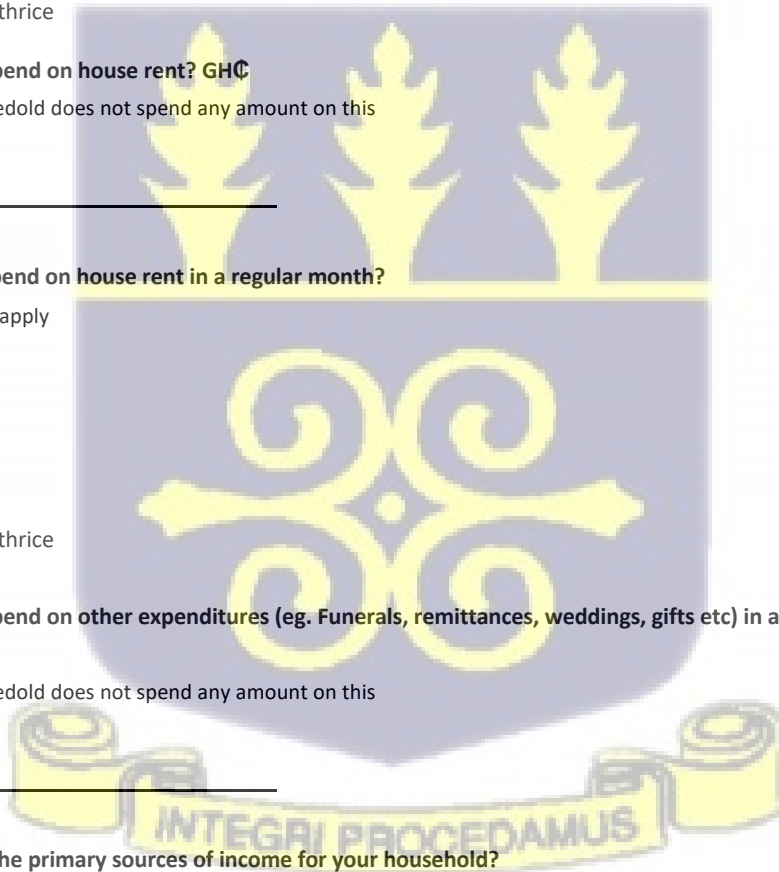
**How much do you spend on other expenditures (eg. Funerals, remittances, weddings, gifts etc) in a regular month? GH¢**

Write zero if the household does not spend any amount on this

\_\_\_\_\_

**9. What are the primary sources of income for your household?**

Tick (✓) all that apply



- Salary or wage
- Investments and savings
- Rental income or business
- Social assistance, government benefits, or pension
- Informal work or petty trading
- Donations
- Others (please specify)

If other, please state the other primary sources of income for the household

---

**10. Do you have savings?**

Tick (✓) only one that apply

- Yes
- No

**11. How many people in your household contribute economically (e.g. are employed)?**

**12. Which of the following economic activities do you and the other contributors engage in?**

Tick (✓) all that apply

- Agriculture (including fishing)
- Government work
- Business
- Artisanal, manufacturing, and construction (masonry, carpentry, tailoring, hairdressing, mechanics, etc.)
- Informal labour
- Petty trading
- Others (please specify)

If other, please state the other activities you engage in

---

**13. Indicate which of the above economic activities you and the other contributors were still involved in Five years ago for your sources of income.**

Tick (✓) all that apply

- Agriculture (including fishing)
- Government work
- Business
- Artisanal, manufacturing, and construction (masonry, carpentry, tailoring, hairdressing, mechanics, etc.)
- Informal labour
- Petty trading
- Others (please specify)

If other, please specify the economic activities you and the other contributors were still involved in Five years ago for your sources of income.

---

**14. How are these activities (i.e. from question 9) affected by flooding (where 1 is not impacted at all and 5 is severely impacted)?**

Tick (✓) only one that apply

- Not impacted at all
- Somehow impacted
- Impacted
- Moderately impacted
- Severely impacted
- I don't know

**15. How long have you lived in this community?**

Ask for the number of years the household has stay in the community

---

Housing

---

**16. How long has your household been residing in the current location? i.e. how long have they lived in this exact spot. If they have moved house but stayed in the same community, then record the date they moved.**

Tick (✓) only one that apply

- Less than 1 year
- 1 - 5 years
- 6 - 10 years
- More than 10 years

**17. Residential status**

Tick (✓) only one that apply

- Family house
- Own house
- Rent - paid
- Rent-free
- Perching (paying)
- Squatting
- Others (please specify)

If other, please state your own residential status

---

**18. Type of dwelling unit occupied by the household.**

Tick (✓) only one that apply

- Flat / Apartment
- Detached house
- Semi-detached
- Compound house
- Single room
- Uncompleted building
- Kiosk / Container (improvised home)
- Others (please specify)

If other, please state your own dwelling unit

---

**19. Approximately when was this house constructed?**

Tick (✓) only one that apply

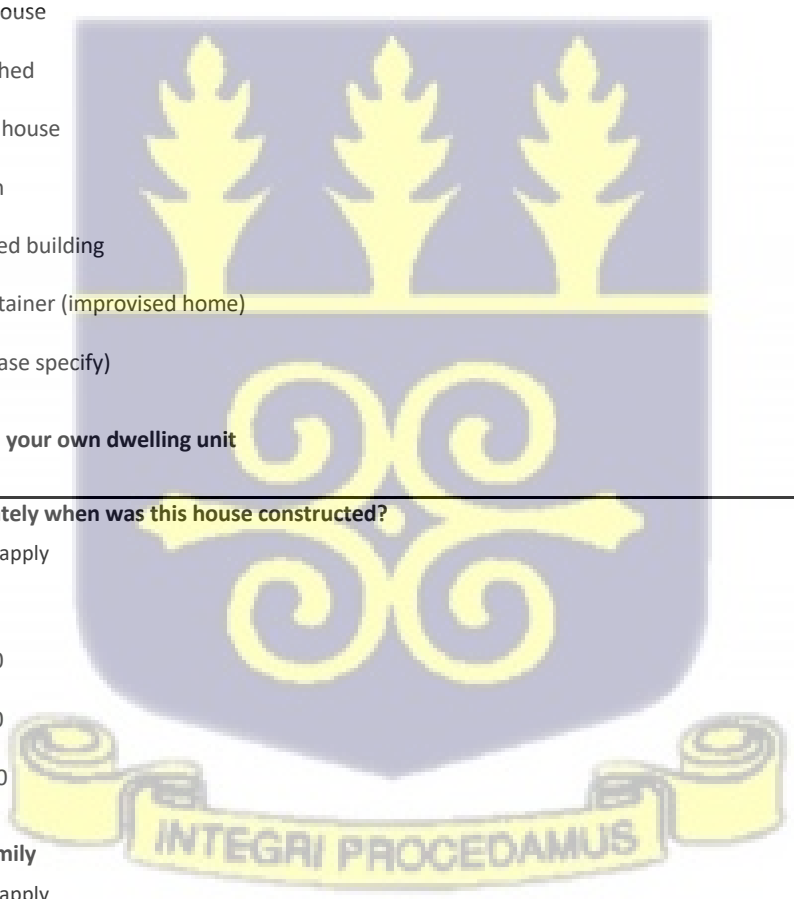
- After 2020
- 2010 - 2020
- 2000 - 2010
- Before 2000

**20. Type of Family**

Tick (✓) only one that apply

- Nuclear (monogynous)
- Nuclear (polygynous)
- Joint / Extended

**21. What is/are the age bracket of people in the household?**



Tick (✓) all that apply

- Below 18 years
- 18 - 35 years
- 36 - 59 years
- 60 years and above

How many people in the household are below 18 years?

\_\_\_\_\_

How many people in the household are between 18 and 35 years?

\_\_\_\_\_

How many people in the household are between 36 and 59 years?

\_\_\_\_\_

How many people in the household are 60 years and above?

\_\_\_\_\_

22. Household size

Household size refers to the total number of people eating from the same pot.

\_\_\_\_\_

23. Number of dependents in education (including university)

\_\_\_\_\_

24. Do any persons with disabilities live in your household?

Tick (✓) only one that apply

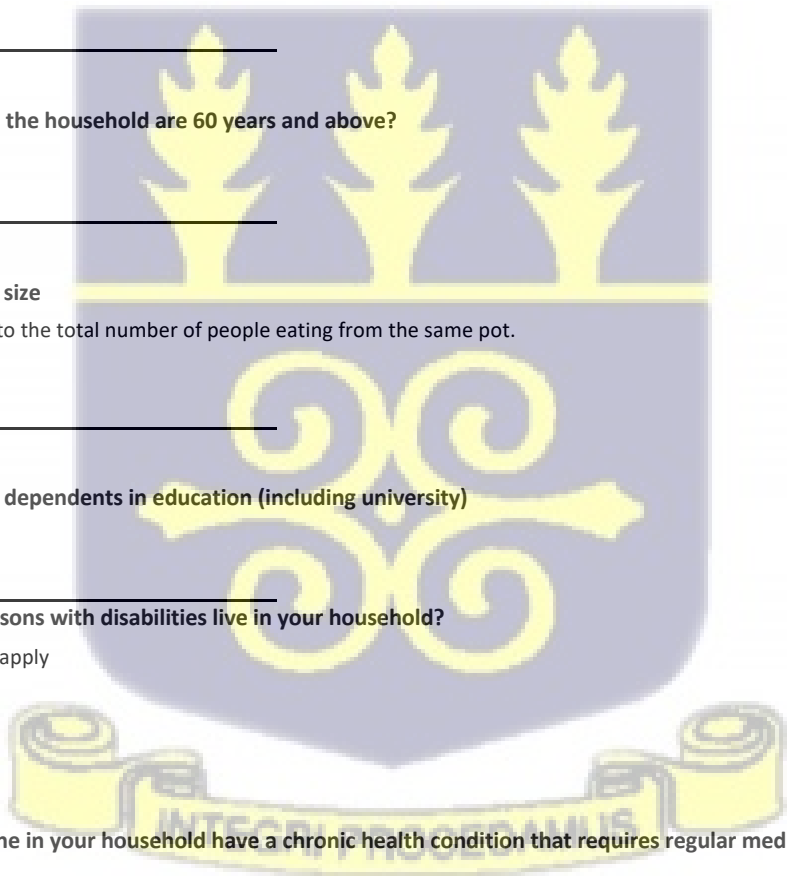
- Yes
- No

25. Does anyone in your household have a chronic health condition that requires regular medication or medical attention?

Tick (✓) only one that apply

- Yes, one or more household members
- No, none

26. Do you receive external contributions to the household, for example from friends or relatives?



Tick (✓) only one that apply

- Yes
- No

**27. What kind of contribution do they give you?**

Tick (✓) all that apply

- Food and water
- Money
- Cloths
- Building materials
- Agricultural input
- Others (please specify)

If others, please state what kind of contribution do they give you?

---

**28. Does external contributions increase when there is a flood?**

Tick (✓) only one that apply

- Yes
- No

Flood Hazard

---

**29. Since you have lived in this community, what changes in temperature have you observed?**

Note that this refers to long-term changes, i.e.>10 years. Tick (✓) only one that apply

- Increases in temperature
- Decreases in temperature
- No change in temperature
- Not sure
- Others (please specify)

If other, please specify what changes in temperature you have observed?

---

**30. Since you have lived in this community, what changes to the length of the rainy season have you observed?**

Many respondents will be not sure, and that is a valid answer. Tick (✓) only one that apply

- Shorter length of rainy season
- Longer length of rainy season
- No change
- Not sure
- Others (please specify)

If other, please specify what changes to the length of the rainy season have you observed?

---

**31. Since you have lived in this community, what changes to the frequency of rainfall have you observed?**

Many respondents will be not sure, and that is a valid answer. Tick (✓) only one that apply

- Reduced frequency of rainfall
- Increased frequency of rainfall
- No change
- Not sure
- Others (please specify)

If other, please specify what changes to the frequency of rainfall have you observed?

---

**32. Since you have lived in this community, what changes to the intensity (heavy or light) of rainfall have you observed?**

Many respondents will be not sure, and that is a valid answer. Tick (✓) only one that apply

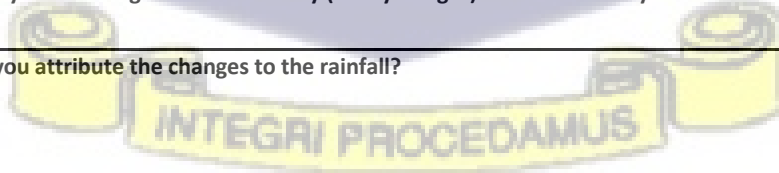
- Reduced intensity of rainfall
- Increased intensity of rainfall
- No change
- Not sure
- Others (please specify)

If other, please specify what changes to the intensity (heavy or light) of rainfall have you observed?

---

**33. What will you attribute the changes to the rainfall?**

Tick (✓) all that apply



- Cutting down of trees
- Bush burning
- Climate change
- Gods will
- Natural variability
- Others (please specify)

If other, please specify what you will attribute the changes to the rainfall?

---

**34. On average, how often do floods occur directly around your household?**

i.e. in or surrounding the household or property. Tick (✓) only one that apply

- Most years
- At least every 5 years
- At least every 10 years
- Less than 5 years
- Never
- Not sure
- Others (please specify)

If other, please specify how often floods do occur directly around your household?

---

**35. How has flooding changed directly around your household since you moved to this house? This refers to flood water in or directly around the household.**

Tick all that apply.

- No change in frequency
- No change in flood water depth
- Increase in frequency
- Decrease in frequency
- Increase in flood water depth
- Decrease in flood
- water depth

Others (please specify)

If other, please specify how flooding has changed directly around your household since you moved to this house?

---

**36. How often does the flood water enter your household?**

This means that the flood water is inside the house, i.e. the areas where people live (sleep, cook, eat). Tick (✓) only one that apply

- Most years
- At least every 5 years
- At least every 10 years
- Less than every 10 years
- Never
- Not sure
- Others (please specify)

If other, please specify how often the flood water does enter your household?

---

**37. How long does the flood usually last?**

Tick (✓) only one that apply

- 0 - 1 day
- 2 - 3 days
- 4 - 5 days
- 1 week or more

**38. In the last flood that occurred, what possessions and properties were damaged in your household?**

Tick (✓) all that apply

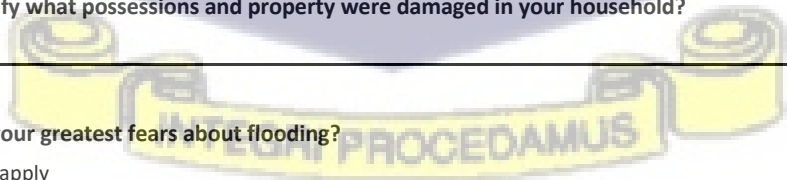
- Building
- Access road
- Services (water, sanitation, electricity)
- Provisions (food medicine)
- Valuables (electronics, jewellery, furniture)
- Others (please specify)

If other, please specify what possessions and property were damaged in your household?

---

**39. What are your greatest fears about flooding?**

Tick (✓) only one that apply



- Personal safety
- Safety of relatives
- Household's goods and possessions
- Building collapse
- Uncertainty of flood occurrence
- Others (please specify)

If other, please specify what our greatest fears about flooding are?

---

Vulnerability Assessment

---

**40. What kind of vehicle do you own?**

Tick (✓) only one that apply

- Car
- Motorbike
- Tricycle
- Bicycle
- Others (please specify)
- None

If other, please specify what kind of vehicle you own?

---

**41. Is it insured against flood damage?**

Tick (✓) only one that apply Yes No

**42. Have you experienced minor, major or none at all financial setbacks due to previous flood events?**

Tick (✓) only one that apply

- Yes, major financial setbacks
- Yes, minor financial setbacks
- No, no financial setbacks

**43. Do you have an emergency savings fund that can cover immediate expenses in case of a flood?**

Tick (✓) only one that apply

- Yes, we have an emergency fund
- No, we do not have an emergency fund
- Not sure

**44. How satisfied are you with the response of first responders (e.g., NADMO, police, fire, rescue teams) during past flood events?**

Tick (✓) only one that apply

- Very satisfied
- Somewhat satisfied
- Not satisfied
- No experience with first responders

**45. Do you have insurance coverage (e.g., flood insurance, homeowners/renters insurance) that could help with flood-related losses?**

Tick (✓) only one that apply

- Yes, for both flood insurance and homeowners/renters insurance
- Yes, for both flood insurance only
- Yes, for homeowners/renters insurance only
- No insurance coverage
- Not sure

**46. Does your household have access to healthcare services, including medical insurance?**

Tick (✓) only one that apply

- Yes, we have access to healthcare services and insurance
- No, limited access to healthcare services

**47. Do you have access to government social services and/or NGO support programs that can assist in preparing for recovery from flood-related challenges?**

Tick (✓) only one that apply

- Yes, we are aware and have access
- No, not aware or limited access

**48. Have you or anyone in your household considered or experienced temporary or permanent relocation due to flood-related concerns?**

Tick (✓) only one that apply

- Yes, we have considered or experienced relocation
- No, relocation has not been considered

Flood Perception and Adaptation



**49. During the flood event, what actions do you take to manage the immediate impact of the flood?**

Tick (✓) all that apply

- Evacuated to a safer location
- Sought help from neighbours or community members
- Sought help from friends and relatives
- Erect temporary barriers or push bacj against water
- Stayed in my home and waited for the flood to recede
- Create holes in the wall or house for the flood water to pass
- Others (please specify)

**If other, please specify what actions you have taken to manage the immediate impact of the flood?**

---

**50. Who is responsible for Flood protection?**

Tick (✓) all that apply

- Individual households
- Government
- Flood adaptation experts
- Company
- Community
- Public (outside of community)
- NGO

**51. Did the flood lead to any changes in community relationships or cohesion?**

Tick (✓) only one that apply

- Yes, there was increased community support and solidarity
- Yes, there was decreased community support and solidarity
- No, there no noticeable changes
- I don't know

**52. How resilient do you think your community is to future flood events? Resilience means ability to cope with, standup to, or recover from the flooding.**

Tick (✓) only one that apply

- Very resilient
- Somewhat resilient
- Not resilient at all

**53. How important is it to build resilience in Tamale to effectively cope with flood events?**



- Very important
- Important
- Somewhat important
- Not important
- Not important at all

54. Do you have access to early warning systems or weather information to inform your actions? Yes

- No
- 

If YES, please where did you access this information?

Tick (✓) all that apply

- TV
- Online
- NADMO
- Others (please specify)

If other, where did you access this information?

---

55. Do you presently use early warning systems or weather information to inform your actions?

Tick (✓) only one that apply

- Yes
- No

If NO, why do you not use early warning systems or weather information to inform your actions?

Tick (✓) all that apply

- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q55

---

56. Have you attended or accessed flooding educational and awareness activities or information?

Tick (✓) only one that apply

- Yes
- No

**If YES, where did you access this information?**

Tick (✓) all that apply

- NGO community activity
- Government community activity
- Self-driven (e.g., online or books)
- Others (please specify)

**If other, please specify where you access the information from?**

---

**If NO, why do you not attend flooding educational and awareness activities or information?**

Tick (✓) all that apply

- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't time to do this
- It don't consider it to be my responsibility
- Multiple reasons
- Another reason

**Please state another reason if respondent says NO to Q56**

---

**57. Do you receive relief items (emergency provisions) following a flood?**

Tick (✓) only one that apply

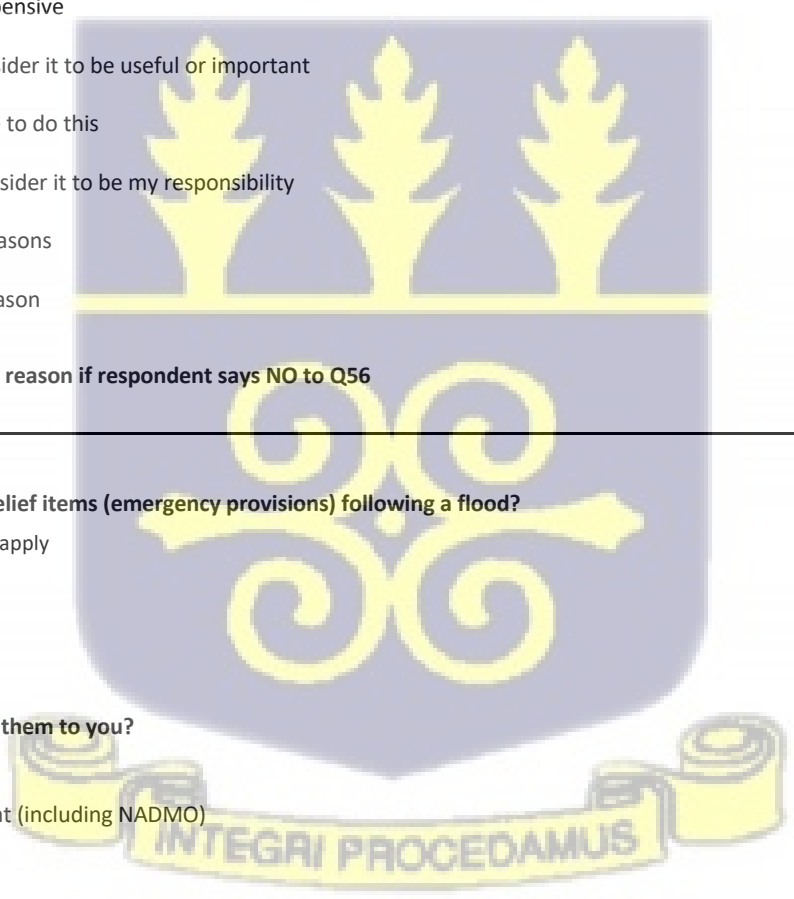
- Yes
- No

**If YES, who supplied them to you?**

Tick (✓) all that apply

- Government (including NADMO)
- NGOs
- Relatives or friends
- Community members
- Others (please specify)

**If other, please specify who supplied them to you**



**Are they always sufficient for your needs?**

Tick (✓) only one that apply

- Yes  
 No

**How long do they take to be delivered?**

Tick (✓) only one that apply

- Less than 1 day  
 1 - 3 days  
 3 - 7 days  
 More than 7 days

**If NO, why do you not have access to them?**

---

**58. How do you think the storm drain network affects flooding for your household?**

Tick (✓) only one that apply

- They improve the flood situation  
 They make the flooding worse  
 They have no effect on the flooding  
 Unsure

**59. Estimate in meters how close the nearest storm drain (i.e. gutter) is to your house?**

\_\_\_\_\_

**60. Estimate in minutes how close the nearest storm drain (i.e. gutter) is to your house?**

\_\_\_\_\_

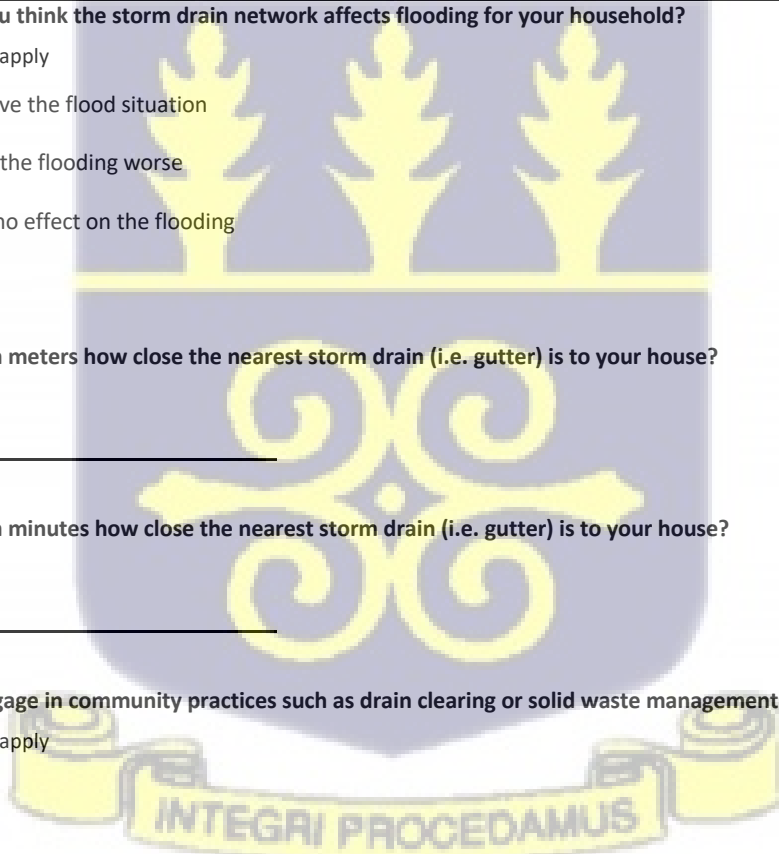
**61. Do you engage in community practices such as drain clearing or solid waste management to reduce flooding?**

Tick (✓) only one that apply

- Yes  
 No

**If NO to Q61, why do you not plan to do this?**

Tick (✓) all that apply



- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if the respondent says NO to Q61

---

**62. Do you engage in community planning and initiatives to address flooding, e.g. emergency response planning or lobbying local government?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q62, why do you not plan to do this?**

Tick (✓) all that apply

- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q62

---

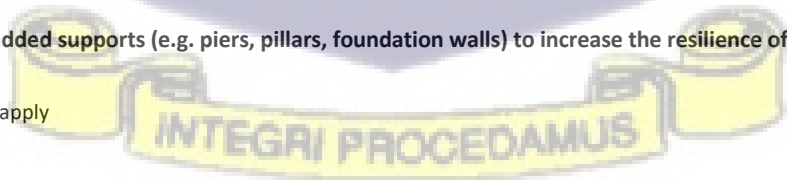
**63. Have you added supports (e.g. piers, pillars, foundation walls) to increase the resilience of your house to flooding?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q63, why do you not plan to do this?**

Tick (✓) all that apply



- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons

Another reason

Please state another reason if respondent says NO to Q63

---

**64. Have you raised the elevation of your house or property (e.g. platform or gravel)?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q64, why do you not plan to do this?**

Tick (✓) all that apply

- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q64

---

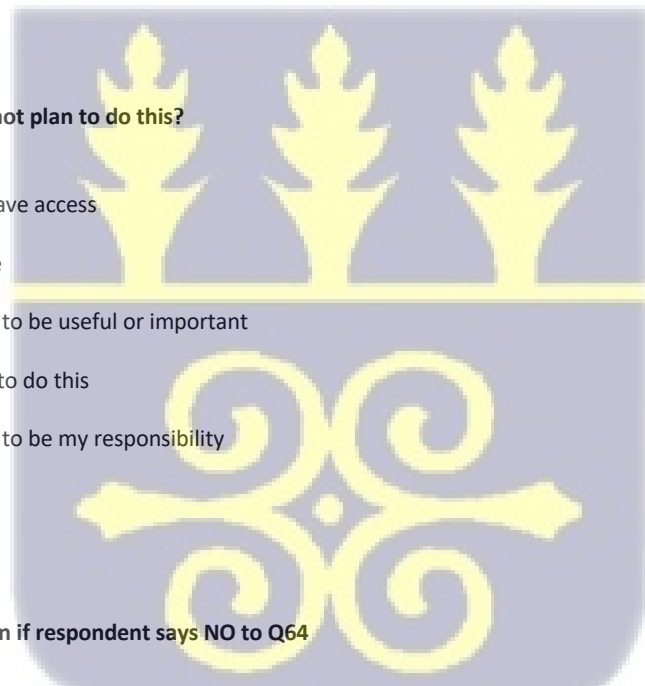
**65. Have you erected barriers (e.g. wall, compound, embankment) around some or all of your household?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q65, why do you not plan to do this?**

Tick (✓) all that apply



- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q65

---

**66. Have you constructed drainage(e.g. sandbag channels) in and/or around your household?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q66, why do you not plan to do this?**

Tick (✓) all that apply

- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q66

---

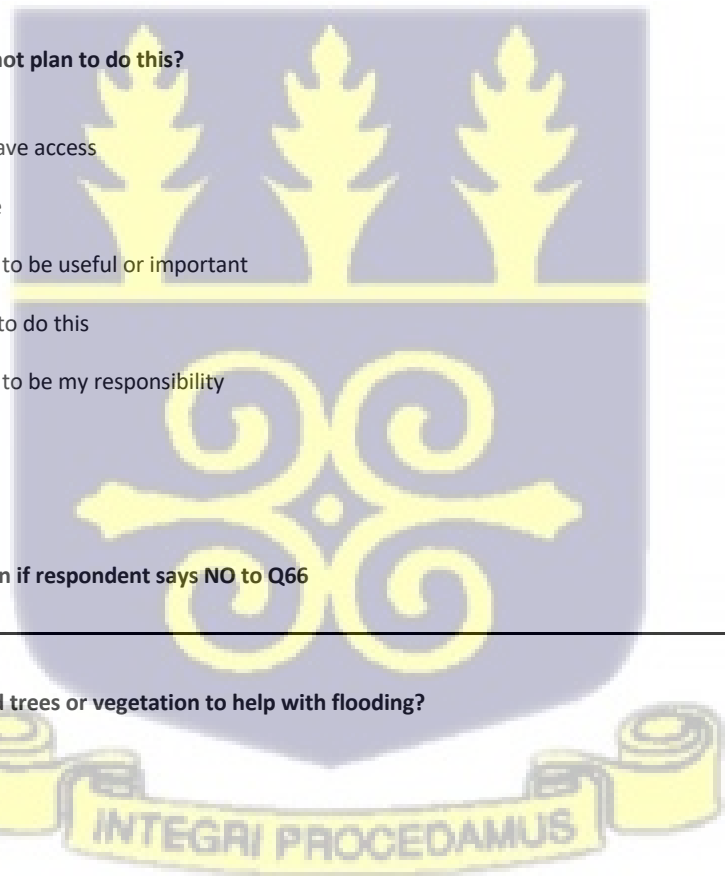
**67. Have you planted trees or vegetation to help with flooding?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q67, why do you not plan to do this?**

Tick (✓) all that apply



- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q67

---

**68. Do you keep/preserve additional provisions (e.g. water, food) in case of a flood?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q68, why do you not plan to do this?**

Tick (✓) all that apply

- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q68

---

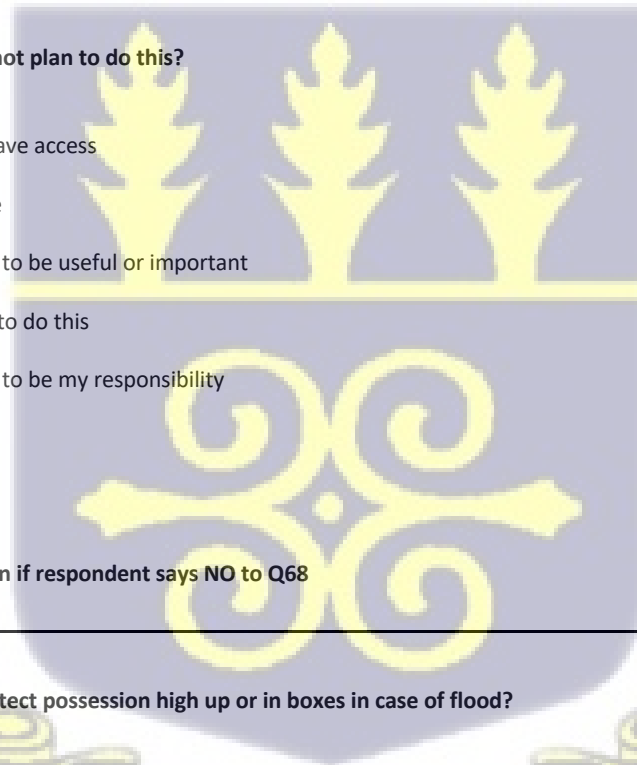
**69. Do you keep/protect possession high up or in boxes in case of flood?**

Tick (✓) only one that apply

- Yes
- No

**If NO to Q69, why do you not plan to do this?**

Tick (✓) all that apply



- I don't have access
- It is too expensive
- I don't consider it to be useful or important
- I don't have time to do this
- I don't consider it to be my responsibility
- Multiple reasons
- Another reason

Please state another reason if respondent says NO to Q69

---

Researcher observations:

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What material are the walls of the house constructed from?

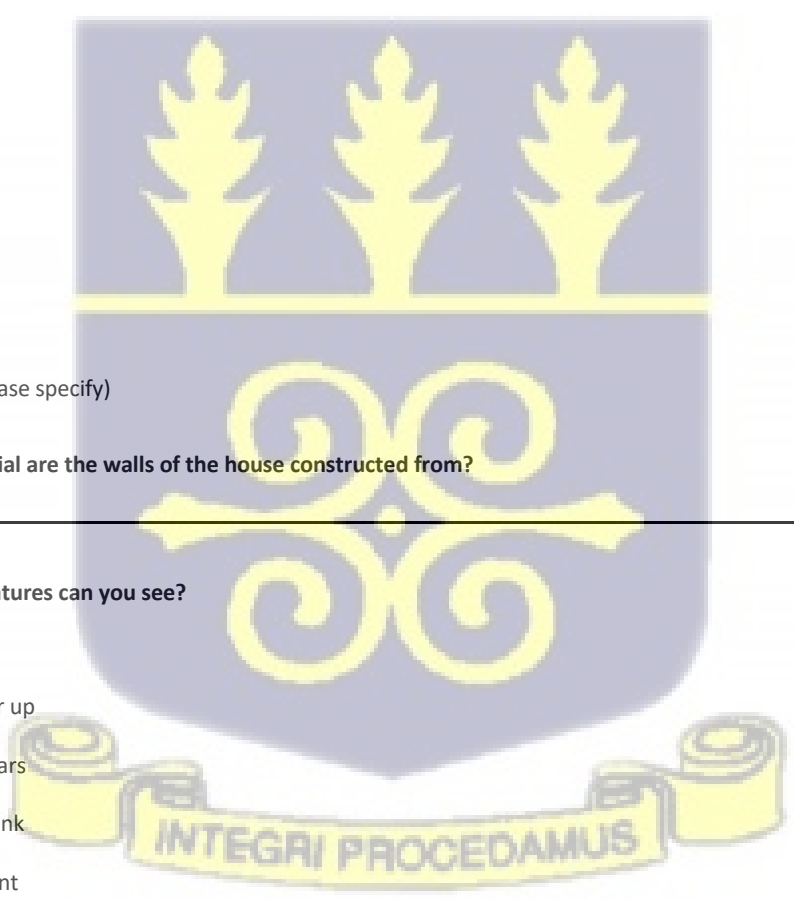
- Concrete blocks
- Mud
- Mud blocks
- Metal
- Wood
- Multiple
- Unsure
- Others (please specify)

If other, what material are the walls of the house constructed from?

---

What adaptation features can you see?

- Platform
- Door higher up
- Piers or pillars
- Sandbag bank
- Embankment
- Compound wall
- Door barriers
- Elevation increase
- Others (please specify)



If other, what adaptation feature can you see?

---

Photo 1 of interesting flood adaptation measures

Click here to upload file. (< 10MB)

What adaptation feature is Photo 1?

---

Photo 2 of interesting flood adaptation measures

Click here to upload file. (< 10MB)

What adaptation feature is Photo 2?

---

Photo 3 of interesting flood adaptation measures

Click here to upload file. (< 10MB)

What adaptation feature is Photo 3?

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Photo 4 of interesting flood adaptation measures

Click here to upload file. (< 10MB)

What adaptation feature is Photo 4?

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Photo 5 of interesting flood adaptation measures

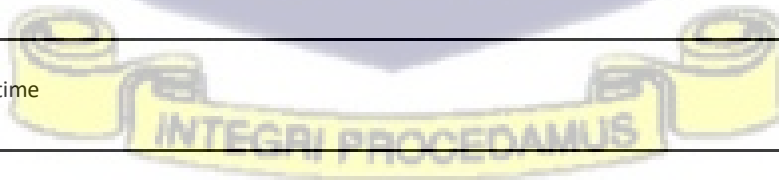
Click here to upload file. (< 10MB)

What adaptation feature is Photo 5?

---

Thank you for your time

---



APPENDIX E: Ethical Clearance



**UNIVERSITY OF GHANA**  
**ETHICS COMMITTEE FOR THE HUMANITIES (ECH)**

P. O. Box LG 74, Legon, Accra, Ghana

*My Ref. No: ECH/194/22-23*

July 31, 2023

Cynthia Azochiman Awuni  
Department of Geography and Resource Development  
University of Ghana  
Legon

**ETHICAL CLEARANCE**  
**(ECH 194/ 22-23)**

The Ethics Committee for the Humanities (ECH) conducted a full board review and approved your protocol titled:

**SPATIAL AND TEMPORAL VARIATION OF FLOOD OCCURRENCE AND VULNERABILITY IN THE TAMALE METROPOLITAN AREA**

**PRINCIPAL INVESTIGATOR: CYNTHIA AZOCHIMAN AWUNI**

Please note that the final review report must be submitted to the Committee at the completion of the study. Your research records may be audited at any time during or after the implementation. Any modification of this research project must be submitted to ECH for review and approval prior to implementation.

Please report all serious adverse events related to this study to ECH within seven (7) days verbally and in writing within fourteen (14) days.

This certificate is valid until July 30, 2024. You are required to submit annual reports for continuing review.

Please accept my congratulations.

Yours Sincerely,

**Professor C. Charles Mate-Kole**  
ECH Chair

Cc: Professor Samuel Agyei-Mensah, Department of Geography and Resource Development, UG  
Prof. Sandow Mark Yidana, School of Physical and Mathematical Sciences, UG  
Prof George Owusu, Institute of Statistical, Social & Economic Research, UG

Tel: +233 30 393 3866

Email: [ech@ug.edu.gh](mailto:ech@ug.edu.gh)

**INTEGRI PROCEDAMUS**