ASSESSING THE EFFECTIVENESS OF STRUCTURAL AND NON-STRUCTURAL FLOOD MITIGATION MEASURES OF BUSHROD ISLAND'S UNPLANNED SETTLEMENTS

By

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A thesis submitted to the Department of Architecture in partial fulfillment of the requirements for the degree of Masters in Disaster Management.

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Declaration

It is hereby declared that

1. The thesis submitted is my own original work while completing degree at BRAC University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material which has been accepted, or submitted, for any other degree or diploma at a university or other institution.
4. I have acknowledged all main sources of help.

As a final statement, I vouch that I am the author of this dissertation and that I have not plagiarized in any way. I have taken all necessary precautions to ensure the authenticity and integrity of my work, and I am confident that this dissertation satisfies the academic requirements placed on me at this level of study.

ABU SUMAILA KAMARA,
ID: 22168001

Approval

The Thesis Titled **"ASSESSING EFFECTIVENESS OF STRUCTURAL & NON-STRUCTURAL FLOOD MITIGATION MEASURES OF BUSHROD ISLAND'S UNPLANNED SETTLEMENTS"** submitted by Abu Sumaila Kamara, (ID: 22168001) of Summer 2023 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master in Disaster Management on July 25, 2023.

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Ethical Statement

As the author of this graduate thesis, I am dedicated to keeping the highest ethical standards throughout the research process. This study adheres to the ideals of objectivity, transparency, and honesty.

First and foremost, I recognize the need of gaining consent from all study subjects after providing them with all pertinent information. I have taken precautions to defend their rights, protect their privacy, and retain their confidence. Any personal information or data collected will be used solely for academic reasons and securely kept.

Furthermore, I extensively studied existing research, appreciating the contributions of other researchers and correctly attributing their work through accurate citations and references. Plagiarism and intellectual property rights have been carefully addressed and avoided.

I commit to maintain impartiality and avoid prejudice or manipulation in data analysis and interpretation. The conclusions and suggestions in this thesis are supported by empirical evidence and are based on rigorous research procedures.

Finally, I commit to disseminate the study findings freely and transparently in order to enhance knowledge in the academic community. Transparency has been maintained by the disclosure of any limitations or possible conflicts of interest.

Overall, my ethical statement demonstrates my steadfast commitment to doing this study in line with the highest ethical standards.

Abstract

Flooding poses a significant threat to the inhabitants of unplanned settlements on Bushrod Island in Monrovia, Liberia. Although flood risk there are mitigation strategies are in place, their effectiveness in reducing the impacts of flooding remains unclear. This study aims to assess the efficacy of both structural and non-structural flood risk mitigation measures in minimizing the dangers and effects of flooding on Bushrod Island. The research objectives are to identify and categorize flood hazards, evaluate the effectiveness of flood mitigation measures, and propose improvements to address specific flood risks. By answering research questions about flood hazards, the measures' effectiveness, influencing factors, and potential improvements, this study will provide valuable insights into flood risk reduction strategies for similar contexts elsewhere.

This research sheds light on how well these precautions work to reduce flood risks in different contexts. The research incorporates couple of mixed tools and techniques such as primary and secondary data, and qualitative and quantitative analysis. The research also used survey and interview as data collection tools using the combination of purposive and stratified random sampling. The nature of the research is analytical and the purpose is centered on fundamental research tactics while the research design is conclusive.

Since the long-term effectiveness of the available mitigation measures in the study area remain uncertain, the study will focus on identifying the hazard risks, vulnerabilities, and assess the immediate impact of flood mitigation measures, but also investigate the durability of both structural and non-structural measures over time which is essential to understanding their continued efficacy.

Additionally, understanding the extent and nature of flood damage is essential to comprehensively evaluate the impact of the assessed measures. It will help in determining the economic losses, and social implications faced by the communities during flood events. This data is vital for decision-makers and stakeholders to prioritize investment in appropriate flood risk reduction strategies.

By addressing these research gaps, the researcher can offer more comprehensive and practical recommendations for improving the existing and new flood risk reduction strategies in the study area and potentially inform flood risk management practices in other similar contexts nationally.

Moreover, it will aid in enhancing the understanding of the economic, social, and environmental consequences of floods, which is vital for formulating evidence-based policies and strategies for effective flood risk management in Bushrod Island's unplanned settlements and similar contexts.

Keywords: *Flood; Flood Mitigation; Bushrod Island, Unplanned Settlement; Structural Measures, Non-Structural Measures, Hazard Risk, Vulnerability, Flood Damage.*

Dedication

With gratitude to the Almighty **ALLAH,** I dedicate this dissertation my late parents, **Layee Sumaila Kamara** and **Nancy Kenne Okai,** and to my daughters, **Aminata Natasha Kamara** and **Aisha Kamara.**

To my family, who have been my constant source of love, support, and encouragement throughout my academic journey, your unwavering support and motivation have been critical in keeping me focused and motivated throughout this journey.

Lastly, I dedicate this degree to **ArcelorMittal Liberia Limited**, for the advanced academic scholarship award that has been a critical support in making this achievement possible.

Acknowledgement

I would like to express my sincere gratitude and appreciation to everyone who has supported and contributed to the completion of my dissertation.

Let me begin by extending my warmest gratitude to my dissertation supervisor Professor Md. Humayun Kabir, PhD, and Co-Supervisor Mr. Mohammad Ferdaus for their guidance, expertise, and support throughout this journey. His insightful feedback, constructive criticism, and encouragement have been instrumental in shaping this dissertation.

I would also like to acknowledge the Professors, Lecturers and Staffers at the Postgraduate Programs in Disaster Management (PPDM) Department and the entire BRAC University family for their assistance and support. Your expertise, feedback, and guidance have been invaluable in shaping my career and understanding of the subject matter.

I would like to express my heartfelt appreciation to the participants who generously contributed their time and efforts to this study and without whose cooperation, this research would have been quite impossible.

To my family and friends, I acknowledge your support and encouragement. Your unwavering motivation has been critical in keeping me focused throughout this journey.

I would like to express my gratitude to the library staffers, who have assisted me with my research and provided me with access to relevant resources. Their support has been invaluable in enabling me to complete this dissertation.

Lastly, I would like to thank my corporate sponsor ArcelorMittal Liberia Limited, for their support and assistance. Their sponsorship and financial contribution have been crucial in enabling me to complete this research and degree program.

In conclusion, I would like to express my deepest appreciation to everyone who has contributed to the completion of this dissertation. Your support, encouragement, and contribution have been instrumental in enabling me to complete this project

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List of Abbreviations and Acronyms

ADB	African Development Bank
EPA	Environmental Protection Agency of Liberia
FEMA	Federal Emergency Management Agency
GoL	Government of Liberia
GCP	Google Cloud Platform
IPCC	Intergovernmental Panel on Climate Change
LACE	Liberia Agency for Community Empowerment
LISGIS	Liberia Institute of Statistics & Geo-Information Services
LHS	Liberia Hydrological Service
LNRSC	Liberia National Red Cross Society
LWSC	Liberia Water & Sewage Corporation
MCC	Monrovia City Corporation
MCW	Million Cubic Watt
MME	Ministry of Mines & Energy
MPW	Ministry of Public Works
MW	Mega Watts
NCCRC	National Center for the Coordination of Response Mechanisms
NDMA	National Disaster Management Agency of Liberia
NHA	National Housing Authority
NMS	National Meteorological Service
NOAA	National Oceanic & Atmospheric Administration
NPHIL	National Public Health Institute of Liberia
PHEOC	Public Health Emergency Operation Center
UNDDR	United Nations Office for Disaster Risk Reduction
SLUMDAL	Slump Dwellers Associations of Liberia
SPSS	Statistical Package for the Social Sciences
WAPP	West African Power Pool
WB	World Bank
WHO	World Health Organization

Glossary

Flood:	Floods refer to the overflow of water onto normally dry land, usually caused by heavy rainfall, rapid snowmelt, or the failure of water control systems (IPCC, 2012). Floods can occur in various forms, including riverine floods, flash floods, coastal floods, and urban floods (UNDRR, 2019). They are characterized by their unpredictability, magnitude, and destructive potential
Flood Risk:	Flood risk includes both the likelihood that a flood will occur and any potential effects it may have on built environments and human populations. It is influenced by a number of variables, such as the frequency and size of floods, the vulnerability of exposed elements, and the ability to handle and recover from flood events (UNISDR, 2009). Planning for flood mitigation must consider and manage flood risk.
Flood Mitigation:	In order to lessen or avoid the negative effects of floods, actions, strategies, and measures are taken known as "flood mitigation. It aims to reduce flood-related damages, safeguard infrastructure, protect human life, and encourage sustainable development in flood-prone areas. Depending on their nature, flood mitigation strategies can be divided into structural and non-structural (Crichton, 2010).
Structural Measure:	The physical interventions used in structural flood mitigation involve changing or controlling the water flow. Dams, levees, floodwalls, embankments, channel improvements, and reservoirs are among those that must be built and maintained (IPCC, 2012). The goals of structural measures are to control water levels, redirect or store extra water, and create floodwater conveyance routes.
Non-Structural Measure:	Non-structural measures include: Policies, strategies, and practices that increase resilience and decrease vulnerability are referred to as non-structural flood mitigation measures. They include zoning laws, floodplain mapping, early warning systems, emergency preparedness, public awareness campaigns, and community involvement (UNDRR, 2019).

CHAPTER ONE

Introduction

1.1 Contextual Background

Liberia is a West African country with 5.2 million people. The Country has a tropical climate with heavy rainfall and a dry season. The capital city, Monrovia, is considered one of the wettest cities in the world due to poor urban planning and rapid population growth. Unplanned settlements, such as Bushrod Island, have become a significant issue in the country due to poor infrastructure, unsanitary conditions, and subpar housing. The island frequently floods during the rainy season due to its location near the Mesurado and St. Paul Rivers which are tributaries of the Atlantic Ocean.

Flooding incidents have caused significant property damage, fatalities, and evictions, increasing the risk of malaria and water-borne illnesses. This has led to the destruction of property and businesses, causing significant economic and livelihood impacts. Flooding is a persistent issue in Liberia, particularly in urban areas with haphazard unplanned settlements. Bushrod Island, in Greater Monrovia District, Montserrado County, is one of the most flood-prone areas, resulting in substantial losses of properties and at times loss f lives.

Structure and non-structure flood risk mitigation strategies have been used to address the persistent flooding issue, but an assessment of their effectiveness in lowering the risk is still pending. This study aims to evaluate the effectiveness of structural and non-structural flood risk mitigation measures in lowering the risk in unplanned settlements on Bushrod Island. The effectiveness of flood risk mitigation measures in reducing flood risk in Monrovia's unplanned settlements has been evaluated, finding that structural measures like drainage systems, retention ponds, and river dredging can effectively decrease the area's flood risk. Non-structural measures, such as campaigns to increase public awareness and educate the public, were less successful due to low public involvement. Ali and Dan'azumi, (2023) found that urbanization has increased surface runoff and flood risk, leading to the need for green infrastructure like rain gardens and green roofs.

Adjei et al., (2019) also found that Ghana's Ashaiman municipality faces a greater risk of flooding due to increased rainfall due to global warming. Both structural and non-structural measures can be successful in lowering the risk of flooding in urban areas, depending on factors such as public participation, resource availability, and suitability of the measures to the local context. This study aims to add to the existing literature by assessing the efficacy of flood risk mitigation measures in the specific context of Bushrod Island's ad hoc settlements in Liberia. Flooding is a major natural hazard that affects millions of people and costs billions of dollars in damage worldwide. Bushrod Island is a crucial location for investigating the effectiveness of both structural and non-structural flood risk mitigation measures due to the presence of numerous unplanned settlements. Structural measures involve building drainage systems, flood protection walls, and other water flow-controlling infrastructure, while non-structural measures focus on lowering the risk of flooding through community-based programs like land-use planning and early warning.

A study evaluated the efficiency of various flood risk mitigation measures in lowering flood risk in Monrovia's unplanned settlements (Innis, 2022). These measures sometimes even have unfavorable outcomes, like worsening waterlogging or uprooting vulnerable communities (Innis, 2022). Even though they are frequently less noticeable, non-structural measures have the potential to be very effective at minimizing the effects of flooding in unplanned settlements (Flomo, 2021). Thompson et al., (2020), in their study, advocated the adoption of both structural and non-structural measures, such as the building of retention ponds, the installation of early warning systems, and the provision of flood insurance, to reduce the risk of flooding.

For unplanned settlements, structural measures may not be the first line of defense against flooding due to the lack of funding, resources, and poor planning. Non-structural measures, such as land-use planning and community-based initiatives like flood early warning systems and evacuation plans, can be effective in minimizing flooding effects in unplanned settlements. However, implementing these measures can be challenging due to inadequate funding, government support, and opposition from local communities.

Furthermore, factors like the unique context of each settlement and available resources also affect the efficacy of both structural and non-structural flood risk mitigation measures. Policymakers and practitioners must consider the advantages and disadvantages of each type of measure to minimize the effects of flooding on unauthorized settlements and other vulnerable communities worldwide.

1.2 Problem Statement

Flooding presents serious hazards to the lives and livelihoods of inhabitants in unplanned communities on Bushrod Island in Montserrado County, Liberia. Although certain flood risk mitigation strategies have been put in place in the region, it is unknown how successful they have been in lowering the dangers and effects of flooding on the community. There is little knowledge of the efficacy of both structural and non-structural flood risk mitigation measures in lowering the risk and vulnerability of these communities, despite the prevalence and significant impact flooding has on Bushrod Island's unplanned settlements.

1.3 Study Objectives

The broad objectives of the study is to assess how well flood risk reduction strategies work in minimizing the effects of flooding on Bushrod Island’s unplanned settlements that can be used to evaluate both structural and non-structural measures.

The specific objectives include:

- Identify and categorize the types of flood hazards experienced in the study area.
- Assess the effectiveness of both structural and non-structural flood mitigation measures on Bushrod Island.
- Propose recommendations to improve existing or new measures to address the specific flood hazard risks and vulnerabilities.
- Understand the nature and extent of flood damage and its economic impact.

1.4 Research Questions

To achieve the study’s broad and specific objectives, the research seeks to address and answer the following questions:

- What are the flood hazards and flood risks experienced in the study area?
- How effective are the structural and non-structural flood mitigation measures?
- What are the factors affecting the effectiveness of both structural and non-structural flood risk mitigation measures?
- How can the existing measures be improved or new measures be developed to better address the flood hazard risks and vulnerabilities?

1.5 Research Scope

The study is to evaluate the efficacy of both structural and non-structural flood mitigation measures of Bushrod Island's unplanned settlements. The is to also identify the area's current flood risk mitigation strategies and assess how well they work to minimize the risks and effects of flooding on local people and their properties. Additionally, the study aims to offer suggestions for improving local flood risk reduction measures.

1.6 Research Limitation

Some restrictions on the study may make the results less generalizable. Firstly, because Bushrod Island's unplanned settlements are the only ones this study examines, its conclusions might not be generalizable to other regions with different socioeconomic and environmental circumstances. Second, the study relies on observation, field visits, and respondents' self-assessment data, which might lack robustness. The study was constrained by the accessibility and availability of data and resources, which could reduce the investigation and analysis depth.

1.7 Purpose of the Research

The research seeks to advance theoretical knowledge, explore fundamental principles, or contribute to the existing body of knowledge in a particular field, a fundamental research approach would be more appropriate. Fundamental research focuses on expanding theoretical understanding and does not necessarily have immediate practical applications.

This study aims to assess the efficacy of both structural and non-structural flood risk mitigation measures in the unplanned settlements of Bushrod Island. The purpose of the study is to determine how well these measures have worked to minimize the risk and effects of flooding in these settlements as well as to determine the variables that influence their efficacy.

The study was inspired by the fact that the unplanned settlements on Bushrod Island are particularly susceptible to flooding because of their location in low-lying areas and their deficient infrastructure. There are a lot of people living in these settlements, many of whom are poor and lack access to necessities like clean water and sanitary facilities.

The study has several distinct purposes as follows:

Its first purpose is to assess the efficiency of non-structural measures like early warning systems, evacuation plans, and community-based flood management strategies as well as structural measures like dikes, dams, and other physical barriers for reducing flood risk.

Second, it aims to pinpoint the crucial aspects of these measures' design, implementation, upkeep, and local socio-economic and political context that affect their efficacy.

Lastly, this study aims to evaluate the efficacy of both structural and non-structural flood risk mitigation measures in Bushrod Island's unplanned settlements to provide evidence-based recommendations for improving flood risk management in these settlements. Policymakers, planners, and practitioners involved in urban flood risk management will find the study to be of great value and a valuable addition to the body of knowledge on flood risk management.

1.8 Significance of the Research

Understanding how flooding affects residents' lives and livelihoods depends on the study of flood risk mitigation measures in unplanned settlements of Bushrod Island. These areas are particularly prone to flooding due to their low-lying terrain and inadequate infrastructure. To minimize the effects of flooding on residents, policymakers and practitioners can create and put into action the appropriate measures. Since most research on flood risk reduction has been conducted in planned urban environments, the study will add to our understanding of this topic.

Since floods are expected to increase in frequency and intensity across a wide range of regions, the study is also important for understanding climate change. Climate change has increased the West African rainy season's intensity by 20 percent, leading to more frequent prolonged rain events with a 1 in 10 chance of occurring each year, and a twofold increase in short periods of intense downpours in the Lower Niger Basin region, exacerbating recent floods.

In recent studies, Brammer (2021) highlighted the negative consequences of limited knowledge on flood vulnerability, particularly in Sub-Saharan Africa. The lack of understanding led people to attribute flood issues to factors like divine punishment from a Supreme Being, rather than acknowledging the role of altered natural climate and climate change. Despite these misconceptions, the aftermath effects of floods persist. Similarly, Kingsford (2020) emphasized that human-induced changes in the natural climate have also contributed to flooding and other environmental hazards, such as erosion. Throughout history, societies have demonstrated their ability to adapt to diverse climates and environmental changes.

CHAPTERTWO

Literature Review

2.1 Flood Mitigation: Definition and Concept

2.1.1. Definitions

Natural disasters like floods present a serious risk to infrastructure, the environment, and human life. To lessen the effects of floods and improve community resilience, effective flood mitigation measures are crucial. This research explores the ideas and definitions of flooding, flood risk, and flood mitigation while emphasizing important measures for reducing flood risks.

Flood-the overflow of water onto normally dry land that typically occurs during or after excessive rainfall, rapid melting of snow, sea-level rise or a malfunctioning of water control system (IPCC, 2012). In addition to riverine and flash floods, coastal and urban floods can also happen (UNDRR, 2019). They are distinguished by their unpredictability, size, and potential for destruction.

Flood Risk-includes both the likelihood that a flood will occur and any potential effects it may have on built environments and human populations. It is influenced by a number of variables, such as the frequency and size of floods, the vulnerability of exposed elements, and the ability to cope and recover from flood events (UNISDR, 2009). Planning for flood mitigation must consider and manage flood risk.

Structural Measures-the physical interventions used in structural flood mitigation involve changing or controlling the water flow. Dams, levees, floodwalls, embankments, channel improvements, and reservoirs are among those that must be built and maintained (IPCC, 2012). Structural Measures are meant to control water levels, redirect or store extra water, and create floodwater conveyance routes.

Non-Structural Measures encompass non-physical actions like policies, strategies, and practices such as zoning laws, floodplain mapping, early warning systems, emergency preparedness, public awareness campaigns, and community involvement, aimed at enhancing flood awareness, preparedness, and adaptability to reduce vulnerability and increase resilience (UNDRR, 2019).

Effective flood mitigation necessitates an integrated and multifaceted strategy that combines both structural and non-structural measures tailored to the unique traits and requirements of the affected regions (IPCC, 2012). The purpose of flood mitigation is to lessen the impact of floods on communities, infrastructure, and people's lives. Having a solid understanding of flood, flood risk, and flood mitigation concepts and definitions is the basis for creating successful strategies. Communities can increase their resilience and reduce the damaging effects of floods by putting in place a combination of structural and non-structural measures that are tailored to local conditions.

2.1.2. Concept of Flood Mitigation

Flood is one of the most frequently occurring natural catastrophes that have a worldwide impact on millions of people. Effective flood risk mitigation strategies must be in place owing to the increased frequency and severity of floods brought on by exacerbating climate effects. The two basic kinds of flood risk reduction strategies are structural and non-structural strategies. Physical infrastructure like dams, levees, and floodwalls are examples of structural measures, whereas legislation, regulations, and awareness campaigns are examples of non-structural measures.

In minimizing the effects of floods, the efficacy of flood risk reduction techniques is essential. Although structural solutions are frequently seen as the best options, they are not always practical or economical. In metropolitan locations with limited land, non-structural techniques can be quite effective in lowering the danger of flooding.

The effectiveness of both structural and non-structural flood risk reduction methods has been evaluated in several studies elsewhere. Chakraborty and Das, (2017) assessed the efficacy of structural and non-structural interventions in reducing flood hazards in Kolkata, India. According to the study, structural measures like embankments and pumping stations are less successful than non-structural measures like early warning systems and evacuation schedules.

Iacobellis et al., (2019) evaluated the efficiency of structural and non-structural interventions in reducing flood hazards in Italy in another research. Even in places with strong structural protections, the study indicated that non-structural measures like emergency planning and readiness were crucial in lowering flood risk.

Van Eerd et al., (2014) assessed the Dutch flood risk reduction strategies' efficacy as well. The study discovered that the best method for lowering the danger of flooding was a mix of structural and non-structural interventions. In addition to non-structural measures like land-use planning and flood insurance, structural measures like floodgates and dikes were essential.

In their 2017 evaluation of the efficacy of flood risk mitigation measures in Denmark, Skougaard-Kaspersen et al., (2017) discovered that non-structural interventions including public awareness and communication were crucial for lowering flood risk. The significance of stakeholder involvement in flood risk management was also highlighted by the study.

To assess the efficacy of flood risk reduction strategies in China, Xu et al., (2019) conducted research which concluded that non-structural methods, particularly in metropolitan areas, such as land use planning and education, were crucial in lowering flood risk.

Ali and Dan'Azumi, (2023) assessed the application of analytical probabilistic model in assessing the effect of run-off and the study discovered that the best method for lowering the danger of flooding was a mix of structural and non-structural interventions.

In the wake of Hurricane Harvey, Cutter et al., (2019) carried out a study to evaluate the efficacy of flood risk reduction methods in the United States. According to the study, community involvement and non-structural variables like social networks were crucial.

The effectiveness of structural and non-structural interventions in lowering flood risk in Taiwan was evaluated by Tsai et al., (2020). According to the study, structural solutions were less efficient in reducing flood damage than non-structural ones, such as land-use planning and flood insurance.

Another investigation by Merz et al., (2010) evaluated the efficiency of several flood risk reduction strategies throughout Europe. Their study discovered that the best strategy for minimizing the danger of flooding was a combination of structural and non-structural interventions.

In conclusion, figuring out which flood risk reduction strategy is successful requires evaluating the efficacy of the structural and non-structural flood risk mitigation techniques. Cost-effectiveness, environmental impact, social acceptability, and sustainability should all be taken into account throughout the evaluation. Many studies have been done to evaluate the efficiency of various flood risk reduction strategies.

A variety of elements need to be taken into account when evaluating the efficacy of flood risk reduction strategies. The best method for lowering the danger of flooding may be a combination of structural and non-structural solutions. Nevertheless, the local environment and particular flood features affect these methods' efficacy.

2.2 Current Flood Threats

2.2.1 National/Local Context of Flood Threats

Monrovia is regarded as one of the wettest cities on earth with abundant rainfall occurring. In the Greater Monrovia District where Bushrod Island is located, the rainfall for instance reaches 5000 mm per annum while the interior plateaus and low mountainous areas receive less rain with an average annual rainfall of about 2,030 mm. The rainy season typically lasts from May through November with an average temperature of 25 degrees Celsius for the summer months.

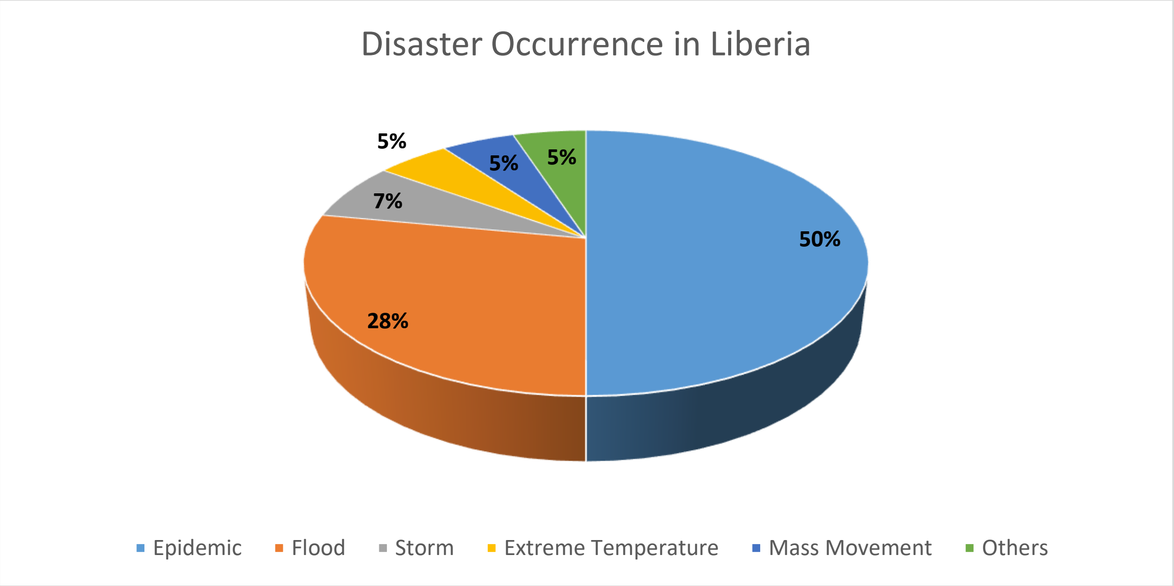


Figure 2.1: Proportion of Disaster Occurrence in Liberia (1991-2021).
Source: National Disaster Management Agency.

The dry season typically lasts from December to April and is characterized by the **Harmattan** winds. In the rainy season, relative humidity can range from 90 to 100 percent, while in the dry season, it can range from 60 to 90 percent. According to the most recent climatology (1991-2021), the coastal areas experienced rainfall throughout the year with a peak from June to September. Flooding in Liberia is seasonal and it is the second most prevalent disaster event. Floods account for 28% of all disaster occurrences in Liberia.

Around 2.2 million people in Liberia are vulnerable to flooding, 320,000 to coastal erosion, and 2.1 million to fire and windstorms. Furthermore, the nation is anticipated to experience a rise in the risk of these natural disasters as a result of the effects of climate change.

2.2.2. Global Context of Flood Threats

According to the 2022 emergency management Database (EM-DAT) of UNDRR, the total average of all disasters type recorded for the past two decades-(2002-2021) was 370 as compared to 387 annual average occurrences of floods alone in just 2022. Moreover, Africa recorded 79 out of the total 387 annual average disasters in 2022. Floods alone accounted for 45.5% (176 out of all disaster-type occurrences) in 2022 as compared to 43.4% (168 out of all disaster-type occurrences) for the past two decades 2002-2021 respectively. The total number of flood deaths recorded in 2022 (7954 deaths) was far greater as compared to the total average of recorded flood deaths (5159 deaths) for the last two decades 2002-2021.

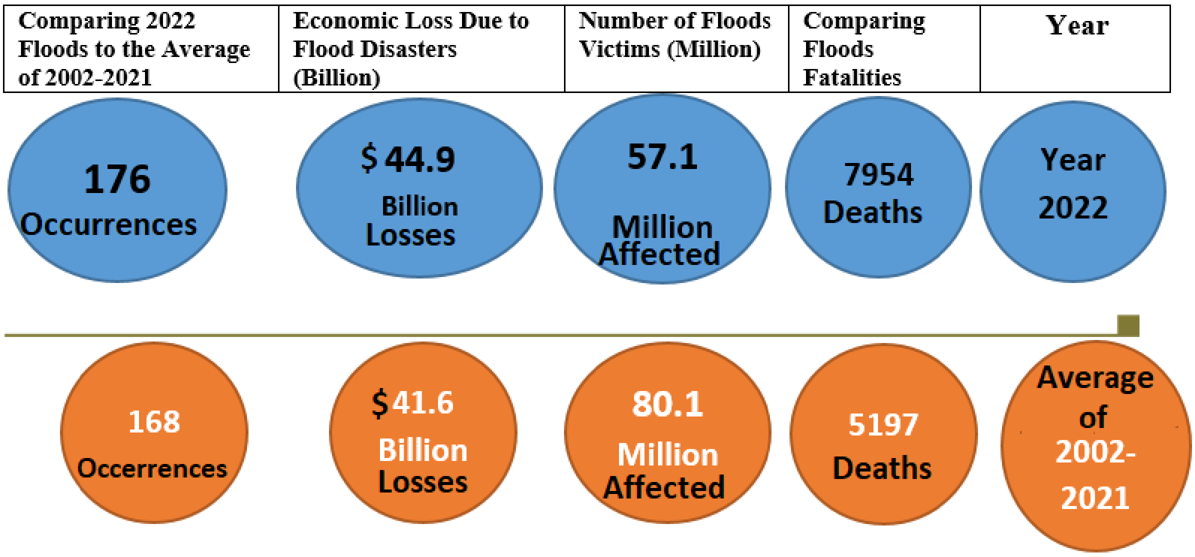


Figure 2.2. Comparing Global Threats of Floods from 2002-2022.
Source: UNDRR 2022.

Additionally, flooding alone impacted 57.1 million people globally in 2022 as compared to the total annual average of 80.1 million from 2002-2021 and the economic losses from the impact of floods in 2022 was 44.9 billion while the total average loss recorded from 2002-2022 was 41.6 billion. Lastly, the impact of catastrophes on people and the economy was disproportionately greater in Africa, as seen by the 16.4% share of fatalities compared to 3.8% in the previous two decades (UNDRR, 2022).

Flooding events are also likely to lead to compound and cascading disaster scenarios where landslides, and wave actions- (sea erosion as a result of sea level rise), meteorological-(storm surges), and biological- (disease outbreak).

2.3 Flood Mitigation Necessities

Due to the frequency of varying climate variables, Liberia is susceptible to both natural disasters and hydro-meteorological hazards, which have led to weather and climatic conditions like droughts and erratic precipitation. The country's infrastructure in both rural and urban areas is at risk due to sea level rise, storm surges, torrential rain, flooding, and increased erosion. According to this research, floods are categorized as coastal, pluvial, or riverine floods depending on their sources, degree of destruction, and potential forecasting methods.

To minimize the risk of flooding and its effects on residents' lives and livelihoods, effective flood risk management is essential for the unplanned settlements of Bushrod Island.

The following are some of the factors that make flood risk management necessary in these settlements:

2.3.1. Increase Resilience

Flood risk management strategies can help to strengthen community resilience by lowering the likelihood of flooding, enabling residents to better withstand the effects of floods when they do occur.

2.3.2. Safeguard Lives, Assets and Livelihoods

Effective flood risk management strategies can help to minimize the devastating effects that floods can have on residents' lives, assets and livelihoods, safeguarding their safety.

2.3.3. Uphold Financial Stability

Residents of these unplanned settlements, who may rely on their businesses or other livelihoods activities to support their families can suffer significant financial losses as a result of floods. Effective flood risk management strategies can reduce these losses, preserving the economic stability of these communities.

2.3.4. Safeguard the Environment

Floods can harm the local environment by causing soil erosion, vegetation loss, and damage to the habitats of wildlife. To minimize these effects and protect the local environment for future generations, effective flood risk management measures are necessary.

2.3.5. Reduce Burden on Emergency Services

Emergency services, which must respond to the needs of the affected communities, can be severely strained by floods. Effective flood risk management measures can minimize the burden on these services by reducing the risk of flooding and its effects, allowing them to concentrate on other priorities.

Lastly, effective flood mitigation is essential for Bushrod Island's improvised settlements because it can help to minimize the risk and impact of flooding and enhance the resiliency and well-being of residents.

2.4 Summary of Literature Review

The efficiency of structural and non-structural flood risk reduction methods has been the subject of several kind of research. Levees, flood barriers, and drainage systems are examples of structural infrastructure, whereas land use laws, early warning systems, and insurance policies are examples of non-structural infrastructure.

According to research in by Sanyal and Lu, (2005) in Bangladesh, structural solutions were less successful than non-structural ones at lowering flood risks. The research contests that long-term sustainability and cost-effectiveness are better served by non-structural approaches like community-based flood management.

Similarly, Iwuoha et al., (2019) discovered that non-structural actions including community awareness and education were successful in lowering flood risks in Nigeria’s unplanned urban communities. The study also discovered that the best strategy for reducing flood risks was a mix of structural and non-structural solutions.

In contrast, research conducted in Ethiopia by (Ayalew and Yamagishi, 2005) discovered that structural solutions, such as levees and drainage systems, were successful in lowering the danger of flooding in populated areas. According to the study, successful flood risk mitigation requires both structural and non-structural approaches.

In Ghana, a study by Atubiga et al., (2023) discovered that structural interventions were insufficient to reduce the danger of flooding in unplanned communities. To execute successful flood risk reduction techniques, the study suggests a multi-stakeholder strategy engaging local authorities, people, and other stakeholders.

Ultimately, it can be said that successful flood risk reduction in unplanned urban settlements requires a combination of structural and non-structural techniques. Building sustainable and resilient communities requires non-structural measures including community-based flood control, awareness and education campaigns, and early warning systems. On the other hand, structural interventions like levees and drainage systems can reduce flood hazards immediately, but they require ongoing maintenance and may be expensive over time.

CHAPTER THREE

Research Methodology

3.1 Research Methods

This research sheds light on how well these precautions work to reduce flood risks in different contexts. The study used established qualitative methods of data collection.

Total research participants: 450, Informal discussions with 9 persons, conducted 21 key informant interviews, 16 Focus group discussions, and Questionnaire survey sections targeting 228 participants in 19 sections. This was supported by geographic and other observation of contexts and study areas. Descriptive statistical analysis is conducted successfully to summarize results and to generate recommendations

3.2 Methodology

To determine the most efficient structural and non-structural flood mitigation strategies, the research starts with thorough literature survey and literature analysis. The variables influencing these measures' efficacies are also noted in the literature study.

Survey, Key Informant Interviews (KIIs), Informal Discussions and Focus Group Discussions (FGDs) were used in the research to gather information and data relative to research objectives.

The below figure summarizes the research methodology adopted by the researcher:

Figure 3.1. Summary of Research Methodology. Source: Study 2023.

3.3 Sample Size and Sampling Techniques

A mix matrix of stratified random sampling and purposive sampling techniques are employed during the research on evaluating the efficacy of flood risk reduction measures.

3.3.1. Sample Size

Based on the sampling methods, geography, demography of the population, community size, and degree of accuracy needed, the sample size for this research is **450 participants in total.** The sample size is such that to ensure a sufficient sampling that is representative of the overall population as well as the risk, hazards, and vulnerabilities in the study area.

3.3.2. Stratified Random Sampling

In stratified random sampling, the target population will be divided into different segments, or strata, according to a variety of factors like age, gender, wage level, or region. To guarantee that the selection is representative of the entire population and study area, random samples are chosen from each stratum. For instance, Bushrod Island inhabitants in Greater Monrovia District are the target group in the assessment of the efficacy of flood mitigation measures. Age, gender, flood experience, flood mitigation knowledge, and residential area are just a few possible divisions of the strata. The researcher will then choose a random selection of locals from each stratum.

3.3.3. Purposive Sampling

Contrarily, purposive sampling entails choosing individuals who satisfy predetermined requirements that are pertinent to the study issue as key informants. This approach is helpful as the research wishes to investigate a particular group of people or when that group has distinctive traits or experiences. For instance, the researcher of this study decided to purposefully sample people who have been personally impacted by flooding in the study area or those who reside in high-risk flood zones and those in charge of policy and decisions when evaluating the efficacy of flood risk mitigation steps in Bushrod Island.

3.4. Data Collection Tools

3.4.1 Observation and Informal Discussion

Through systematic observations and informal dialogues, researchers have effectively investigated the physical environment in previous studies (Liew et al., 20221). In this particular study, the focus was on examining mitigation measures and their efficacies, flood hazard types across different locations, landscape conditions, and implementation techniques. Additionally, the researcher also observed the influence of floods and local factors, including building materials and construction techniques, climate, land use, and cultural and political factors. Furthermore, during the field survey, the researcher conducted nine (9) informal discussions as pilot for the data collection to engage in insightful discussions with residents from various spears of the communities. These conversations were tailored to each person's unique experience and were recorded for further analysis and verification purposes.

3.4.2. Key Informant Interviews (KIIs)

Key informant interviews have proven to be a valuable research tool according to previous research on the effectiveness of structural and non-structural measures (Raikes et al., 2023; Dawson et al., 2011; Mullins and Soetanto, 2011). In this study, the author conducted **twenty-one (21)** key informant interviews, both during and after the field survey, utilizing a combination of structured and unstructured approaches.

One KII per respondents were conducted from the following institutions: National Disaster Management Agency, (NDMA), Liberian Red Cross Society (LNRS), Ministry of Mines & Energy (MME), Environmental Protection Agency (EPA), National Center for the Coordination of Response Mechanism (NCCRM), Liberia Institute of Statistics & Geo-Information Services (LISGIS), National Meteorological Service (NHS), Liberia Hydrological Service (LHS), Monrovia City Corporation (MCC), Liberia Agency for Community Empowerment (LACE), Slum Dwellers Association of Liberia (SLUMPDAL), Ministry of Public Works (MPW), National Public Health Institute of Liberia (NPHIL), and National Housing Authority (NHA), International Federation of Red Cross (IFRC), Action Aid and Catholic Relief Service (CRS), and followed by the four local Government Leaderships.

3.4.3. Focus Group Discussions (FGDs)

Focused group discussions are a prevalent method employed in qualitative research to delve into research issues by tapping into the collective experiences of a homogeneous group of individuals (Mishra, 2016). This data-gathering technique has been extensively utilized when studying both pre- and post-disaster scenarios (Abdelaziz et al., 2022; Tariq et al., 2020; Kreibich et al., 2017). In line with the mixed methods approach adopted in this investigation, three (3) sections of focused group discussions (FGDs) were independently conducted with the residents of the townships in Vai Town, and four (4) FDGs sections each within the Townships of Clara Town, Logan Town, and New Kru Town respectively with twelve (12) participants each per sections. Additionally, four (4) sections of FDGs were conducted with the Fishing and Business Community of Bushrod Island. Another five days was scheduled for schools [fourteen (14) Junior and Senior Secondary Schools] within the four Townships. Each section of FDG had twelve (12) participants in attendance per section. The role of moderation was fulfilled by the researcher throughout the FGDs with the aim to maintain a focused discourse and effectively staying clear of any distractions that might hinder the exploration of the research questions and objectives. The conversations took place indoors and outdoors within the confines of the study locations. Both male and female participants felt at ease willingly sharing their perspectives and experiences on a unified platform. Table 3.1 below summarizes the Data Collection Methods:

Table 3.1. Summary of Data Collection Method.

	Target Groups	**Number of Participants**	**Number of Talk Section**	**Duration**
Informal Discussion	General Public	9 Persons	9	2 Days
Key Informant Interviews (KIIs)	Focus Persons of Ministries, INGOs and Agencies	21 Staffers	21	5 Days
Focus Group Discussions (FDGs)	14 Schools	192 Students	16	5 Days
Questionnaire Survey	Community Residents	180	15	5 Days
	Fishing and Business Community	48	4	2 Days
Total	------------------------	**450**	**63 Sections**	**19 Days**

Source: Study 2023.

3.5. Data Analysis Methods

The act of turning data into insightful information is known as data analysis. The combination of both qualitative and quantitative data analysis techniques is used in this investigation.

Information herein is gathered from first-hand observations, investigations, focus group discussions, in-depth interviews, and literature survey and reviews from the archives of relevant department, agencies, ministries, and organizations linked to the subject matter. This helped the researcher in making sure that all the data from the study and the archives were precise and trustworthy.

The source and kind of information gathered includes:

- Literature Review
- Historical Data
- Topographic Data
- Climatological Data
- Demographic Data
- Cost-Benefit & Damage Analysis

3.5.1. Quantitative Data Analysis

To examine the survey data, statistical analysis will used. We can find trends in the data and evaluate the efficiency of structural and non-structural flood risk reduction solutions using statistical analysis. The data are transcribed and analyzed using tools like version 22 of the Statistical Package for the Social Sciences (SPSS), Advanced Excel, and simple statistics. Odey (2019), Ajede (2021), and Oseji (2022) all used these statistical approaches to analyze the impacts of floods in Nigerian urban areas.

3.5.2. Qualitative Data Analysis

The information from the interviews will be examined using content analysis. In content analysis, themes and patterns are found in the data. This research used a system of classification to assess the transcripts after were transcribed from the interviews. To analyze the data, the researcher utilizes Google Cloud Platform (GCP) as a tool to transcribe audio interview data to text.

3.6. Research Participants

The research participants represent a fraction of the national demography of Liberia. The ages of participants range between 18 to 57 years with women accounting for 56% and male 44% respectively. While interview locations were also selected carefully based flood severity in the areas, respondents were also carefully and randomly selected based on their flood experiences and the duration of stay in their communities.

3.7 Study Area

Bushrod Island is a suburb community of Monrovia- the political capital city of Liberia. The Island is located in Montserrado County which is the most populated of all the 15 counties within the Country. Montserrado County is divided into four administrative districts; Careysburg District, Todee District, St. Paul River District, and Greater Monrovia District where the Bushrod Island is located. The Island is also divided into three (3) Zonal areas; (New Kru Town as Zone 100, Logan Town as Zone 200, both Clara Town and Vai Town as Zone 300).

The Island is geographically encircled by the Atlantic Ocean, Mesurado (Du) River, St. Paul River and Stockton Creek (the tidal channel that connects both the St. Paul and Mesurado rivers). The island measures approximately 19 km^2 in area (7.5 by 2.5 kilometers in length and width), respectively, and rises on average 3 meters above sea level. Due to its low elevation and location in a delta area, the island is extremely vulnerable to flooding. The Island consists of four (4) Townships namely: **New Kru Town, Logan Town, Clara Town, and Vai Town** respectively. The Island consists of 37 communities 14 of which are settlements with high risk of flooding. The Bushrod Island has a population of 402,799 inhabitants.

Map of Study Area

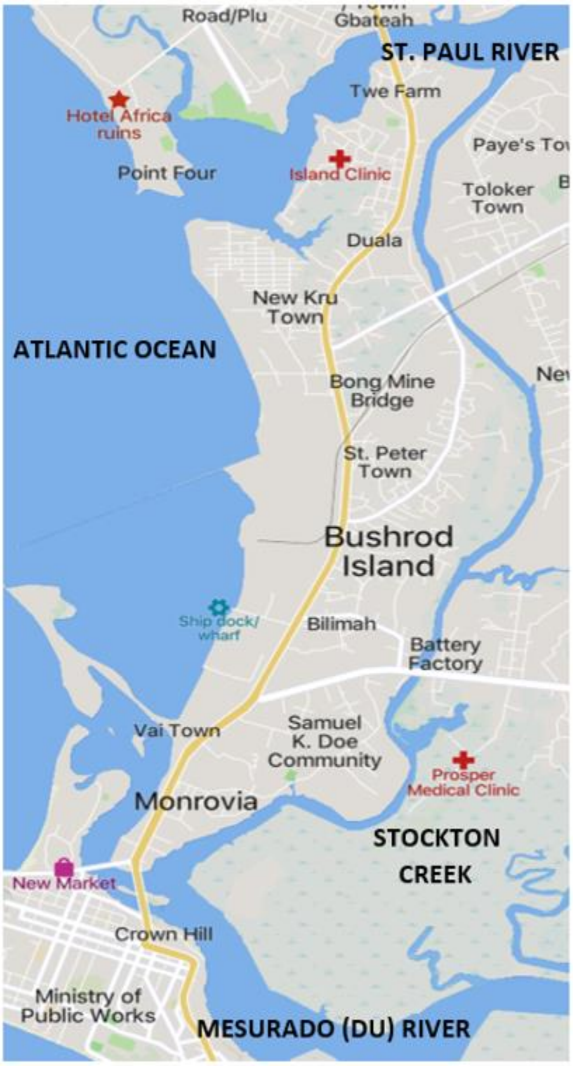


Figure 3.2 Map of Bushrod Island (Study Area).

3.7.1. Geography of Study Area

A low-lying land with an elevation of 10-38 meters above sea level. The area consists of weathered quartz-rich kaolinitic clay-consisting of interlocking clay and very fine to fine quartz sand which is a factor for the low water absorption ability of the soil.

- **The Mesurado/Du River:** A significant river that flows through Monrovia, the country's capital, before emptying into the Atlantic Ocean is the Mesurado River, also known locally as Du River. The river's starting point is thought to be about 30 meters (98 feet) above sea level, and its total length is approximately 25 kilometers (16 miles). Sinda Town, which is located immediately to the east of Monrovia, is the main source of the Mesurado River.
- **St. Paul River:** St. Paul is one of the six major rovers in Liberia. It occupies 9 percent of the Country's basin area. The 475 km long river has 1730 km^2 of basin area in Liberia and a total basin area of 19617 km^2 respectively. It hosts the Country's largest hydropower Dam (Mt. Coffee Dam) and the White Plains water treatment plant.

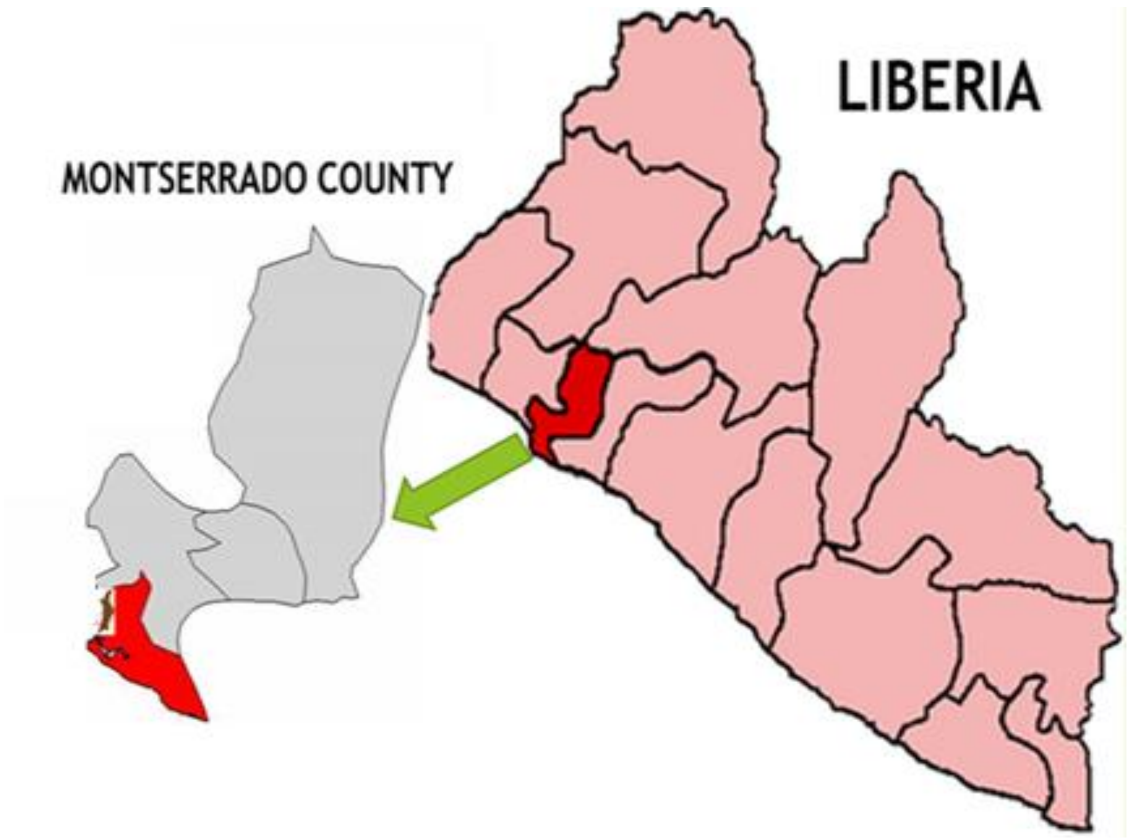


Figure 3.2. (A & B). (Left) Map of Montserrado County with Greater Monrovia District and Map of Liberia (Right).

CHAPTER FOUR

Flood Hazard Risks, and Flood Vulnerabilities

4.1. Flood Hazard Risks of Bushrod Island

Bushrod Island in Liberia's Greater Monrovia District is prone to recurrent flooding, posing serious risks to the local populace and infrastructure. To lessen the effects of floods in this area, effective flood risk assessment and mitigation strategies are essential. This chapter examines the flood risks that Bushrod Island faces, investigates ways to assess flood risks, and suggests localized flood risk reduction tactics.

In addition to coastal flooding from storm surges, Bushrod Island is also susceptible to riverine flooding from the nearby Mesurado River, backed-up urban drainage systems, and other flood hazards. Risks to the populace are made worse by the Island's low-lying topography, insufficient drainage systems, and the unplanned settlements (Jones, 2022).

Floods on Bushrod Island's unplanned settlements can be categorized into three main groups: riverine, pluvial, and coastal floods. The causes, traits, and effects of these floods on populated areas vary. Each of these flood types and their characteristics in unplanned urban settlements will be covered in this section.

4.1.1. Coastal Floods

When the land near the coast is submerged by seawater, coastal floods happen. They may be brought on by storm surges, tsunamis, or the sea level rising as a result of climate change. Coastal floods can be particularly devastating in unplanned urban areas because they can destroy structures and infrastructures close to the coast. Coastal floods can also have negative effects like soil erosion, crop and fishery damage, and fatalities. Cities like Lagos, Accra, and Monrovia in West Africa are frequently affected by coastal flooding because of factors including urbanization, rising sea level, and insufficient coastal defense systems (Awoyemi et al., 2020).

Figure 4.1 (A & B). Image A-(Top) Shoreline of Popo Beach eroded by Coastal Floods. Image B-(Bottom) Six Bedrooms house damage by sea erosion in New Kru Town, Bushrod Island.

Source: Study Survey Data 2023.

4.1.2. Pluvial Floods

When drainage systems are overwhelmed by heavy rainfall, pluvial floods, also referred to as flash floods, happen, inundating low-lying areas. Due to inadequate drainage systems, poor planning, and rapid urbanization, pluvial floods are frequent in unplanned urban settlements. Urbanization has increased runoff and reduced infiltration in West African cities like Freetown and Monrovia, where rainfall patterns have become more erratic due to climate change (Haque et al., 2019). Pluvial floods can kill people and harm crops, infrastructure, and buildings.

Figure 4.2 (A & B). Image A (Top). Partial view of an inaccessible road and bridge due to Pluvial Floods. Image B (Bottom) Flooded house caused by prolonged 7 days rainfall.

Source: Study Survey Data 2023.

4.1.3. Riverine/Fluvial Floods

Figure 4.3 (A & B). Image A-(Top) Vehicles being submerged by Riverine Floods in Tweh Farm Community, Duala along the St. Paul River. Image B-(Bottom) A Community Road flooded by Riverine Floods on Jamaica Road Community along the Stockton Creek.

Source: Study Survey data 2023.

When a river's banks are breached, flooding in the surrounding areas occurs. Heavy rain, snowmelt, or dam releases can all result in riverine floods. Riverine floods, which can result in the destruction of structures and infrastructure close to the riverbanks in unplanned urban settlements, can be particularly devastating. In addition to causing soil erosion, harm to fisheries and crops, riverine floods can also result in fatalities. In West African cities like Lokoja, Monrovia, and Bamako, where urbanization has increased encroachment on river floodplains and decreased rainwater infiltration, riverine floods are frequent occurrences (Olalekan and Akinnawa, 2020). Mesurado River, St. Paul River, and Stockton Creek are the major conveyor of floods on the Bushrod Island.

Given the aforesaid, the three main types of flood hazard risks that occur on Bushrod Island's unplanned urban settlements are **coastal, pluvial, and riverine/fluvial floods**. The causes, traits, and effects of these floods on populated areas vary. While pluvial floods can damage buildings, infrastructure, and crops, coastal floods can destroy structures close to the coast/shorelines. Buildings and infrastructure close to riverbanks may be destroyed by riverine floods. To minimize the effects of floods in unplanned urban settlements, it is imperative to develop flood risk management strategies that take into account the characteristics of each type of hazard risk.

4.2. Flood Risk Assessment

Understanding the scope and potential effects of flooding on Bushrod Island requires a thorough assessment of the risk of flooding. The risk assessment covers a methodical examination of the risks from flooding, the exposure of weak points, the susceptibility and capacity of the affected population.

4.2.1. Hazard Mapping

For the purpose of locating areas at a high risk of flooding, flood hazard zones must be mapped. Analyzing past flood data, rainfall patterns, river discharge rates, and storm surge modeling are some of the things that are involved in this (Samuels et al., 2020). These hazard maps support informed land-use planning decisions by identifying flood-prone areas.

4.2.2. Exposure Evaluation

Insights into the potential effects of flooding were gained by evaluating the exposure of at-risk elements, such as residential areas, crucial infrastructure, and vital facilities. To map and analyze the exposure of vulnerable elements, available geographic information system (GIS) data were evaluated as used by (Smith, 2019).

4.2.3. Vulnerability and Coping Capacity Assessment

Flood risk assessment requires a thorough understanding of the population's vulnerability as well as its capacity. This entails assessing socioeconomic variables, housing situations, accessibility to essential services, and community resilience (UNISDR, 2009). Community consultations and participatory methods helped reveal important local vulnerabilities.

4.3. Vulnerabilities Associated with Flood Hazard Risks

Due to multiple reasons, including its geography, climate, and land-use patterns, Bushrod Island is susceptible to floods. The terrain is characterized by steep slopes, which raises the danger of erosion and flash flooding. The risk of riverine flooding is increased by the country's significant rainfall during the rainy season. The risk of floods is further increased by unplanned urban populations, deforestation, and inadequate drainage systems. Physical, socioeconomic, environmental, health, social, technical, and governance vulnerabilities are just a few of the various kinds of flood vulnerabilities that exist. The overall flood vulnerability of an area is influenced by the distinctive traits of each category of vulnerability.

4.3.1. Physical Vulnerabilities

Infrastructure, structures, and other tangible assets are referred to as having physical vulnerabilities because they are vulnerable to flooding. Floods can seriously harm structures, bridges, roadways, and other essential infrastructure, resulting in property losses, evictions, and even fatalities. For instance, Duah and Owusu (2018) found that physical vulnerabilities, such as the placement of buildings in flood-prone regions, greatly impacted the flood susceptibility of the community in their research on flood vulnerability in Ghana. However, in the unplanned settlements of Bushrod Island, flooding has led to damage to physical assets and infrastructures such as building collapse, land subsidence on major roads, the impact of coastal flooding on the public infrastructures (Redemption Hospital and D. Tweh High School) in New Kru Town amongst others. The Government of Liberia (GoL) in 2020 through the National Housing

Authority (NHA) and the Liberia Agency of Community Empowerment (LACE) constructed 100 housing units of two-bedroom apartments for fire and coastal floods victims who lost their properties and assets. The relocation of the Redemption Hospital from New Kru Town to Upper Caldwell Community are some of the GoL mitigation initiatives.

4.3.2. Environmental Vulnerabilities

The natural environment's sensitivity to the danger of flooding is referred to as an environmental vulnerability. For instance, by altering the natural hydrological cycle and lowering the soil's ability to absorb water, deforestation, land use change, and poor land management techniques can raise the risk of flooding (Brouwer et al., 2018).

Due to its proximity to the Atlantic Ocean, Bushrod Island is vulnerable to coastal erosion, which has worsened flooding risks and threaten infrastructure and settlements along the coastline. The Island’s low-lying nature and geological composition may lead to land subsidence, increasing flood susceptibility and affecting the effectiveness of flood mitigation measures.

Flooding can result in soil and water contamination, potentially impacting the health and livelihoods of the local population and complicating recovery efforts. Urbanization and flood control measures have led to the loss of wetlands, reducing natural flood absorption areas and exacerbating flooding in the settlements.

Flood events have deteriorated the water quality in several parts of Bushrod Island, affecting drinking water sources and creating health hazards for the community. Floods negatively impact the local flora and fauna, leading to potential disruptions in the ecosystem and ecological balance.

The effectiveness of flood mitigation measures is influenced by changing climatic conditions, such as increased rainfall intensity or rising sea levels.

Floodwaters have a detrimental impact on coastal marine habitats mostly owing to the creeping saline intrusion, increase turbidity, as well as contaminants such as chemicals, heavy metals, and debris. These have the potential to destroy aquatic ecosystems, decrease water quality, limit coastal production, and pollute coastal food supplies.

4.3.3. Health Vulnerabilities

The term "health vulnerabilities" describes how vulnerable people or groups are to the health dangers posed by floodwaters. Due to contaminated water sources, floods can cause waterborne illnesses like cholera, dysentery, and typhoid (Pande & Shinde, 2016). Floods can also have negative effects on one's bodily and emotional well-being. In the case of Bushrod Island, the frequent outbreak of waterborne diseases such as malaria, diarrhea and cholera due to the impact of flooding cannot be underestimated. Statistics from national public health institute of Liberia, (NPHIL) during the Ebola and Corona Virus outbreaks showed an increase in the number of cases during the rainy season where flooding occurred.

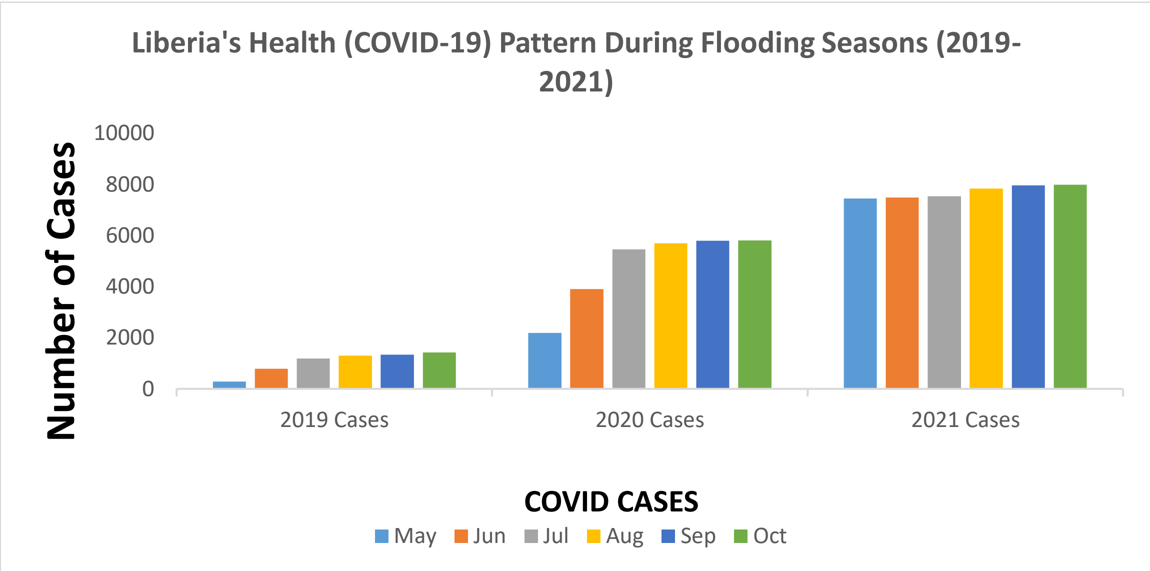


Figure 4.4. Health (COVID-19) Vulnerability Pattern during Flooding Seasons (2019-2021). Source: National Public Health Institute of Liberia 2022.

4.3.4. Economic Vulnerabilities

Economic risks describe how some people or groups are more vulnerable to flooding danger than others as a result of their economic standing. Communities and low-income families are more likely to experience significant flood effects because they have less access to resources like money and insurance. (Ologunorisa, 2019). The absence of early notification systems, evacuation facilities, and medical treatment, among other crucial resources, can also cause socioeconomic vulnerabilities. Flooding in Monrovia has over the period created situations that lead to days of absence at work and at school, obstruction of businesses, or even loss of livelihood as in the case of many residents on Bushrod Island including the fishing communities of Fanti Town and Popo Beach areas in the Borough of New Kru Town.

Figure 4.5 Impact of Coastal Flood with Livelihood Vulnerability Scenarios. Image A (Top) Fishing Depot of Popo Beach in (2015) Vs Image B (Bottom) Fishing Depot in 2023.

Source: Study Survey Data 2023.

4.3.5. Social Vulnerabilities

Social vulnerabilities are defined as a person's or a group's vulnerability to the social dangers connected with flooding. Social unrest brought on by floods may include eviction, relocation, and loss of income. Cultural and societal norms that prevent some groups, like women, from participating in decision-making processes connected to flood risk management can also lead to social vulnerabilities (Kelman et al., 2018). The obstruction of movement of persons and delivery of goods and services during flooding events are among few of the social vulnerabilities on Bushrod Island. Lateness or absence from work or school is inevitable.

4.3.6. Technological Vulnerabilities

The term "technological vulnerabilities" describes how susceptible technology is to the danger of flooding. For instance, floods have the potential to seriously harm vital technological structures, such as electricity lines, communication networks, and transit systems (Narayan et al., 2018). Monsoonal rainfall is usually accompanied by strong wind/storm surges that usually impose serious damage to technological infrastructures like telecommunications towers and electricity poles thereby causing disruption to phone calls and internet services on Bushrod Island is recurrent.

4.3.7. Governance Vulnerabilities

Governance risks describe how vulnerable a system's water risk is. Corruption, a lack of accountability, and a lack of public involvement are examples of poor governance practices that can make a town or area more vulnerable to flooding (Bubeck et al., 2013).

In summation, it is crucial to comprehend the numerous kinds of flood vulnerabilities to create successful flood risk management plans. Policymakers, practitioners, and academics can create focused initiatives to address the underlying causes of flood risk and lessen the population's total susceptibility by finding the specific vulnerabilities that exist in a given community or area.

4.4 Flood Generation Mechanisms

There are multiple mechanisms responsible for generating floods. This research is narrowed down to the following based on informed decision from the Questionnaire Survey and FDGs:

Table 4.1. Quantitative Analysis of Perceptions for Flood Generating Mechanisms.

Flood Generation Mechanisms							**(N=420)**
S/N	**Mechanisms**	**Response**	**Frequency**	**(%)**	**Response**	**Frequency**	**(%)**
1	River Basin/Catchment Characteristics	YES	294	70	NO	126	30
2	Topographic Mechanisms	YES	378	90		42	10
3	Population						
a.	Population Density	YES	315	75	NO	105	25
b.	Construction in Floodplains	YES	328	78	NO	92	22
c.	Overcrowded Infrastructures	YES	361	86	NO	59	14
4	Climatic Mechanisms						
a.	Precipitation	YES	370	88	NO	50	12
b.	Sea-Level Rise	YES	252	60	NO	168	40
c.	Wind/Storm Surges	YES	210	50	NO	210	50
d.	Climate Change/Global Warming	YES	336	80	NO	84	20

Source: Study Field Data 2023.

4.4.1 River Basin/Catchment Characteristics

St. Paul River: St. Paul is one of the six major rovers in Liberia. It occupies 9 percent of the Country's basin area. The 475 km long river has 1730 km^2 of basin area in Liberia and a total basin area of 19617 km^2 respectively. The St. Paul River hosts the Mt. Coffee Dam- (the Country's largest hydropower Dam) and the White Plains Water Treatment Plant.

The basin and catchment characteristics of the St. Paul and Du Rivers per this research is are bound by the LHS gauging stations in Monrovia and the Haindi; upstream the Mt. Coffee Hydro Dam as seen in the table below:

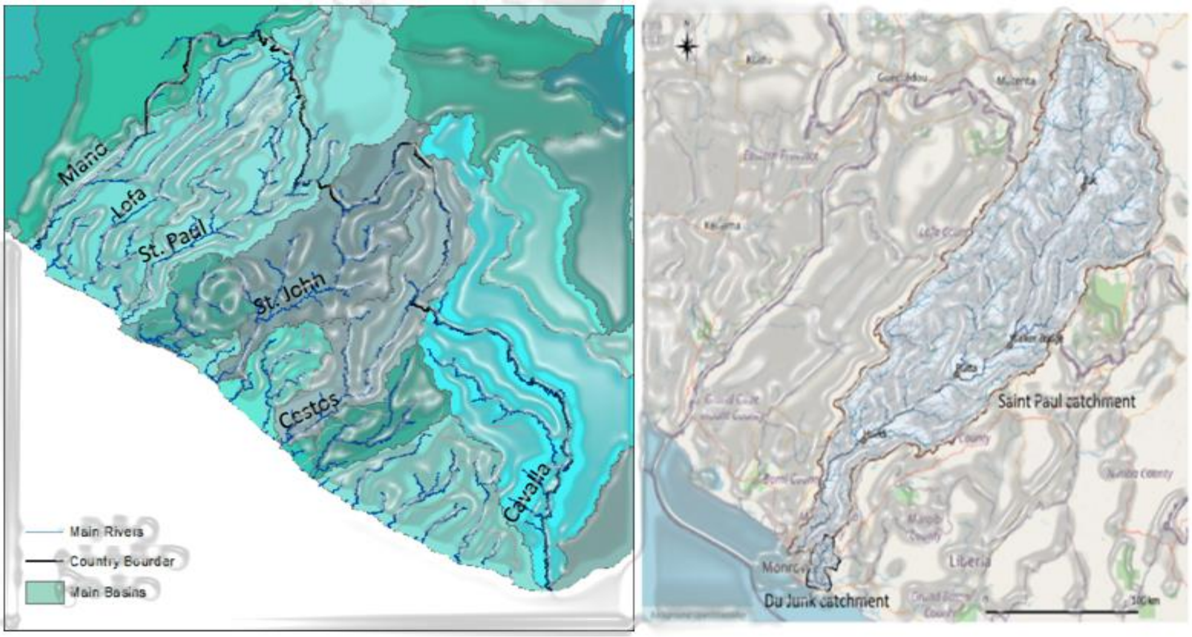


Figure 4.6 (A & B). Image A-(Left) Relief Map of Liberia indicating the six major River Basins. Image B-(Right) St. Paul River Basin and Du Junk Catchments. Source: Liberia Hydrological Service, 2023.

Table 4.2. St. Paul River/Catchment Characteristics.

St. Paul River Gauging Station		**Time Series**		**Catchment**	
River	St Paul River	Start Date	26-Apr-2012	Area	18276 km^2
Basin ID	04 St. Paul 001	End Date	26-Sep-2022	Stream Length	381 km
Location	10.36175 °N 6.90211 °W	Water Year	May to April	Minimum Elevation	130 m
Rating Curve	Developed with 60 recordings of flows within the range 40.8m3/s to 1750m3/s	Minimum Daily Flow	7.847 m3/s, 25/03/2022	Maximum Elevation	1610 m
		Maximum Daily Flow	2397 m3/s, 14/09/2016		
		Mean Flow	473.68 m3/s		
		Mean Specific Flow	26l/s/km2		
		Mean Annual Catchment Run-off	817 mm		
		Gap Filled	<1%		

Source: Liberia Hydrological Service, 2023.

4.5 Human-Induced Mechanisms

The elements of human actions or human activities that cause flooding in the study area are summarize in the figure below:

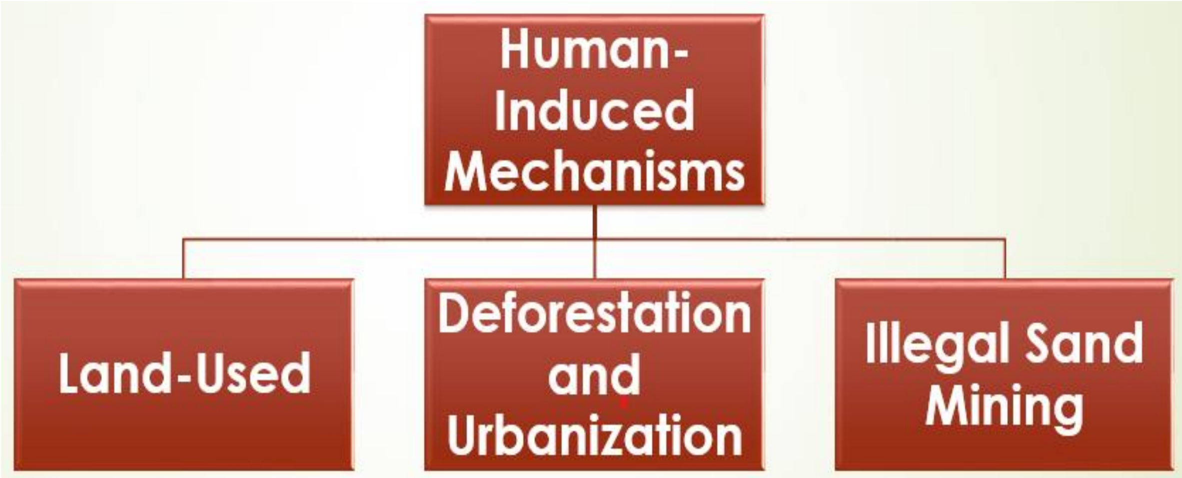


Figure 4.7. Elements of Human-Induced Mechanisms.

4.5.1. Land-Use

Land-use is the term used to describe how humans use, manage, or develop land. Certain land-use activities might require changing the natural landscape and drainage patterns which result in flooding. Data from LISGIS and NHA shows Bushrod Island's land-use patterns from 2008 and 2020 as seen below in the table:

Table 4.3 (A & B). Bushrod Island's Land-Use Variation Data (2008 & 2020).

2008		**Residential**				Indust	Com	Total	Total	Habitable	Unlivable	Total
Zone		Ext. Low Den.	Ext. High	On-going	Total Reside			(Net)	(Net)/H	Area	Area	Area
		(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(%)	(ha)	(ha)	(ha)
100	**New Kru**	213	46	1	260	14	26	300	72	416	97	513
200	**Logan Town**	171	33	0	204	21	29	254	52	489	135	624
300	**Clara Town**	54	8	90	152	3	24	179	80	225	17	242
Total		**438**	**87**	**91**	**616**	**38**	**79**	**733**	**204**	**1,130**	**249**	**1,379**

2020		**Residential**					Indust	Com	Total	Habitable	Unlivable	Total
Zone		Low	Medium	High	On-going	Total			(Net)	Area	Area	
		(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)	(ha)
100	**New Kru**		146	123		269	16	29	314	410	103	513
200	**Logan Town**		80	110		190	50	23	263	504	120	624
300	**Clara Town**		57	75		132	7	48	187	232	10	242
Total		**-0-**	**283**	**308**		**591**	**73**	**100**	**764**	**1,146**	**233**	**1,379**

Source: Liberia Institute of Statistics & Geo-Information Services and National Housing Authority.

4.5.2. Deforestation and Urbanization

Plants and trees retain moisture and stop soil erosion. The amount and speed of surface water runoff can increase due to deforestation, particularly in hills and mountains, leading to flooding downstream. Development that includes the construction of structures such as homes, roads, and other buildings results in the creation of impermeable surfaces that stop water from penetrating the soil. Due to the increased volume and speed of surface water runoff, metropolitan areas may experience floods.

4.5.3. Illegal River/Beach Sand Mining

Sand mining changes the natural environment by generating erosion, widening waterways, riverbank collapse, and water pollution. These actions exacerbate coastal or riverine flooding in the surrounding neighborhoods. Illicit River and beach sand mining along the coast of New Kru Town, along the St. Paul and Mesurado Rivers as well as the Stockton Creek for commercial and personal used has posed serious threats of recurrent flooding events.

4.6 Population

4.6.1. Population Density of Settlements at High Risks.

The number of people living in flood-prone locations is growing as the world's population rises, which raises the danger of floods. Having a high population density might cause floods in the following ways. The population of Monrovia increased from 970,824 in 2008 to 1.6 million in 2022 while that of Bushrod Island also increase from 282,529 in 2008 to 452,103 respectively. Gonz, (2019) identified settlements of Bushrod Island with high flood risk along with their population density at risk using QGIS.

Table 4.4. Bushrod Island Population and Population Density of Settlements at High Risks.

Year	**Population**	**Growth Rate**	**Settlements @ High Risk of Flood**	**Population Density**	**Flood Risk** 0.1469 – 1.0241
2008	282,529		Tweh Farm	0.813167	0.8411
2009	293,180	3.77%	Duala	0.827505	0.9285
2010	294,172	3.73%	Popo Beach	0.810226	0.8596
2011	305,321	3.79	New Kru Town	0.608476	0.9230
2012	316,740	3.74	Point Four	0.594170	0.7727
2013	328,712	3.78	Bong Mine Bridge	0.543080	0.8576
2014	340,927	3.73	St. Peter Town	0.674253	0.8585
2015	353,745	3.76	Logan Town	0.843481	0.8724
2016	367,116	3.78	Sayon Town	0.858464	0.8824
2017	380,772	3.72	Jamaica Road	0.894663	0.9128
2018	394,974	3.73	Bilimah	0.900243	0.8662
2019	408,640	3.46	Caldwell Road	0.537743	0.8761
2020	422,574	3.41	Clara Town	0.908752	0.9872
2021	437,068	3.43	Vai Town	0.871447	1.024
2022	452,103	3.44			

Source: Study Survey Data 2023, & Liberia Institute of Statistics & Geo-Information Services.

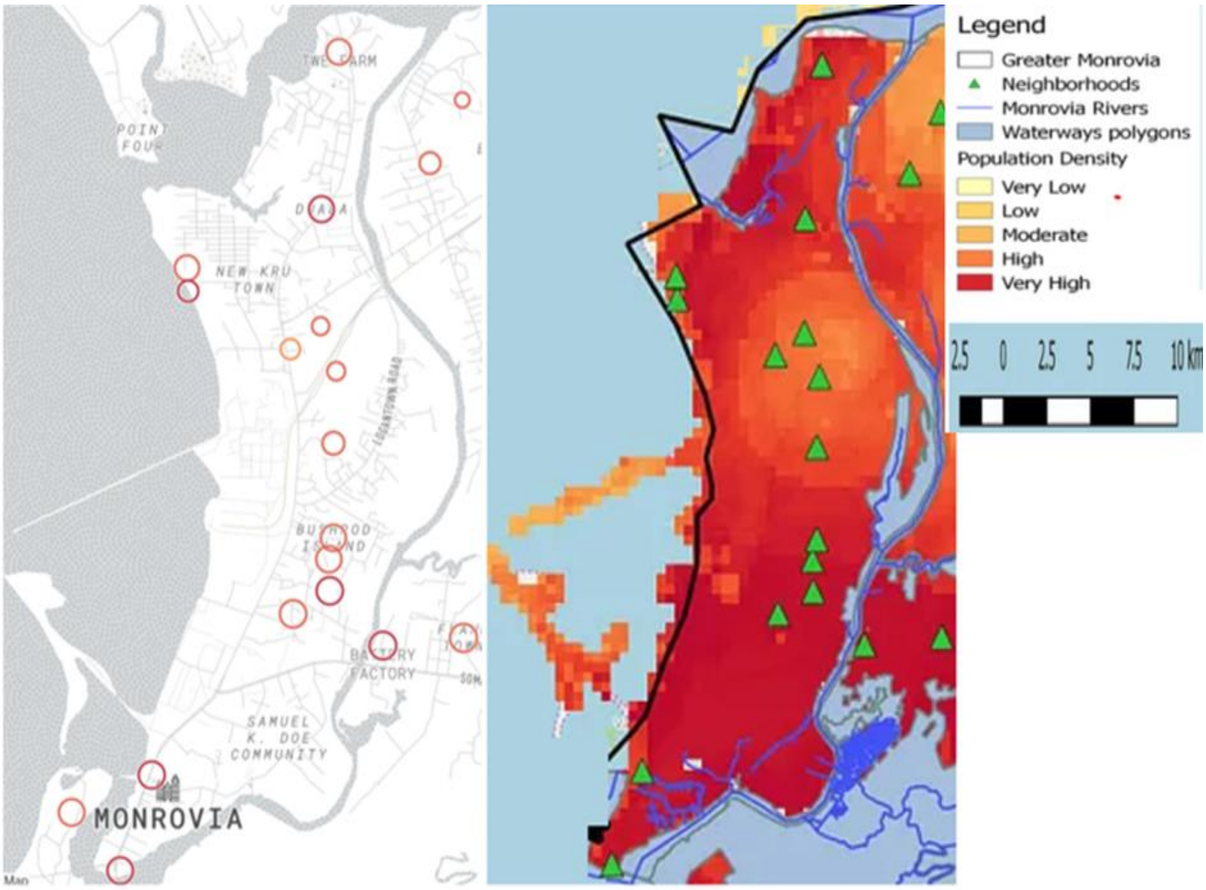


Figure 4.8 (A & B). (Left) Hazard Map of Settlements with high flood risks (B. Right) Risk Map of Bushrod Island Indicating Population Density at Risk of Flood Hazards.

Source: National Disaster Management Agency, 2021.

4.6.2. Construction in Floodplains

Urbanization is frequently a result of population increase, and as cities grow, unplanned settlements are frequently established in flood-prone locations. During a flood event, this may result in major property damage and fatalities. More recently, the city has expanded to encompass the low-lying, mangrove-filled eastern portions of Bushrod Island as well as the Stockton Creek and Mesurado estuary regions, which are normally mangrove swamps that have been cleared for development. The slum communities have areas of perpetual standing water that are utilized for inappropriate waste disposal thus posing a health risk.

4.6.3. Overcrowded Infrastructures

As more people settle in a region, the sewage and drainage systems may be unable to handle the extra demand. Flooding may result from this during periods of heavy precipitation.

4.7 Topographical Mechanisms

Bushrod Island is a low-lying land with an elevation between 3-30 meters above sea level. The area consists of weathered quartz-rich kaolinitic clay- consisting of interlocking clay and very fine to fine quartz sand which is a factor for the low water absorption ability of the soil.

Around 5 and -8.9mm of land deformed between the years 2004 and 2020. In Clara Town specifically, a mean deformation of 1mm/year was found (World Bank, 2019). The upward and downward deformation appears to be dispersed over the whole region with a little discernible pattern that would imply that subsidence may worsen flood danger for significant areas. This translates to 0.15 and -0.27 meters in 2050 assuming a constant change (World Bank, 2019).

The Bushrod Island includes a coastal strip to the east, as well as the west-facing side of the Island, which is bordered to the south and north by the estuaries of the Mesurado and St. Paul rivers and to the east by Stockton Creek. This area includes New Kru Town, Logan Town, Clara Town, Freeway, and the Harbor area. Nearly wherever you look, you can see pockets of low-lying wetlands made up of mangroves in the Mesurado and parts of wetlands terrain.

Overall, the major topographic elements include the *abundance of swamps and wetlands, proximity to water bodies, low elevation.*

4.8 Climatic Mechanisms

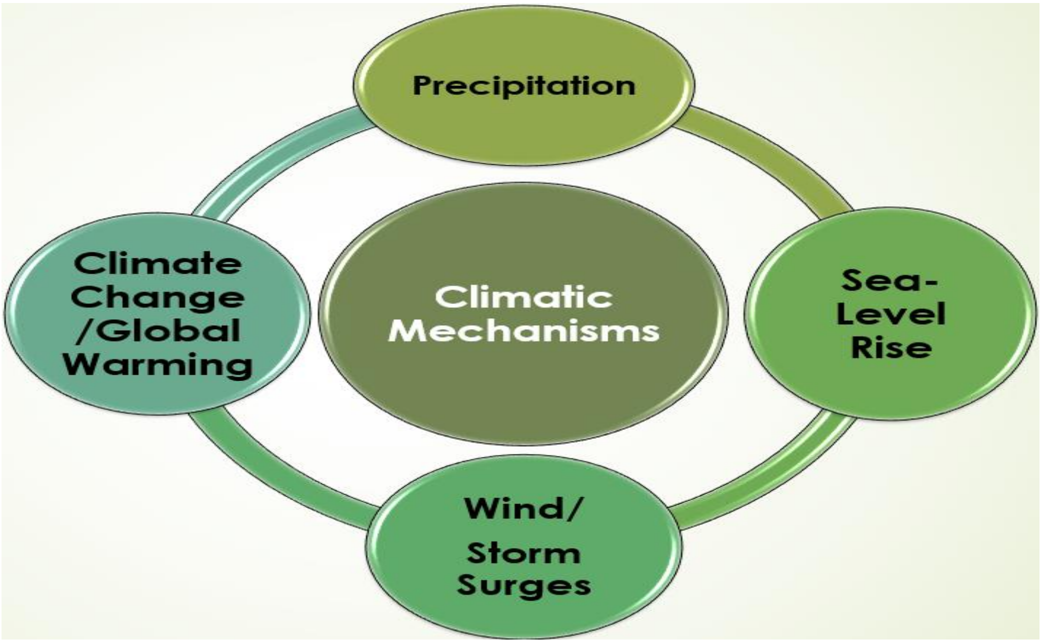


Figure 4.9 Elements of Climatic Mechanisms.

4.8.1. Precipitation

A day in Monrovia is considered to be wet if there have been at least 1.0 mm of liquid or liquid-equivalent precipitation. There is a larger than 32% probability of rain on any given day during the 6.4-month-long wetter season, which runs from April 18 to October 30. With an average of 18.1 days with at least 1.0 mm of precipitation, August is the month with the rainiest days in Monrovia. August, with an average of 18.1 days, is the month with the rainiest days in Monrovia. According to this classification, rain alone has the highest likelihood of all types of precipitation, peaking at 61% on the 28th of August. Monrovia enjoys substantial seasonal fluctuation in monthly rainfall since the rain falls throughout the year in Monrovia. The month with the greatest rain in Monrovia is September, with an average rainfall of 282 mm. January has the least rain in Monrovia, with an average rainfall of 10.2 mm.

4.8.2. Sea-Level Rise

The coast of Liberia is expected to experience an increase in sea level rise, which will increase the frequency of flooding in coastal cities, particularly Monrovia. It has been estimated that a 1-meter rise in sea level would put an estimated 230,000 people at risk annually and cause a loss of 2,150 square kilometers of land and infrastructure valued at US$250 million. Because of increased flooding brought on by sea level rise, Liberians will also be more susceptible to epidemics of cholera, cholera-like illnesses, and diarrhea, as well as more cases of water-borne diseases. Due to its high mortality rate, malaria poses the biggest threat to public health.

4.8.3. Wind/Strom Surges

All through the year, Monrovia experiences seasonal variations in the direction of the city's average hourly wind. From May 1 to December 17 (seven and a half months), the wind is most frequently from the south, reaching a peak percentage of 87 percent on June 25. For four and a half months, from December 17 to May 1, the wind is most frequently out of the west, reaching a peak percentage of 44% on January 1.

From June 4 to October 14, which is a period of four and a third months, there are more winds than seven and a half miles per hour on average. August, when winds in Monrovia average 10.3 miles per hour, is the windiest month of the year. Between October 14 and June 4, there are seven and a half months of relative calm. With an hourly wind speed of 5.2 miles per hour on average, December is the calmest month of the year in Monrovia.

4.8.4. Climate Change/Global Warming

As the population expands, energy usage rises, increasing greenhouse gas emissions. As a result of global warming, meteorological disasters like floods may become more common and severe. Liberia's annual CO_2 emission from the fuel industry increased from 1.13 million tons in 2020 to 1.20 million tons in 2021 (Ritchie et al., 2020). A major contributing factor to flooding is global warming, which raises average global temperatures. More water evaporation from the Earth's surface occurs as temperatures rise, increasing atmospheric moisture. In low-lying areas, this increase in moisture may result in more frequent and severe rainfall events that can cause flooding. In addition, glaciers and ice caps may melt as a result of global warming, raising sea levels. Coastal areas are more vulnerable to flooding from storms and high tides as the sea level rises. Sea level rise can have a significant impact on coastal communities, causing property damage, habitat loss, and population displacement.

And finally, as a result of altered weather patterns brought on by global warming, storms may become more frequent and intense. When these storms hit, rivers may overflow and there may be flash flooding as a result of the heavy rain and strong winds they produce.

In conclusion, increased atmospheric moisture, rising sea levels, and altered weather patterns are all significant causes of flooding. To lessen the frequency and severity of flooding events and to lessen their effects on communities and ecosystems, it is crucial to address the underlying causes of global warming.

4.9. Factors Affecting the Effectiveness of Mitigation Measures.

The factors were assessed from the combination of both the Questionnaire Survey and FDGs conducted with participants of the research which informed the researcher of the underlying factors affecting the effectiveness of the mitigation measures implemented on the Bushrod Island. The below table contains summaries of how respondents perceived these factors along with the frequencies of their perceptions:

Table 4.5. Quantitative Analysis of Perception for Factors Affecting the Effectiveness of Mitigation Measures.

Factors Affecting The Effectiveness of Mitigation						**(N=420)**	
S/N	**Factors**	**Response**	**Frequency**	**(%)**	**Response**	**Frequency**	**(%)**
1	Political Will & Governance Framework	YES	450	100	NO	0	0
2	Capacity	YES			NO		
3	Infrastructure Availability	YES					
4	Community Engagement & Participation	YES	332	79	NO	88	21
5	Climate Change	YES	450	100	NO	0	0
6	Funding & Financial Resources	YES	357	85	NO	63	15
7	Land-Use Practice	YES	336	80	NO	84	20
8	Technical & Engineering Design	YES	317	75	NO	105	25
9	Environmental Context	YES	361	86	NO	59	14
10	Integration & Coordination	YES			NO		
11	Awareness & Adaptive Management	YES	319	76	NO	1001	24

4.9.1. Political Will and Governance Framework

In West Africa, political will has a significant impact on how well flood risk mitigation measures work. Governments in the area must give flood risk management a high priority and devote enough resources to its implementation. There might be conflicting priorities in some situations, such as infrastructure development taking precedence over flood risk reduction.

The policy and governance framework in place has an impact on how effective flood mitigation measures are. The efficacy of measures can be increased, and their long-term sustainability ensured, by having clear policies, regulations, and enforcement mechanisms related to flood risk management.

Participants overwhelmingly agreed 100% about this factor being a major impediment to the effectiveness of mitigation efforts in the study area.

4.9.2. Capacity

The technical know-how and human resources needed for effective flood risk management must be sufficient. The technical know-how and skilled labor required to plan and put in place flood risk management measures, however, are in short supply in many West African nations which include Liberia. Lack of funding for training and education programs are few of the causes of this shortage.

4.9.3. Infrastructure Availability

The standard and availability of infrastructure also affect how well flood risk reduction measures work. For instance, adherence to building code and effective drainage systems and flood barriers require suitable infrastructures. The effectiveness of measures to reduce flood risks on Bushrod Island consistently hampered by the lack of inadequacy of infrastructures.

4.9.4. Community Engagement and Participation

The success of flood risk management strategies depends on community participation. By ensuring that flood risk management strategies are adapted to local needs and priorities, involving communities in their planning and implementation can increase their effectiveness. However, in some circumstances, communities' opposition to flood risk management measures may limit their efficacy. The community's involvement and participation in the planning, implementation, and upkeep of flood mitigation measures are essential to their success. By involving the community, policies are customized to meet local needs and are implemented with support from the community.

4.9.5. Climate Change

Effective flood risk management strategies are significantly impacted by climate change. The likelihood of flooding in the area will rise as a result of climate change-related increases in rainfall frequency and intensity. To account for these shifts in weather patterns, robust flood risk management strategies must be developed to match the current realities.

4.9.6. Funding and Financial Resources

For the implementation of flood risk management measures, funding is essential. The effectiveness of flood risk management strategies is hampered in many cases by funding constraints. To pay for flood risk management measures, governments in West Africa, particularly Liberia, may need to look to external funding sources such as foreign aid or loans. The effectiveness of flood mitigation measures can be significantly impacted by the availability of financial resources and funding for their implementation and maintenance. Both structural and non-structural measures must be implemented, as well as ongoing monitoring and maintenance, which all require adequate funding.

4.9.7. Land-Use Techniques

The effectiveness of flood risk management strategies can also be influenced by land-use practices. By decreasing the ability of forests to absorb rainfall, for instance, deforestation can raise the risk of flooding. Additionally, by reducing the amount of land available for infrastructure development, unplanned settlements in urban areas can reduce the efficacy of flood risk management measures.

4.9.8. Technical and Engineering Design

The effectiveness of the flood mitigation strategies put in place can be influenced by their size and scope. It is more likely that a measure will be successful if it is properly designed and implemented at the right scale to address the localized flood risks.

For flood mitigation measures to be effective, they must be technically designed and engineered. To ensure the functionality and resilience of structures like levees, flood walls, and drainage systems, proper design, construction, and maintenance are crucial.

4.9.9. Environmental Context

The effectiveness of flood mitigation measures can be impacted by the environmental context which includes the physical geography, hydrological characteristics, and climate patterns of a region. For the purpose of choosing appropriate solutions and assessing their efficacy, it is crucial to comprehend the particular environmental circumstances.

4.9.10. Integration and Coordination

Effective mitigation depends on the coordination and integration of the various stakeholders and industries involved in flood risk management. Collaboration between government organizations, community groups, and other relevant parties ensures a thorough and well-coordinated approach to flood mitigation.

4.9.11. Awareness and Adaptive Management

Enhancing the efficacy of flood mitigation measures requires the capacity to adapt and draw lessons from the past. Adjustments and improvements are possible thanks to ongoing monitoring, evaluation, and feedback mechanisms, which are based on lessons learned.

To conclude, given the region's susceptibility to flooding, effective flood risk management is essential in Bushrod Island and Liberia as a whole. Numerous factors, including but not limited to those listed above, have an impact on how effective flood risk management measures are.

For the flood risk management measures, including those on Bushrod Island, in Liberia to be implemented successfully, these issues must be addressed.

4.10. Policy Implications for Flood Risk Management

The study has some policy ramifications for flood risk management not just on Bushrod Island but in similar contexts elsewhere in the county and the Country.

First and foremost, more funds and resources need to be allocated toward non-structural measures like early warning systems, community-based disaster risk reduction initiatives, and campaigns to raise public awareness of floods. These actions, which have been proven to be successful in lowering susceptibility in unplanned urban communities to flood risks, ought to be given top priority in frameworks for planning and policy.

Second, stricter enforcement of building codes and regulations is required, particularly in unplanned urban settlements, to guarantee that new constructions are resistant to flood risks. Incentives for modifying existing structures to make them more flood-resistant should also be part of the policy.

Thirdly, to lessen the likelihood of flooding in the unplanned settlements, the policy should give priority to the provision of basic infrastructure, such as drainage systems and effective waste management. Collaboration between federal, state, and local governments, as well as private sector actors, is necessary for this.

Finally, the policy should support the incorporation and integration of both structural and non-structural measures into a thorough framework for flood risk management. To ensure that the policy is implemented successfully and sustainably, it will be necessary to establish partnerships between government organizations, regional communities, and global organizations.

CHAPTER FIVE

Structural and Non-Structural Measures

5.1 Structural Measures

Physical structures or alterations created to lower the danger of flooding are known as structural flood mitigation measures. Structural flood mitigation strategies utilized on the unplanned settlements of Bushrod Island include:

5.1.1 Dam and Reservoir

Dams and reservoirs are substantial constructions designed to regulate river water flow and avert flooding. These facilities can also serve as water reservoirs for irrigation and other uses (Davie et al., 2017). The Mount Coffee Hydro Power Plant situated on the St. Paul River basin currently has an output capacity of 88MW with an extension project of an additional 44MW including a water storage reservoir. The Mount Coffee Dam, a preeminent storage facility in Liberia, holds 239 million cubic meters (MCM) of water from the St. River Paul. The dam serves as a significant source of drinking water and generates hydropower for Monrovia and its environs.

Figure 5.1 (A & B). Mount Coffee Hydro Dam and the White Plains Water Treatment Plant Intake Pipes as a structural measure.
Source: Study Survey Data 2023.

5.1.2 Coastal Defense

Coastal embankments/revetments are constructions erected along shoreline to protect it against erosion and floods brought on by waves and tides. These structures, which can be formed of concrete, rock, or other materials, are intended to soak up wave energy before the waves reach the coast (Heinz Center, 2008). The construction of 1,200 meters of rock wall revetment on the shoreline of Popo Beach, New Kru Town is ongoing and gearing toward completion.

Figure 5.2 (A, B & C). 1200 meters of Coastal Defense Project funded by UNDP implemented by Ministry of Mines & Energy in New Kru Town, Bushrod Island.

Source: Study Survey Data 2023.

5.1.3 Structural Elevation

Elevation is the process of elevating a building's foundation and structure above the flood plain during construction. This action can both extend the property's lifespan and effectively reduce flood damage.

Figure 5.3 (A & B). Images of Buildings elevated above floodwater height via Structural Elevation Techniques in Logan Town and SKD Community on Bushrod Island.
Source: Study Survey Data 2023.

5.2 Non-Structural Measures

Measures that do not require physical interventions are referred to as non-structural flood risk reduction strategies. Land use planning, early warning systems, and flood insurance are among the examples. In comparison to structural solutions, non-structural measures are frequently thought to be more economical and sustainable.

5.2.1 Flood Warning System

To offer early notice of impending floods, flood warning system employ the use of technology. By enabling homeowners to take preventative action before a flood hits, this approach may reduce flood damage. In 2022, the Government of Japan funded the establishment of the National Early Warning & Emergency Operations Center (NEWEOC) at the Disaster Management Agency. The $2 million USD project was implemented by UNOPS, including the dedication of a regional Hub established in central Liberia, Gbarnga, and Bong County.

5.2.2 Acquisition and Relocation

Acquiring properties in flood free locations and moving the occupants there are referred to as purchase and relocation. In high-risk locations, this technique may be costly but it may also reduce flood damage.

Figure 5.4. New housing Units constructed for Fire and Costal Flood Victims in New Kru Town, Bushrod Island as an example of acquisition & relocation.
Source: Study Survey Data 2023.

5.2.3 Building Code and Zoning Regulations

Building code enforcement and zoning laws entail making sure that structures in flood-prone locations are built to resist flooding. By ensuring that structures are constructed to resist flooding, this approach can be beneficial in minimizing flood damage. Zoning laws control how land is used in flood-prone locations. By prohibiting construction in flood-prone locations or promoting it in less-prone locations, this approach may be beneficial in limiting flood damage. Though Liberia's 14 years of civil war (1989-2003) saw a complete absence of the rule of law, the wave of urban migration of people from rural to urban cities like Monrovia exacerbated the construction of buildings in floodplains, drainage areas and wetlands as in the case of Bushrod Island. The Monrovia City Corporation (MCC), Ministry of Public Works (MPW), Environmental Protection Agency (EPA) and the Ministry of Justice (MOJ) have in recent years embarked on the enforcement of zoning laws, building codes, and the declaration of the Montserrado wetlands and the Mesurado (Du) River as protected areas under the biodiversity & conservation laws of Liberia.

5.2.4 Sand Berm

To avoid or lessen flood damage, sandbags are a popular and affordable flood prevention method. Burlap, plastic, or other strong materials are often used to make sand berms, which are then filled with sand or dirt. To divert or restrict floodwaters, they can be stacked to form walls or barriers (FEMA, 2018). According to the degree of risk and the frequency of flooding episodes, these structures may be short-term or permanent. Moreover, sand berms can assist recreation by allowing access to beaches and enhancing aesthetics (NOAA, 2021).

Figure 5.5 (A & B). Images of Sand Berm being used as Flood Wall.

Source: Study Survey Data 2023.

5.2.5 Living with Floods

Living with floods highlights the value of adaptability and resilience in dealing with floods and is a non-structural flood mitigation method. This strategy acknowledges that flooding is a natural occurrence and that it is frequently difficult to totally eradicate the risk of flooding (UNDRR, 2021). There are several ways to deal with flooding, including early warning systems, evacuation plans, flood insurance, and community-based participation, outreach and awareness. Living with floods can assist communities in reducing the effect of floods and recovering more quickly when they occur by fostering a culture of preparedness and resilience (Kuzma & Luo, 2020).

Figure 5.6 (A, B & C). Living with Floods Scenarios as seen by the traditional resilience and adaptation strategies of residents from Struggle Community, Bushrod Island.

Source: Study Survey Data 2023.

5.2.6 Drainage and Waterway Maintenance

Maintenance of drainage and waterways is an important non-structural flood mitigation method that decreases the danger and effects of floods. It entails a variety of tasks, such as inspection, cleaning, and repair, to detect and treat any problems that might obstruct water flow and lead to floods. Regular inspections can detect blockages produced by debris, silt, or vegetation growth, allowing for prompt obstacle removal and prevention. Clearing drainage channels, culverts, and ditches preserves water conveyance capacity, lowering the risk of water collection and floods. Erosion control methods, such as riprap or vegetation stabilization, aid in the prevention of bank erosion and sedimentation, conserve canal flow capacity and reduce channel obstructions and floods. Another critical component is vegetation control, since overgrown vegetation may restrict water flow and reduce the efficacy of drainage systems.

Figure 5.7. Before & After Scenarios of Drainage & Waterways Maintenance of on Bushrod Island).

Source: Study Survey Data 2023.

CHAPTER SIX

Findings and Summary of Results

6.1 Demographic Characteristics of Research Participants

Table 6.1 Demographic Characteristics of Study Respondents.

(N=450)	**Socio-Economic Characteristics**	**Frequencies**	**Percentages**
Section 1	**Age (%)**		
	18 – 25	110	24.4
	26 – 33	126	28.1
	34 – 41	98	21.7
	42 – 49	72	16.1
	50 – 57	44	9.7
Section 2	**Gender (%)**		
	Male	198	44
	Female	256	56
Section 3	**Household Position (%)**		
	Head of Household	180	40
	Member of Household	270	60
Section 4	**Asset Ownership (%)**		
	Own House(s)	171	38
	Tenant	278	62
Section 5	**Employment Status (%)**		
	Employed with Job	153	34
	Self-Employed	90	20
	Not Employed	207	46
Section 6	**Education Status (%)**		
	Not Educated	54	12
	Primary Education	36	8
	Secondary Education	162	36
	Tertiary Education	144	32
	Vocational Education	54	12

Source: Study Survey Data 2023.

From Table 6.1 Section 1, 24.4% of respondents are in the age bracket of 18-25 years, 28.1% are between the ages of 26-33 years, 21.7% between the ages of 34-41years while 9.7% are between the ages 50-59 years respectively. These age disparities conform to the national population demography which depicts that Liberia has a youthful population overall.

Table 6.1 Section 2 also showed that 44% of the respondents are male while 56% are females. This contradicts the national demographic data which states that the gender parity gap of male-to-female is 52% to 48%. However, the field data show that more females stay at home and available due to their gender roles than males.

In Table 6.1 Section 3, the percentage of household positions for the respondents is 40% for heads of households and 60% for members of households. This shows that more household members stay home as compared to the head of households who goes out daily to provide for their families.

The ownership of assets from Table 6.1 Section 4, showed that 38% of respondents owned a house and 62% are tenants. This shows that are more people who rent homes in urban settlements as compared to those who owned assets.

Table 6.1 Section 5 shows the employment percentage of respondents. 34% of respondents are employed with jobs, 20% are self-employed and 46% are unemployed.

From Table 6.1 Section 6, the education status percentage of respondents shows that 12% of respondents had no education at all, 8% obtained primary education, 36% obtained secondary education, 32% obtained tertiary education and 12% obtained vocational education respectively.

6.1.2. General Flood Hazards Awareness

Table 6.2. Flood Hazard Awareness.

Response	**Frequency**	**Percentage**
Yes	315	70
No	135	30
Total	**450**	**100%**

Source: Study Survey Data 2023.

From Table 6.2, 70% of respondents seem to be aware of the flood hazards they are faced with and the remaining 30% seem to have no idea. This means that the majority of the residents are aware of their flood risks as perceived.

6.1.3. Respondents' Source of Information

Table 6.3 Source of Flood Information.

Source of Information	Observations	Percentage
Family/Friends	135	30
Government Agencies	54	12
Internet (social media)	45	10
Radio/TV	180	40
Newspaper	9	2
International & Local NGOs	27	6
Total	**450**	**100%**

Source: Study Survey Data 2023.

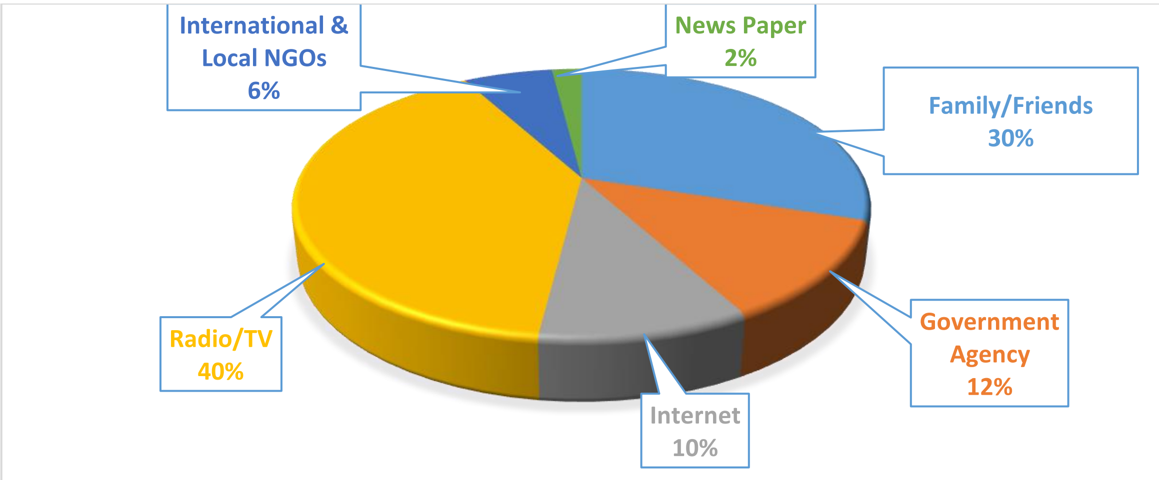


Figure 6.1. Proportion of Residents' Source of Flood Information. (Source: Survey Data 2023).

Disaster information is as important as the source since it can influence any component of the disaster management circle. From Figure 6.1 and Table 6.3, the results of this study revealed that 40% of respondents obtained information from local Radio and Television stations. This demonstrates that radio has always been a significant source of information about disaster preparedness. Thirty percent (30%) of respondents say they got their information from Friends/Families. 10% receive information from the Internet, 12% from Government Agencies, 6% got theirs from local and international NGOs, and 2% from the Newspapers. This perception leads to a conclusion that radio and television are the main sources of disaster information. According to (Cretikos et al., 2008) research, 78.1 percent of information sources came from radio. According to a different study, radio was the most popular information source, used by 44% of participants (Mow et al., 2017, p. 8). Radio has frequently been the primary source of information about disasters, as in this study.

6.1.4. Proportion of Floods by Hazard Types and Source of Flood Water

From Figure 6.2, pluvial floods on average account for 60% of all flood hazard type occurrences and 42% of flood type occurring alone. On average, riverine floods accounts for 30% of all flood hazard type and 17% of flood type occurring alone. Lastly, coastal floods on average constitute 10% of all flood types and 5% of a single flood hazard occurring in the study area. Moreover, 15% of the area experience a combination of pluvial and riverine floods, another 3% experienced pluvial and coastal floods, and 2% experienced riverine and coastal floods in a compounded flood hazard scenario. This means that pluvial floods supplied more than half (60%) of the flood water and are the most prevalent flood hazard by type that triggers and exacerbates the other two floods (Riverine & Coastal Floods) hazards as well.

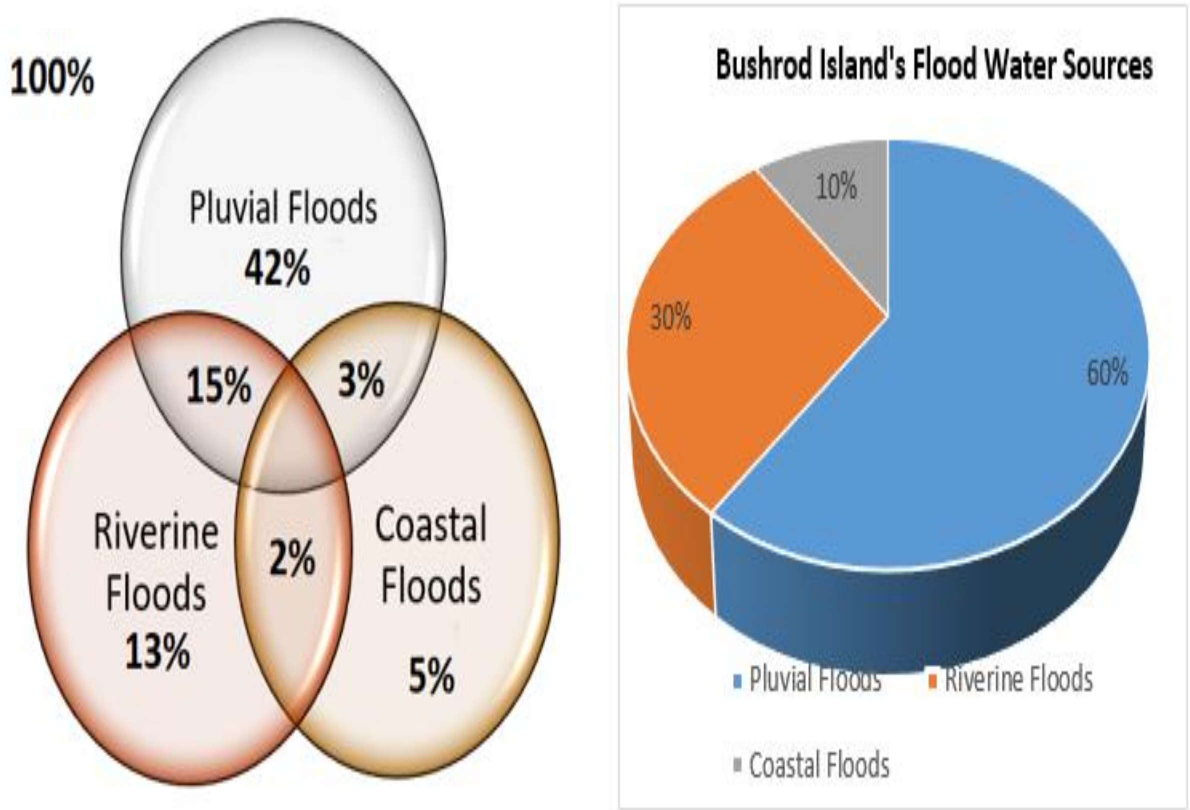


Figure 6.2 (A & B). Figure A. (Left) Proportion of flood Risks by Hazard type on B/Island.

Figure B (Right), Distribution of Floodwater Sources on Bushrod Island.

Source: Study Survey Data 2023.

6.1.5. Bushrod Island’s Flood Severity Effect

Table 6.4. Flood Severity Level.

Level	Frequency	Percentage
Very Severe	117	26
Severe	225	50
Mild	90	20
Not Severe	18	4
Total	**450**	**100%**

Source: Study Survey Data 2023.

From Table 6.4, 26% of the respondents were of the view that the flooding effect in the area is very severe, 50% said it is severe, 20% said it is mild, and 4% said it is not severe. This means that the effect of flooding in the area is extreme as perceived.

6.1.6. Bushrod Island’s Flood Vulnerability Level

Table 6.5 Flood Vulnerability Level.

Level	Frequency	Percentage
Very High	72	16
High	189	42
Moderate	108	24
Low	81	18
Very Low		0
Total	**450**	**100%**

Source: Study Survey Data 2023.

From Table 6.5, 16% of the respondents were of the view that the level of effect of flooding in the area is very high, 24% said it is high, 42% said it is moderate, and 18% said it is low. This means that flood vulnerabilities in the study area are high as perceived by the respondents.

6.1.7. Source of Flood Interventions

Table 6.6. Source of Interventions.

Expect Interventions from	Observations	Percentage
Government	180	40
Neighbors/Community	72	16
Local & International NGOs	126	28
Self	45	10
Don’t Know	27	6
Total	**450**	**100%**

Source: Study Survey Data 2023.

From Table 6.6, 40% of the residents agreed they received interventions from the central Government, and 16% stated that their intervention comes from their neighbors and the community. Another 28% agreed of receiving interventions from local & international NGOs, 10% agreed they depend on themselves for support while 6% of the residents do not know where to get help during or after flooding events. Their perceptions is an indication that the Government is not halfway to meeting the disaster risk management (DRM) needs of flooding events and that the need to improve interventions for flood victims cannot be underpinned.

6.1.8 Flood Water Height

Table 6.7 Height of Floodwaters.

Response	**Observations**	**Percentage**
Chest Level	27	6
Waist Level	72	16
Knee Level	135	30
Ankle Level	207	46
Other Level	9	2
Total	**450**	**100%**

Source: Study Survey Data 2023.

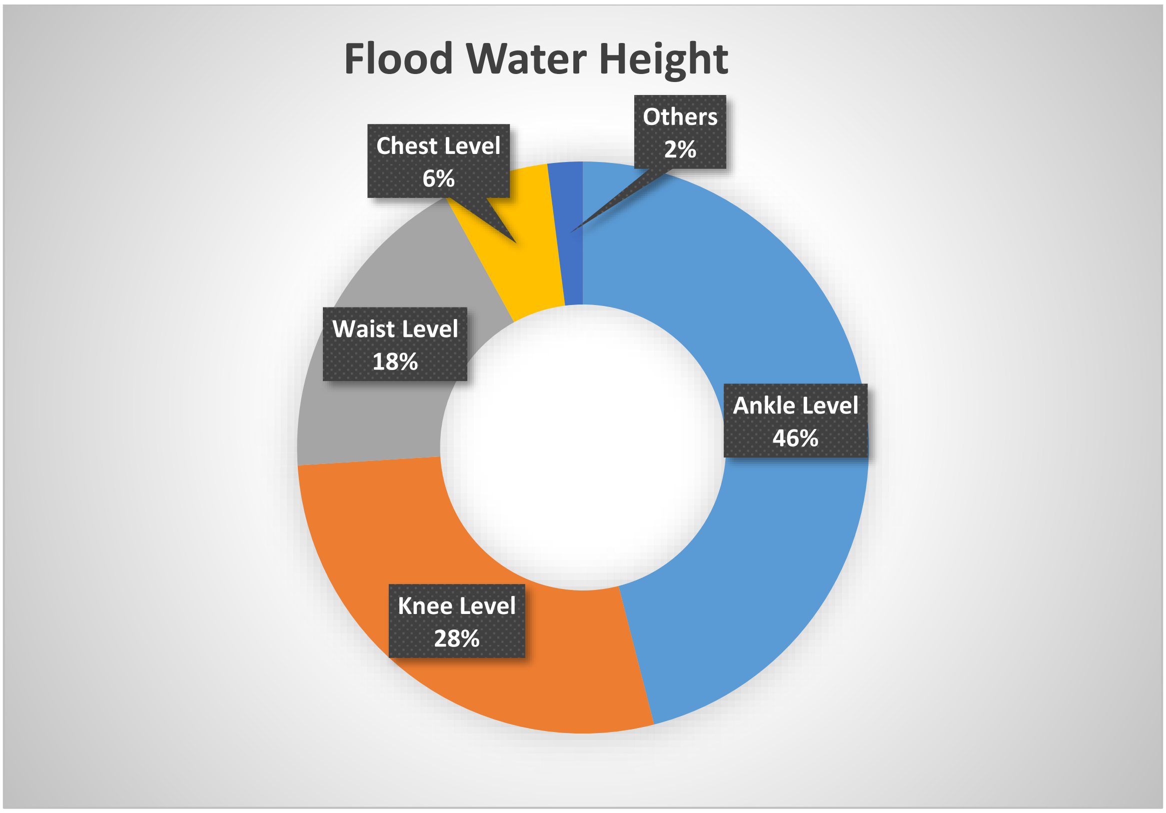


Figure 6.3. Proportion of Flood Water Height.

Source: Study Survey Data 2023.

From Table 6.7 and Figure 6.3, 46% of the respondents agreed that the height of the flood water is at ankle level, 28% indicated the knee level, another 18% said waist level, 6% agreed that it reached chest level and 2% said other levels. Their perceptions affirm the intensity and frequency of rainfall, the difference in low topographic elevations, and the proximity of communities to rivers, creeks, streams, swamps, and the ocean respectively.

6.1.9. Respondents' Flood Experiences

Table 6.8. Flood Experience.

Response	**Frequency**	**Percentage**
1 Year	36	8
3 Years	54	12
5 Years	45	10
7 Years	144	32
9 Years & Above	171	38
Total	**450**	**100%**

Source: Study Survey Data 2023.

From Table 6.8, 38% of respondents had experienced flooding events in the study area for nine (9) years plus, 32% had seven (7) years of flooding experience, 12% had three (3) years of flood experience and another 10% had five (5) years of flood experience, and 8% had one (1) year of flood experience. The differences in respondents' perception are due to migration, longevity of stay in the area, location of assets in the area as well as livelihood activities or social attachments.

6.1.10. Comparison of Incidences of Loss of Lives & Properties

Table 6.9. Incidences of Loss of Lives and Properties.

	2008 (N=970)		**2022 (N=450)**	
Response	**Frequency**	**Percentage**	**Frequency**	**Percentage**
Yes	844	88	333	74
No	116	12	117	26
Total	**960**	**100%**	**450**	**100%**
No. of Deaths	7 Persons		3	
No. of Injuries	12		5	
No. of Asset Loss	58		13	

Source: Study Survey Data 2023 and National Disaster Management Agency, 2009.

Table 6.9 shows a comparative relationship between flood incidences of loss of lives and properties of 2008 which is considered one of Monrovia's worst flooding years to that of 2022. A 2008 survey result indicated that 88% of respondents agreed that there were incidences of loss of lives and properties and 12% said no. On the other hand, this 2022 study data reveals that 74% believed there were flood incidences where lives and properties were lost and 26% of respondents said no. This comparison shows that the 2008 floods incidence had a greater damaging impact than the 2022 incidence even though flooding events have been exacerbated in recent years. The resilience and adaptation strategies of the residents have also strengthen thereby reducing fatality and incidences of property loses.

6.2. The Effectiveness of Structural Measures

The summary of the results below is tabulated using quantitative analysis from the combination of FDGs, KIIs, and questionnaire survey respectively.

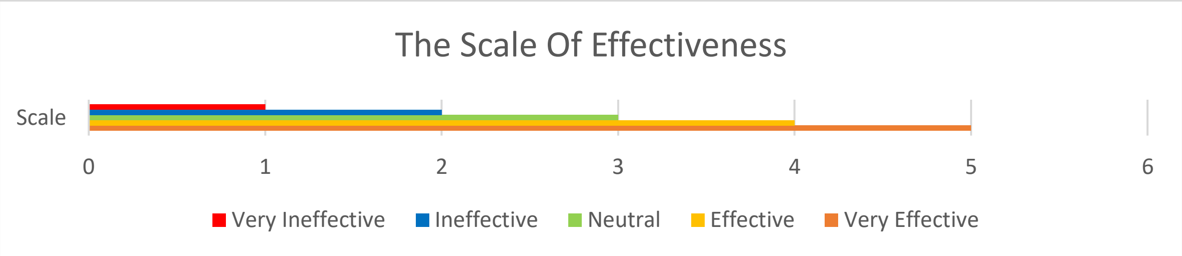


Figure 6.4. Scale used for Measuring the Effectiveness of Mitigation Measures.

Table 6.10. Quantitative Analysis of Respondents Perceptions for Structural Measures' Effectiveness.

Field Data for the Effectiveness of Structural Mitigation Measures (N=450)											
S/N	**Structural Measure**	**Very Effective**	**%**	**Effective**	**%**	**Neutral**	**%**	**Ineffective**	**%**	**Very Ineffective**	**%**
1.	Dam and Reservoir	158	35	180	40	45	10	67	15		
2	Coastal Defense	158	35	135	30	90	20	67	15		
3	Structural Elevation	180	40	162	36	63	14	45	10		

Source: Study Survey Data 2023.

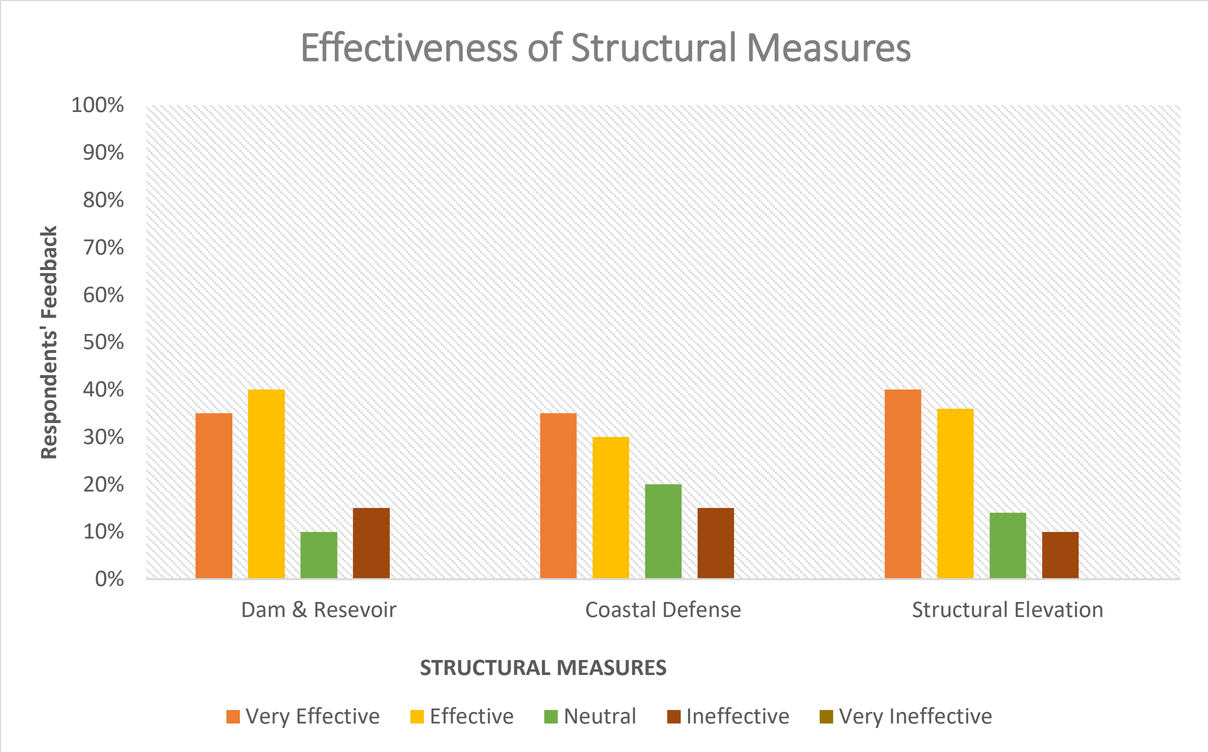


Figure 6.5 Combined Tabulated Results of Study Data for the Structural Measures on Bushrod Island.

Source: Study Survey Data 2023.

6.2.1. Dam and Reservoir

From Figure 6.5 and Table 6.10, 35% of respondents agreed that Dam & Reservoir (Mt. Coffee Hydropower Plant) is very effective, 40% said it is effective, 10% said neutral and 15% said it is ineffective. This means that ***80%*** of the respondents perceived that the measure is effective due to its ability to control river discharge downstream.

6.2.2. Coastal Defense

For coastal defense, 35% of respondents indicated that the measure is very effective, 30% agreed it is effective, some 20% said it is neutral and 15% agreed that it is ineffective. This means that the measure is ***75% effective*** as perceived by respondents**.** The 1200 meters rock revetment being constructed along the shoreline of New Kru Town have dramatically decrease the loss of land to sea erosion along the shores and the number of houses destroyed each in the last two years.

6.2.3. Structural Elevation

Structural elevation which is a construction technique adopted by almost everyone in these unplanned settlements is considered effective for areas that are prone to flooding events. It allows the structures or the foundations to be elevated above flood height to avoid flood waters from entering or submerging the structures. Forty percent (40%) of the respondents agreed that the measure is very effective, 36% agreed it is effective, 14% said it is neutral and 10% agreed it is ineffective. *The overall rating of the measure's* ***effectiveness is 80%*** *as perceived by respondents.*

Lastly, the three (3) identified structural measures in the study location are considered to be either effective.

6.3. The Effectiveness of Non-Structural Mitigation Measures

Field data in Table 6.11 and Figure 6.6 summarizes the effectiveness of the existing non-structural measures in the study area. The summary of the results below is tabulated using quantitative analysis from the combination of FDGs, KIIs, and Questionnaire Survey respectively.

Table 6.11. Quantitative Analysis of Respondents Perceptions for Non-Structural Measures' Effectiveness.

S/N	Non-Structural Measure	Very Effective	%	Effective	%	Neutral	%	Ineffective	%	Very Ineffective	%
1	Acquisition & Relocation		0	117	26	108	24	180	40	45	10
2	Flood Early Warning System		0	180	40	90	20	90	20	90	20
3	Building Codes & Zoning Regulations		0	27	6	198	44	135	30	90	20
4	Sand Berms	126	28	189	42	81	18	36	8	18	4
5	Living With Floods	45	10	270	60	45	10	45	10	45	10
6	Drainage & Waterway Maintenance	162	36	171	38	45	10	36	8	36	8

Source: Study Survey Data 2023.

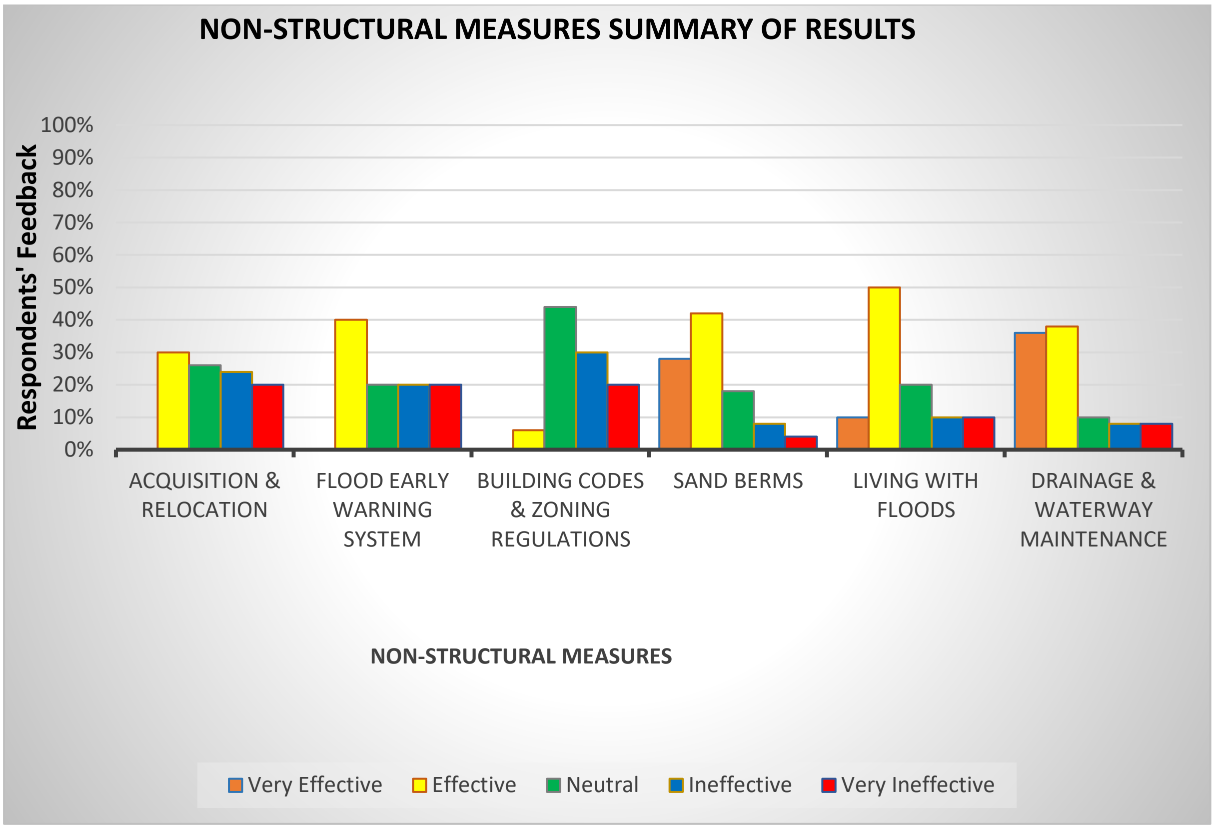


Figure 6.6 Combined Tabulated Field Results for Non-Structural Measures on Bushrod Island. Source: Study Survey Data 2023.

6.3.1. Acquisition and Relocation

Acquisition and Relocation is a very effective widely used measure though costly.

From Figure 6.6 and Table 6.11, 30% of the respondents agreed that it is effective, 26% said neutral, 24% said it is ineffective and 20% said very ineffective. Unfortunately, this widely effective used mitigation measure seemed ***57% ineffective*** (as perceived by respondents) in the case of Bushrod Island. This is because many residents cannot afford to acquire new properties in flood free zone and relocate at their own expense. On the other hand, the Government housing projects and relocation initiatives are most cases insufficient to contain the number of disaster victims. These projects are mostly left halfway uncompleted due to either mismanagement, change of governance priorities or the lack of funding. Moreover, the Government housing projects that reach completion stage, only property owners who lost their houses benefit leaving out ordinary tenants. Lastly, majority of housing estates intended for poor people and disaster victims end up in the possession of people who can already afford them or end up with non-flood/disaster victims that are connected to people in high authority.

6.3.2. Flood Early Warning System

There were equal opinions as it relates to the flood early warning system due to poor community engage and awareness-raising. 40% of the respondents agreed that the measure is effective, 20% agreed that it is neutral, 20% said it is ineffective and another 20% said it is very ineffective. This means that there were **50-50** shared opinion among respondents where 50% of the respondents believed the measure is effective while another 50% believed it is ineffective.

6.3.3. Building Codes and Zoning Regulations

For Building Codes and Zoning Regulations in Table 6.11 and Figure 6.6, Six percent (6%) agreed that the measure is effective, 44% said it is neutral, 30% said it is ineffective and 20 agreed that it is very ineffective. This means that the measure is ***72% ineffective*** as perceived by respondents since most of these unplanned settlements in the study area were either built or expanded during the 14 years of civil war that ended in 2003. Therefore, the weak enforcement of building codes and zoning regulations seems challenging since it will cost the national Government huge budgetary allocation and leads to demolition and/or relocation.

6.3.4. Sand Berm

Since the use of **Sand Berm** as flood walls is cost-effective and afforded, it is a widely applied non-structural mitigation measure in poor rural and unplanned urban communities. From Table 6.11 and Figure 6.6, Twenty-eight (28%) of respondents agreed that this mitigation measure is very effective, 43% agreed that it is effective, 18% said it is neutral, 8% said it is ineffective and 4% said it is ineffective. These results indicate that the measure is ***80% effective*** as perceived by respondents since the measure is cost-effective and easy to use without any technical skills.

6.3.5. Living with Floods

Living with Floods is a non-structural mitigation measure that is used in flood-prone environments based on the application of resilience and adaptation techniques since the residents have very little or no choice as it relates to flooding events. From Table 6.11 and Figure 6.6, Ten percent (10%) of respondents agreed that this measure is very effective, 50% agreed that it is effective, 20% said it is neutral, 10% agreed it is ineffective, while another 10% said it is very ineffective. This result indicates that the measure is ***70% effective*** as perceived by respondents due to the resilience and adaptive nature of the residents living in flood-prone areas.

6.3.6. Drainages and Waterway Maintenance

Though the drainage network in the study area is insufficient due to poor zoning regulation, overpopulation, and overcrowded infrastructures, the consistent maintenance of drainages and waterways has over the years proven effective in transporting and draining flood waters from the surroundings. From Table 6.11 and Figure 6.6 above, 36% of respondents agreed that the measure is very effective, 38% agreed that it is effective, 10% said it is neutral, 8% said it is ineffective and another 8% agreed that it is very ineffective. This result also indicates that the measure is ***79% effective*** as perceived by respondents due to the routine maintenance of drainage structures and waterways within the area by the members of the communities who have taken ownership of the risk reduction strategy to safeguard their lives, properties, and livelihoods.

6.4. Flood Damage Estimation and Cost Analysis

Table 6.12. Estimation of Flood Damage & Cost Analysis.

Time Horizon	**EAAL (USD/Year)**	**% GDP Loss**	**Yrly People Affected (≥10cm)**	**% of B.I Pop. Affected**	**Yrly People Affected (≥1m)**	**% of B.I Pop. Affected**
2022	24,570,000	0.70%	65,193	14.42%	25,137	5.56%
RCP 4.5 2050 Moderate	30,888,000	0.88%	86,171	19.06%	32,145	7.11%
RCP 8.5 2050 Extreme	44,226,000	1.26%	101,994	22.56%	43,764	9.68%
GDP of Liberia 2022: 3.51 Billion			**Bushrod Island Population 2022: 452,103**			

Source: Study Survey Data 2023.

In this section, the World Bank 2019 study on *"Floods Risk Profile of Greater Monrovia",* is used as a baseline for estimating the potential damage of floods on Bushrod Island. The hazard maps of Figure 6.7 illustrate how the current and the future hazard maps would look like. Table 6.12 illustrates the normalized Expected Annual Average Losses (EAAL) for Bushrod Island to give an idea of where the greatest impacts are concentrated. Given that the pluvial risk is the biggest mechanism and that it is dispersed throughout the entire Greater Monrovia District which include Bushrod Island, it makes sense that the largest communities suffer the greatest losses, but on a USD/year/m2 basis, the impact is surprisingly felt throughout the Bushrod Island. Only a portion of New Kru Town experience direct coastal flooding, and tidal flooding affects low-lying areas near the Mesurado estuary and both the Stockton Creek and St Paul River mouth.

The spatial pattern of pluvial flooding is intricate, with distinct accumulation areas. Stockton Creek's environs are severely impacted by fluvial flooding. Unsurprisingly, fluvial risk is concentrated in communities along the rivers- (Mesurado and St. Paul Rivers, and Stockton Creek), with the longer return periods having an even greater impact on these communities.

With increased flood depths and consequently larger inundated areas due to climate change, all of these flood hazards get worse. It's interesting to note that there isn't much of a difference between the 2050 moderate (RCP4.5) and 2050 extreme (RCP8.5) scenarios given how similarly the impact of climate change has affected monthly rainfall over the vast St. Paul basin.

The combined risks-(pluvial, riverine & coastal floods) of Bushrod Island showed that the expected annual average losses (EAAL) in 2022 was $24.57 million USD which constituted 0.70% loss of the total GDP-($3.51 Billion) which affected 65, 193 people (14.42% of Bushrod Island’s population) residing in areas with an elevation equal to or greater than 10cm. Moreover, for those residing in areas with an elevation equal to or greater than 1 meter, 25, 137 people (5.56% of Bushrod Island’s population) were also affected.

A projection for a moderate case scenario (RCP4.5) in 2050 predicted $30.89 million USD in losses constituting 0.88% of the total GDP. A total of 86,171 people (19.06% of Bushrod Island’s population) residing in areas within an elevation equal to or greater than 10cm are expected to be affected. Consequently, 32,145 people (7.11% of Bushrod Island’s population) of those residing in areas within an elevation equal to or greater than 1 meter, shall be affected.

For the extreme (RCP8.5) case scenario in 2050, the prediction shows $44.23 million USD in losses constituting 1.26% of the total GDP. A total of 101,994 people (22.56% of Bushrod Island’s population) residing in areas within an elevation equal to or greater than 10cm are expected to be affected. Consequently, 43,764 people (9.68% of Bushrod Island’s population) of those residing in areas with an elevation equal to or greater than 1 meter, shall be affected.

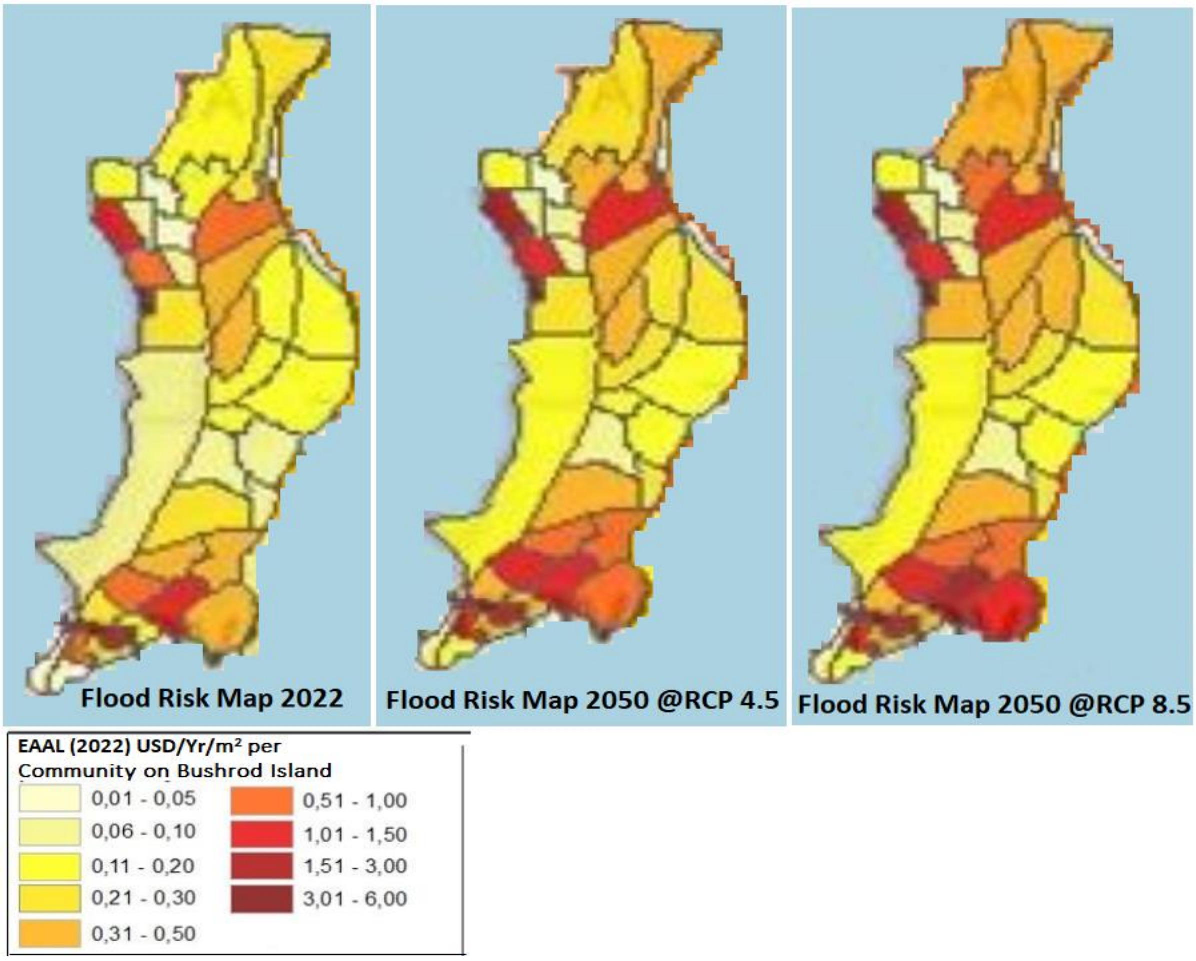


Figure 6.7 (A, B & C). Image A (Left). Flood Risk Map of Bushrod Island showing the Current hazards and risks.

Image B (Middle). Flood Risk Map of Bushrod Island showing Future Projections of moderate scenario in 2050 @RCP4.5.

Image C (Right). Flood Risk Map of Bushrod Island showing Future Projections of extreme scenario in 2050 @RCP8.5.

Source: National Disaster Management Agency, and National Center for the Coordination of Response Mechanisms.

The overall effectiveness of both structural and non-structural flood mitigation measures varies with respondents' perceptions.

The estimation of flood damage highlights the potential losses and impact of floods on Bushrod Island, with projections indicating increasing losses in the future. In 2022, 0.70% 0f total GDP was loss to flooding events amounting to 24.5 million while the future projections in 2050 at RCP 4.5 (moderate condition) will accumulate 30.9 million and at RCP 8.5 (extreme condition) will cost 44.2 million respectively.

CHAPTER SEVEN

Conclusion and Recommendations

7.1.1. Summary of Findings

The summary of findings presents key findings regarding the demographics of respondents, perceptions regarding flood awareness, information sources, flood types, flood severity, sources of intervention, and the estimation of flood damage in the area.

The overall effectiveness of both structural and non-structural flood mitigation measures varies with respondents' perceptions. The Table below presents a tabulated summary of the overall field data for flood mitigation measures using quantitative analysis from the combination of FDGs, KIIs, and Questionnaire Surveys respectively as seen in the table below:

Table 7.1 Quantitative Analysis of Overall Effectiveness for Mitigation Measures.

S/N	Structural Measures	Overall Effectiveness
1	Dam and Reservoir	80% of Respondents perceived it as effective
2	Coastal Defense	75% of Respondents perceived it as Effective
3	Structural Elevation	83% of Respondents Perceived it as Effective
S/N	**Non-Structural Measures**	
1	Acquisition & Relocation	57% of Respondents perceived it as Ineffective.
2	Flood Early Warning System	Neutral (50% Effective & 50% Ineffective) As Perceived by Respondents.
3	Building Codes & Zoning Regulations	72% of Respondents perceived As Ineffective.
4	Sand Berms	80% of Respondents perceived it as Effective
5	Living With Floods	70% of Respondents perceived it as Effective
6	Drainage & Waterway Maintenance	79% of Respondents perceived it as Effective

Source: Study Field Data, 2023.

The findings from the study are:

- The age distribution of respondents in Bushrod Island's unplanned settlements reflects the youthful population of Liberia, with 52.2% falling in the 18-33 age brackets.
- There gender parity among the survey respondents suggests that more females (56%) were available mostly due to their gender roles and responsibilities.
- Sixty percent (60%) of respondents are members of households rather than heads of households, indicating a higher presence of household members staying at home.
- Sixty-two percent (62%) of respondents are tenants rather than homeowners, highlighting the prevalence of rented homes in urban settlements.
- Employment statistics show that 46% of respondents are unemployed, indicating a need for more job opportunities.
- Education levels vary among respondents, where 36% had obtained secondary and 32% obtained tertiary education.
- The majority of residents (70% as perceived by respondents) are aware of the flood hazards they face in the area indicating the need for awareness and education.
- Radio and television are the primary sources of disaster information as perceived by 40% of respondents, highlighting their importance in disseminating information about disaster preparedness. However, the need to incorporate other easy and cost-effective of information dissemination cannot be underestimated.
- Pluvial floods are the most prevalent type of flood hazard in the area (accounts for 60% of flood occurrence in the study area as perceived by respondents), followed by riverine and coastal floods.
- The severity of flooding and its impact on residents is significant, and 86% of respondents considered it severe and having a high level of effect on the affected communities.
- Government intervention to providing support and assistance during flooding events is low (40% as perceived by respondents) and not meeting the needs of the communities adequately.
- The height of floodwater during events varies, with ankle and knee levels being the most common accounting for 46% and 30% as perceived by respondents respectively.
- Seventy percent (70%) of residents thinks they had experienced flooding events between 7-9 years, indicating a long-standing issue in the area.

- The comparison between the 2008 and 2022 flood incidents suggests a drastic decrease in flood damage and fatalities, indicating improved resilience and adaptation.
- The estimation of flood damage highlights the potential losses and impact of floods on Bushrod Island, with projections indicating increasing losses in the future. In 2022, 0.70% 0f total GDP was loss to flooding events amounting to 24.5 million while the future projections in 2050 at RCP 4.5 (moderate condition) the loss will accumulate to 30.9 million and at RCP 8.5 (extreme condition) will cost 44.2 million respectively.

These findings indicate the importance of addressing the specific flood risks and vulnerabilities facing the residents of Bushrod Island's unplanned settlements, including enhancing education levels, and implementing effective flood mitigation measures. The results also underscore the significance of integration of mitigation measures, community engagement, sustainable urban planning, and improvement of government interventions to mitigate the impact of flooding in the area.

7.1.2 Conclusion

The findings of this study provide valuable insights into the flood risks and vulnerabilities faced by the residents of Bushrod Island's unplanned settlements in Monrovia, Liberia. The youthful age distribution of respondents indicates the need for targeted disaster awareness and education campaigns tailored to the younger population. The gender parity among respondents highlights the availability of more females, primarily due to their traditional gender roles, which should be considered in disaster planning and response for the inclusion of gender-sensitive priorities.

The prevalence of rented homes and the higher percentage of household members staying at home underscores the importance of considering the needs of tenants and non-heads of households in flood mitigation strategies.

Addressing the high unemployment rate is essential to enhance the resilience of the community against flood-induced economic shocks.

The study identifies radio and television as the primary sources of disaster information, indicating their vital role in disseminating information about disaster preparedness. However, efforts should be made to incorporate other easy and cost-effective channels to reach a wider audience and ensure comprehensive disaster communication.

The dominance of pluvial floods highlights the urgency of addressing drainage issues and implementing effective stormwater management measures. The severity of flooding and its impact on the community demands robust and sustainable flood mitigation initiatives.

The comparison between the 2008 and 2022 flood incidents suggests improved resilience and adaptation, leading to reduced flood damage and fatalities in recent years. However, the projected future losses indicate the need for continuous efforts in flood risk reduction and adaptation to changing climate conditions.

The government's intervention in supporting flood-affected communities is insufficient, necessitating enhanced disaster response mechanisms and improved support during and after flooding events.

In conclusion, this study emphasizes the importance of comprehensive and integrated flood risk management strategies in Bushrod Island's unplanned settlements. These strategies should encompass education and awareness programs, sustainable urban planning, community engagement, and effective structural and non-structural flood mitigation measures. By addressing the specific vulnerabilities and needs of the community, and incorporating innovative and cost-effective measures, it is possible to enhance the resilience of Bushrod Island's residents against flood risks and hazards. Implementation of these recommendations will lead to a safer and more sustainable future for the inhabitants of the area in the face of increasing flood challenges.

The study stresses the importance of a comprehensive and integrated strategy to successfully manage flood risks. Floods can be mitigated in susceptible communities using both structural and non-structural means.

Adapt long-term resilience that requires prioritizing infrastructure upgrades, sponsoring community participation and education activities, and incorporating flood risk concerns into urban planning and land use management procedures.

It encourages all parties concerned, including Government ministries and agencies, regional institutions, and INGOs work together to put these ideas into effect. In this way, we may mitigate the harmful consequences of floods, build resilient communities, and assure long-term development in the face of increased flood hazards.

7.2 Recommendations for Practice and Improvement of Existing and New Measures.

Following the findings and conclusion from the research "Assessing the effectiveness of structural and non-structural measure of Bushrod Island's unplanned settlements", the following recommendations are prescribed:

7.2.1. Structural Measures

Dam and Reservoir

Phase two (2) of the expansion project of the Mt. Coffee Dam will increase its capacity from 88MW to 132MW. The construction of a second Dam of 150MW capacity some 80km above the old Mt. Coffee Dam on the same River will also constitute a decrease in the mean and annual river discharge and regulate the flow rate downstream. The river is also the only source of water supply for the entire city of Monrovia a factor that decreases the river's discharge downstream.

In view of the above mentioned, the following recommendations are hereby prescribed for improvement of this structural measures:

- **Enhance Dam Infrastructure:** Regular maintenance, modernization, and expansion of existing dams can improve their effectiveness in flood control and water management.
- **Implement Early Warning Systems:** Integrate real-time monitoring and flood forecasting systems to provide timely alerts to downstream communities, allowing for preparedness and evacuation if necessary.
- **Coordinate with Disaster Management Agencies:** Establish effective communication and coordination mechanisms between dam operators and disaster management agencies to ensure a synchronized response during flood events.
- **Public Awareness and Education:** Educate communities about the benefits of dam and reservoir systems, flood risks, and emergency preparedness to increase cooperation and compliance.
- **Reservoir Management:** Adopt flexible water release strategies based on weather forecasts, downstream conditions, and flood risk assessments to optimize water storage and minimize flood impacts.

- **Regular Risk Assessments:** Conduct periodic risk assessments to identify potential vulnerabilities, assess the effectiveness of existing measures, and adjust strategies accordingly.
- **Multi-Purpose Projects:** Encourage the development of multi-purpose dam projects that not only focus on flood control but also incorporate water supply, irrigation, hydropower generation, and recreational uses.

Coastal Defense

Recommendations and alternatives to using Rock Revetment as a coastal defense measure to mitigate coastal flood risks and hazards, focusing on cost-effectiveness, durability, and sustainability. By considering these recommendations, coastal communities can better protect themselves against flood risks and hazards.

- **Geotextile Sand Containers (GSC):** Consider using GSC structures, which are cost-effective and durable. They consist of sand-filled containers with geotextile fabric that can withstand wave energy, provide erosion control, and offer a more environmentally friendly option than traditional rock revetments.
- **Hybrid Systems:** Combine rock revetment with other measures like beach nourishment or living shorelines to create a more comprehensive and sustainable coastal defense system that adapts to changing coastal conditions.
- **Recycled Materials**: Explore using recycled materials, such as crushed concrete or glass, as an alternative to natural rocks for constructing revetments, reducing environmental impact and lowering costs.
- **Climate-Resilient Design:** Design coastal defense structures with climate change projections in mind, considering potential sea-level rise and extreme weather events to ensure long-term durability and effectiveness.
- **Erosion Monitoring:** Implement regular monitoring of coastal erosion rates and adjust maintenance and reinforcement efforts accordingly to maximize the revetment's lifespan and optimize cost-effectiveness.
- **Financial Incentives:** Establish financial incentives and grants for communities to adopt sustainable coastal defense measures, encouraging the use of eco-friendly alternatives like living shorelines.

- **Regular Maintenance:** Ensure ongoing monitoring and maintenance of the rock revetment to address any damages or erosion promptly, preserving its effectiveness in protecting against coastal flooding.
- **Ecosystem-based Approach:** Combine rock revetments with natural features such as mangroves and salt marshes to create a more resilient coastal defense system, promoting biodiversity and reducing erosion.
- **Beach Nourishment:** Consider beach nourishment as an alternative measure, where sand is added to eroded beaches to act as a natural barrier against coastal flooding.
- **Stakeholder Collaboration:** Engage local communities, governments, and private sector entities in the decision-making process to foster cost-sharing partnerships and ensure long-term maintenance and sustainability of coastal defense structures.

Structural Elevation

Structural elevation, as a hard engineering measure for flood mitigation, involves raising buildings and infrastructure above flood levels to reduce flood impacts. To improve its technical and engineering design, several key aspects must be considered in order to optimize its effectiveness.

- **Site-Specific Analysis:** Conduct thorough hydrological and hydraulic studies to understand flood patterns, water levels, and flow velocities in the area. This data will inform the appropriate elevation level needed for structures.
- **Architectural of Foundation Design:** Ensure the structural foundations can withstand increased loads and buoyancy forces during flooding. Employ innovative Architectural and foundation technologies like piling or floating foundations to enhance stability.
- **Building Materials:** Select flood-resistant and durable materials to minimize damage during floods and ensure long-term structural integrity.
- **Engineering Standards:** Adhere to relevant building codes and engineering standards to guarantee safety and compliance with regulations.
- **Climate Change Projections:** Consider future climate change scenarios to design for higher flood levels and increased flood frequency.
- **Integration with other Measures:** Combine structural elevation with other flood mitigation strategies like green infrastructure and floodwalls for a comprehensive approach.

- **Cost-Effectiveness**: Evaluate the cost-benefit ratio of structural elevation compared to other measures to ensure the most efficient allocation of resources.

By addressing these factors, structural elevation can be optimized as an effective and reliable flood mitigation measure, enhancing resilience and protecting communities from flood-related damages and risks.

7.2.2. Non-Structural Measures

Acquisition and Relocation

Acquisition and Relocation, as a non-structural flood mitigation measure, can be highly effective in mitigating flood risks and hazards if properly managed. By adhering to these recommendations, Acquisition, and Relocation can effectively reduce flood risks and hazards by relocating vulnerable communities to safer areas, protecting lives, livelihoods, and properties from the devastating impacts of floods.

- **Identification of Vulnerable and High-Risk Zone:** Identify high-risk flood-prone areas and prioritize acquisition and relocation efforts for communities residing in these zones.
- **Comprehensive Planning:** Develop well-coordinated relocation plans that consider the social, economic, and environmental needs of affected communities to ensure smooth transitions.
- **Community Engagement:** Involve affected communities in decision-making processes and ensure their active participation in the relocation planning to enhance acceptance and cooperation.
- **Adequate Funding:** Secure sufficient funding and resources to support the acquisition and relocation process, ensuring a successful and timely implementation.
- **Monitoring and Evaluation:** Establish mechanisms to monitor and evaluate the effectiveness of the relocation program, making necessary adjustments as needed.
- **Climate-Resilient Infrastructure:** Construct new settlements with climate-resilient infrastructure and disaster-resistant housing to enhance resilience against future flood events.
- **Early Warning Systems:** Deploy early warning systems to alert communities about impending flood events, providing residents with sufficient time for safe relocation.

- **Education and Awareness:** Raise awareness among residents about the benefits of relocation, emphasizing the long-term safety and protection from flood risks.
- **Government Support:** Ensure strong governmental support and commitment to prioritize acquisition and relocation initiatives as part of comprehensive flood risk management strategies.
- **Land-Use Regulations:** Implement strict land-use regulations in high-risk flood-prone areas to prevent new settlements and developments in vulnerable zones.

Flood Early Warning System

Regarding whether the study area's flood early warning system is effective, respondents' perceptions were split 50/50. On average, 50% of respondents thought the measure was effective, while 50% thought it was ineffective. Flood forecasting and warning systems are game changer for reducing the risk of flooding despite being relatively complex, consistently requiring servers with continuous backup, connected to rain and river gauges. A significant technological vulnerability factor for such systems is the dependability of the power and internet supplies, as well as the accessibility of qualified system administrators.

For Bushrod Island's flood early warning system to reach its full potential and effectiveness, the following recommendations should be considered:

- Develop an ICT architecture (hardware and software) to host the forecasting system (both locally offline or online) as a supplement to Radio and Television, which served as the most popular medium of information dissemination in the study area.
- Construct and install the forecasting system in the flood prone communities, including selecting the most suitable, affordable, and reliable hosting solution and the accountable organizations (keeping in mind local capacities).
- Produce a comprehensive operation and maintenance manual, train the key players in the flood warning chain, and include a role-playing exercise with a flood case study in which all actors can actively participate.

Building Codes and Zoning Regulations

As a result of the Island's poorly planned structure layout, 72% of respondents from both the FDGs and questionnaire survey believed that these non-structural mitigation measures in the study area were ineffective. Recommendations therefore include:

- Create building regulations for stronger structures above flood levels (assume a certain level of safety). In order to better control urban development and risk exposure, building codes would be connected to city zoning and building permits.
- Develop straightforward, cost-effective construction designs for elevated foundations for buildings and structures, wooden board walkways, inventive sustainable floating homes, and reinforced concrete piles.
- Emphasis be placed on investigating low-cost/innovative materials for the pathways and foundations (such as recycled material paving/planks), reducing dependence on outside financing and making the measures mores scalable across the area.
- Give locals access to funding and training so they can start cooperatives or small construction businesses. Additionally, it is anticipated that this strategy will produce local, low-skilled jobs within the communities.
- Liberia Land Authority (LLA), should draft zoning designations and maps as well as a legal framework for the creation of city zoning for development.
- Prioritize the importance of permits and zoning should be made a priority in terms of educating city officials, and the local communities.
- Single institution should be designated for the issuance of permits, enforcement, and with the authority to recommend for prosecution.

Sand Berm

The used of sand berm as floodwall around private buildings seemed pretty effective as perceived by 85% of the respondents on Bushrod Island even though the impact is temporal and short term, recommendation for alternative long-term sustainable measures for flood mitigation to complement or replace the use of sand berms are proposed. One approach is constructing levees or floodwalls using cost-effective Geo-Bags along hotspots of Stockton Creek shoreline, which would provide more robust and permanent protection against flooding. Additionally, green infrastructures, such as Detention ponds, rain gardens and bioswales, will help absorb and manage excess floodwater.

Living with Flood

The efficacy of Living with Flood scenario on the Bushrod Island was proven to be 75% effective as respondents' perception indicated from both the FDGs and Questionnaire Survey. The following recommendations is prescribed:

Awareness and Education

Though the education gap among residents seems wide, especially in the slum settlements, the following recommendation must be taken into account:

- Create a community-wide awareness-raising campaign as the foundation for all other activities.
- Inform the affected population about the flood risk in a manner that is easily digestible and suitable for broadcast including the use of local languages.

Land-Use

Urban planning plays a crucial role in managing the exposure of assets and addressing safety concerns. By implementing land use zoning, cities can not only identify and encourage the development of low to no-risk areas but also foster densification in these regions. This process, known as 'urban consolidation', involves various strategies such as capturing the value of low-risk land, providing incentives for higher-density housing, imposing taxes on underutilized safer zones, enforcing regulations for multi-story buildings, and establishing 'No build zones' in higher risk areas. Effective land use zoning is essential for creating a well-managed and secure urban environment.

Response

Implementation of community-level flood response plans (evacuation of people and property), calls for a flood forecasting system to simulate near-future water levels in the city, coupled with a Warning System. This may be as easy as the forecasting organization directly informing the pertinent agencies (e. g. firefighters, police, paramedics, local government offices, television news, print and online media, and radio stations are just a few examples.

The research's findings suggest that a simple, locally appropriate community-level flood response plan be developed which include:

a. Process for warning people timely.

b. Search and rescue.

c. Routes for evacuation to safety.

d. Straightforward egress techniques.

e. Preparedness measures for locals to improve post-flood recovery and lessen vulnerability in their communities.

Recovery

Short-Term

These measures aim to address urgent needs and ensure the safety and well-being of the impacted communities in the aftermath of flooding including but not limited to:

- Providing emergency relief services (cash, food and non-food items), shelter, medical assistance, and basic needs to affected individuals.
- Improved water, sanitation and health facilities to reduce health vulnerability and the risk of post-flood waterborne diseases such as cholera, diarrhea, dysentery, malaria, and skin irritation.

Long-Term

Long-term recovery initiatives focus on sustainable solutions to mitigate future flood risks and enhance resilience. The goal is to build resilient communities and minimize the impact of flooding in the long run.

- Focus on rebuilding damaged infrastructure, homes, and livelihoods.
- Implementing flood risk reduction measures, such as improved drainage systems and flood-resistant constructions, helps prevent future disasters.
- Community engagement and public awareness campaigns to foster resilience.
- Collaboration of efforts involving government agencies, NGOs, and local communities for successful and sustainable flood recovery initiatives.

Drainage and Waterway

To effectively address pluvial flooding, the research proposes implementing the **Blue-Green-Grey solutions**, using **Logan Town as a prime example.** These solutions integrate various measures to manage rainwater. They aim to promote natural infiltration, while also diverting rainwater from key areas and retaining it in less vulnerable zones. The combined approach of blue-green-grey drainage and waterway measures involves blue solutions, which employ open water areas for temporary floodwater storage; green solutions, which preserve wetlands and vegetated areas to facilitate soil infiltration and temporary surface runoff storage; and grey solutions, which rely on traditional drainage systems designed to efficiently drain roads and residential zones, redirecting floodwater and runoff to blue or green areas.

Figure 7.1 demonstrates how integrating Green-Blue-Grey drainage infrastructure can effectively reduce the risk faced by the inhabitants of Bushrod Island. The proposed **Blue solution** involves the creation of a new shallow detention pond with increased storage capacity. The **Green solution** focuses on conserving and safeguarding the existing wetland depression from any development, known as the ***'No go zone'*** in the zoning measure. The **Grey solution-** highlighted in red, entails improving the roadside drains by enlarging their openings and ensuring proper leveling with an appropriate outlet structure into the Stockton Creek.

It is also suggested that a bypass channel be constructed in upper Stockton Creek to enhance the flow rate and prevent riverine flooding at the confluence of St. Paul River and Stockton Creek. These measures, although relatively cost-effective, require thorough engineering studies. They can consist of a combination of different strategies, such as concrete drains directing water towards rehabilitated/protected urban wetlands, permeable paving to enhance infiltration, or green swales (vegetated strips that capture and store floodwater/run-off from roads and residential areas). It is important to note that this approach must be integrated with city zoning regulations and other infrastructure planning.

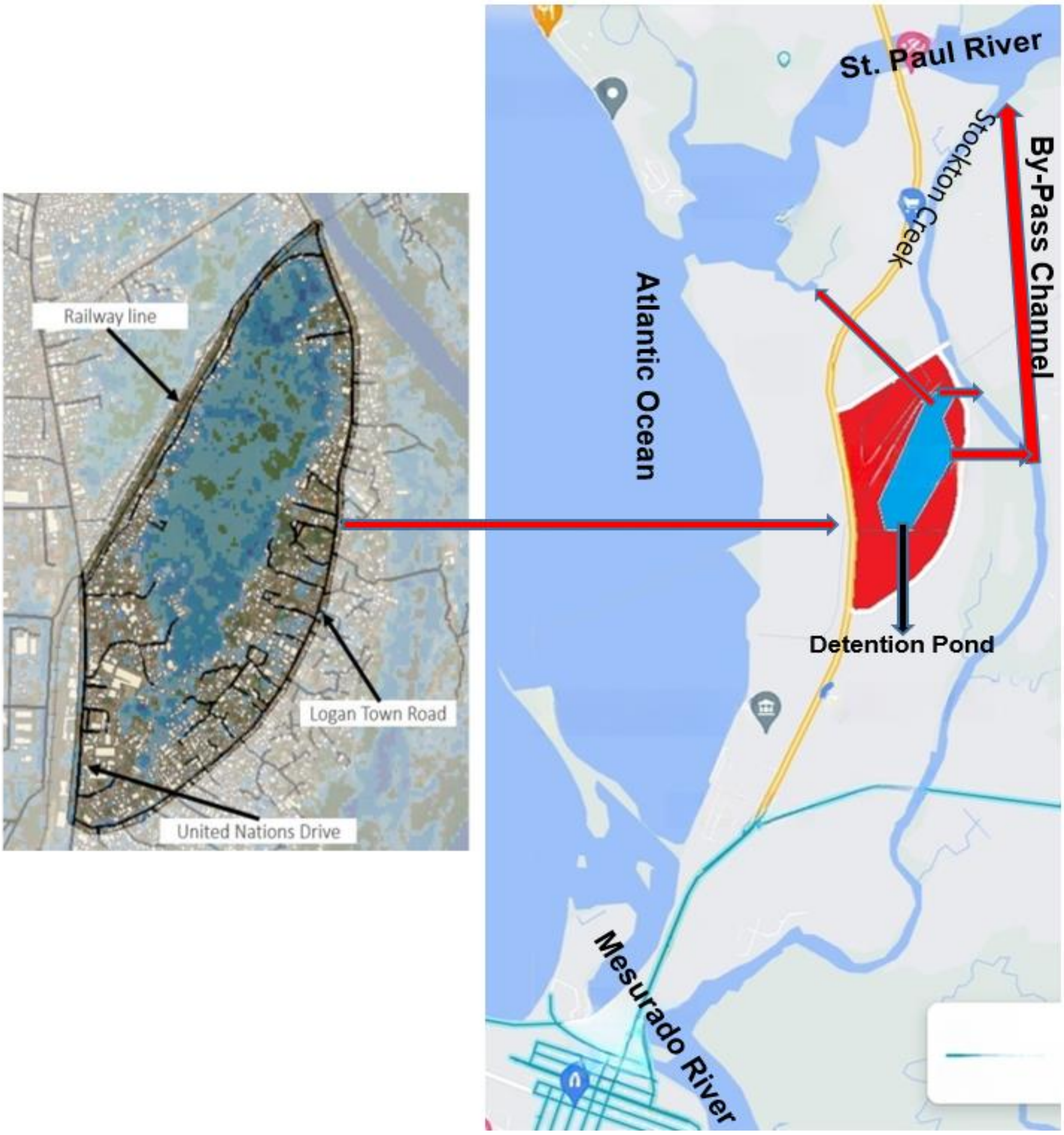


Figure 7.1. Proposed Green-Blue-Grey Drainage System Infrastructure.

REFERENCES

Abdelaziz, S., Gad, M., & Ahmed, H. (2022). Flash Floods Hazard Degrees Assessment Applying Multi-Attributes Utility Theory for Gulf of Suez Basins, Egypt. JES. Journal of Engineering Sciences, 0(0). https://doi.org/10.21608/jesaun.2022.59895.1030

Adelekan, I. O., Johnson, C., & Krausse, M. (2015). Climate change, disasters and adaptation in the African Sahel. Regional Environmental Change, 15(4), 621-635. https://doi.org/10.1007/s10113-014-0672-4

Adjei, K. A., Nkrumah, F., & Fosu-Mensah, B. Y. (2019). Impact of Climate Change on Flood Risk in Ashaiman Municipality, Ghana. Environmental Science and Pollution Research, 26(18), 18363-18372.

Ajede, P. (2022). Local Government Reports on Flood Incidence and Environmental Hazards: Ukwuani Local Government Review, Department of Environment, 2021. Official Report.

Ali, S and Dan'azumi, S. (2023). Application of Analytical Probabilistic Models in Urban Runoff Control Systems' Planning and Design: A Review. *ProQuest*, 1640. https://doi.org/10.3390/w15091640

Anornu, G. K., Annor, F. O., Addae, E., & Kuma, J. S. (2019). The Impact of Urbanization on Flood Risk in Accra Metropolitan Area. Journal of Environmental and Public Health, 2019, 1-16.

Atubiga, J. A., Atubiga, A. B., Nyade, L. T., & Donkor, E. (2023). Evaluating the Perennial Flooding on the White Volta River and the Bagre Dam Spillage on Agricultural Activities in Sudan Savanna in the Upper East Region, Ghana. International Journal of Multidisciplinary Research and Analysis, 06(03). https://doi.org/10.47191/ijmra/v6-i3-11

Awoyemi, T., Aigbavboa, C., & Oyeyipo, O. (2020). Enhancing Construction Project Risk Management using Building Information Modelling: A Systematic Literature Review. Journal of Engineering, Design and Technology, 18(6), 1654-1686

Ayalew, L., & Yamagishi, H. (2005). The application of GIS-based Logistic Regression for Landslide Susceptibility Mapping in Kakuda-Yahiko Mountains, Central Japan. Geomorphology, 65(1-2), 15–31. https://doi.org/10.1016/j.geomorph.2004.06.010

Brammer, H. (2021). Floods in Bangladesh - Food Mitigation and Environmental Aspects, Geographical Journal, Vol. 156, pp. 158 -165.

Bubeck, P., Botzen, W. J., & Aerts, J. C. (2013). A Review of Risk Perceptions and Other Factors that Influence Flood Mitigation Behavior. Risk Analysis, 33(1), 24-49.

Brouwer, R., Akter, S., Brander, L., & Haque, E. (2018). Socioeconomic Vulnerability and Adaptation to Environmental Risk: A Case Study of Climate Change and Flooding in Bangladesh. Risk Analysis, 38(6), 1171-1193.

Chakraborty, P., and Das, I. (2017). A Review of Flood Models. Journal of Hydrology, 541, 746-762.

COVID-19 Situation Reports, National Public Health Institute of Liberia. (n.d.). Retrieved July 23, 2023, from https://www.nphil.gov.lr/index.php/covid-19-situation-report/

CRED Publication - 2022 Disasters in Numbers | UN-SPIDER Knowledge Portal. (n.d.). Www.un-Spider.org. Retrieved June 2, 2023, from https://www.un-spider.org/news-and-events/news/cred-publication-2022-disasters-numbers

Crichton, D. (2010). The Risk triangle. In The Risk Triangle (pp. 11-29). Springer.

Cretikos, M., Eastwood, K., Dalton, C., Merritt, T., Tuyl, F., Winn, L., & Durrheim, D. (2008). Household Disaster Preparedness and Information Sources: Rapid Cluster Survey After A Storm in New South Wales, Australia. BMC Public Health, 8(1), 195. https://doi.org/10.1186/1471-2458-8-195

Cutter, S. L., Ash, K. D., & Emrich, C. T. (2019). The Geographies of Community Disaster Resilience. Global Environmental Change, 56, 90-106.

Davie, T., Crickard, D., & Yu, H. (2017). An Experimental Study on The Effects of Computer-Aided Design Tools on Creativity in Architectural Design. Journal of Architectural Engineering, 23(1), 04016031.

Dawson, R. J., Ball, T., Werritty, J., Werritty, A., Hall, J. W., & Roche, N. (2011). Assessing The Effectiveness of Non-Structural Flood Management Measures in Thames Estuary Under Conditions of Socio-Economic and Environmental Change. Global

Environmental Change, 21(2), 628–646. https://doi.org/10.1016/j.gloenvcha.2011.01.013

Duah, A., & Owusu, A. B. (2018). Urban Flood Risk Management in Developing Countries: The Case of Accra, Ghana. Environmental Development, 27, 22-30.

FEMA 2018 National Preparedness Report. (n.d.). Www.preventionweb.net. Retrieved June 2, 2023, from https://www.preventionweb.net/publication/fema-2018-national-preparedness-report

Flomo, Jr., M. S. (2021). Assessing the Disaster Preparedness of Inhabitants of Montserrado County, Liberia. International Journal of Engineering Applied Sciences and Technology, 6(4). https://doi.org/10.33564/ijeast.2021.v06i04.008

Foster, C., Evans, A., Marchand, M., & Walker, G. (2014). Vulnerability and Resilience to Floods in the UK: A Review. Regional Environmental Change, 14(2), 375-390.

Gonz, A. (2019, July 16). Identifying Settlements of High Risk of Floods in Greater Monrovia, Liberia. Medium. https://medium.com/@anagonz/identifying-settlements-of-high-risk-of-floods-in-greater-monrovia-liberia-b71ac13249cd

Haque, A. N., Rahman, M. S., Akter, T., & Alam, K. (2019). Urban Flood Vulnerability Assessment Using Multi-Criteria Analysis: A Case Study of Dhaka City, Bangladesh. International Journal of Disaster Risk Reduction, 34, 295-306.

Hunt, A., Watkiss, P., Stringer, L., & Evans, E. (2018). Climate Change Impacts and Adaptation in Cities: A Review of The Literature. Climatic Change, 151(3-4), 363-381

Iacobellis, V., Napolitano, F., & Lirer, S. (2019). Probabilistic Flood Hazard Analysis in Urban Areas: A Methodology for Combining the Results of 1D and 2D Hydraulic Modelling. Natural Hazards and Earth System Sciences, 19(1), 169-184.

Innis, P. G. (2022). Official Risks and Everyday Disasters: The Interplay of Riskscapes in Two Unplanned Settlements in Monrovia. Urban Forum. https://doi.org/10.1007/s12132-022-09465-9

Intergovernmental Panel on Climate Change (IPCC). (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Cambridge University Press.

Iwuoha, G., Onyegegbu, N., & Eludoyin, A. (2019). Flood risk mapping and assessment in a tropical coastal city: Case of Calabar, Nigeria. Journal of Environmental Management, 237, 265-278.

Jones, A. B. (2022). The Impact of Flooding on Vulnerable Populations in Unplanned Settlements: A Case Study of Bushrod Island, Liberia. Journal of Disaster Management, 15(3), 45-62.

Kamara, A. B., Rautenbach, C. J. W., & Okyere, C. Y. (2019). Evaluation of flood control infrastructure in urban areas: Case study of Accra, Ghana. Journal of Flood Risk Management, 12(S1), e12522.

Kelman, I., Wright, N. G., & Nicholls, R. J. (2018). An Investigation of Flood Fatalities in Mainland Britain 1940–2012. Natural Hazards and Earth System Sciences, 18(7), 2169-2181.

Kingsford, R.T. (2020), Ecological Impacts of Dams, Water Diversions and River Management on Floodplain Wetlands in Australia; Austral Ecology, Vol. 25(2), pp. 109-127.

Kreibich, H., Di Baldassarre, G., Vorogushyn, S., Aerts, J. C. J. H., Apel, H., Aronica, G. T., Arnbjerg-Nielsen, K., Bouwer, L. M., Bubeck, P., Caloiero, T., Chinh, D. T., Cortès, M., Gain, A. K., Giampá, V., Kuhlicke, C., Kundzewicz, Z. W., Llasat, M. C., Mård, J., Matczak, P., & Mazzoleni, M. (2017). Adaptation to Flood Risk: Results of International Paired Flood Event Studies. Earth's Future, 5(10), 953–965. https://doi.org/10.1002/2017ef000606

Kuzma, S., & Luo, T. (2020). The Number of People Affected by Floods Will Double Between 2010 and 2030. *Www.wri.org*. https://www.wri.org/insights/number-people-affected-floods-will-double-between-2010-and-2030.

Liew, Y. S., Mat Desa, S., Md. Noh, Md. N., Tan, M. L., Zakaria, N. A., & Chang, C. K. (2021). Assessing the Effectiveness of Mitigation Strategies for Flood Risk Reduction in the Segamat River Basin, Malaysia. Sustainability, 13(6), 3286 https://doi.org/10.3390/su13063286

LISGIS Official. (n.d.). Www.lisgis.gov.lr. Retrieved July 23, 2023, from https://www.lisgis.gov.lr/globalsearch.php

Merz, B., Kreibich, H., Schwarze, R., & Thieken, A. (2010). Review Article 'Assessment of Economic Flood Damage'. Natural Hazards and Earth System Sciences, 10(8), 1697-1724.

Mow, I. C., Shields, C., Sasa, H., & Fitu, L. (2017). Towards People Centred Early Warning and Disaster Response System in Samoa: The Use of ICT by Samoans During Disaster. The Electronic Journal of Information Systems in Developing Countries, 81(1), 1–18. https://doi.org/10.1002/j.1681-4835.2017.tb00594.x

Mullins, A., & Soetanto, R. (2011). Enhancing Community Resilience to Flooding Through Social Responsibility. International Journal of Safety and Security Engineering, 1(2), 115–125. https://doi.org/10.2495/safe-v1-n2-115-125

Narayan, S., Beck, M. B., & Srinivasan, V. (2018). Evaluating The Effectiveness of Structural and Non-Structural Flood Mitigation Measures in Changing Climate: A Case Study in the United States. Journal of Hydrology, 559, 437-449.

NOAA. (2021). Global Climate Report - Annual 2021 | National Centers for Environmental Information (Ncei). https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202113

Odey, E. O. (2019). Evaluating The Effectiveness of Flood Risk Mitigation Measures: A Case Study of Flood-Prone Areas in Nigeria. Journal of Environmental Management, 231, 791-800.

Olagunorisa, E. A. (2019). Flood Risk Assessment and Management in Coastal Urban Areas: A Case Study of Port Harcourt, Nigeria. Natural Hazards, 99(2), 887-903.

Olalekan, A. S., & Akinnawa, O. O. (2020). Evaluating The Effectiveness of Flood Risk Mitigation Measures in Urban Areas: A Case Study of Ibadan, Nigeria. Journal of Environmental Planning and Management, 63(8), 1544-1564.

Oseji, I. J. (2022). Assessing the Impact of Structural and Non-Structural Flood Mitigation Measures in Urban Areas: A Case Study of Lagos, Nigeria. International Journal of Disaster Risk Reduction, 61, 102267.

Pande, M. M., & Shinde, R. (2016). Assessing The Effectiveness of Structural and Non-Structural Flood Risk Mitigation Measures: A case study of Pune City, India. Natural Hazards, 80(3), 2075-2099.

Raikes, J., Henstra, D., & Thistlethwaite, J. (2023). Public Attitudes Toward Policy Instruments for Flood Risk Management. https://doi.org/10.1007/s00267-023-01848-3

Ritchie, H., Mathieu, E., Rodés-Guirao, L., Appel, C., Giattino, C., Ortiz-Ospina, E. & Roser, M. (2020). Measuring global economic inequality. Our World in Data.

Sagoe-Addy, K., Twumasi, Y. A., Nyamekye, E. A., Amankwaa, E. F., & Amponsah, P. E. (2017). Assessment of Flood Vulnerability and Adaptation Strategies in the Amansie West District, Ghana. Environmental Systems Research, 6(1), 1-11.

Samuels, C., Johnson, P., & Thompson, L. (2020). Assessing the Social and Economic Impacts of Flooding in Unplanned Settlements: A Study of Bushrod Island, Liberia. International Journal of Urban and Regional Research, 44(2), 189-210.

Sanyal, J., & Lu, X. X. (2005). Application of Remote Sensing in Watershed-Scale Hydrology. Hydrological Processes, 19(4), 789-816.

Skougaard-Kaspersen, P., Sørensen, C. S., Arnbjerg-Nielsen, K., & Drews, M. (2017). Benefits of Green Infrastructure for Urban Climate Adaptation. Urban Climate, 19, 1-17.

Smith, D. R. (2019). Flood Vulnerability and Risk Assessment in Unplanned Settlements: A Case Study of Bushrod Island, Liberia. Natural Hazards, 85(1), 123-145.

St. Paul River at Haindi; Liberian Hydrological Services. (n.d.). Retrieved July 23, 2023, from https://lhsliberia.com/water-data/st-paul-river-at-haindi/#side-menu

Tariq, M. A. U. R., Farooq, R., & van de Giesen, N. (2020). A Critical Review of Flood Risk Management and the Selection of Suitable Measures. Applied Sciences, 10(23), 8752. https://doi.org/10.3390/app10238752

Tay, D. A., & Ocansey, R. T. A. (2022). Impact of Urbanization on Health and Well-Being in Ghana. Status of Research, Intervention Strategies and Future Directions: A Rapid Review. Frontiers in Public Health, 10. https://doi.org/10.3389/fpubh.2022.877920

Thompson, R. L., Lassaletta, L., Patra, P. K., Wilson, C., Wells, K. C., Gressent, A., Koffi, E. N., Chipperfield, M. P., Winiwarter, W., Davidson, E. A., Tian, H., & Canadell, J. G. (2019). Acceleration of Global N2O Emissions from Two Decades of Atmospheric Inversion. Nature Climate Change. https://doi.org/10.1038/s41558-019-0613-7

Tsai, F., Lin, Y., & Chang, Y. (2020). Assessing The Effectiveness of Flood Mitigation Measures Using a Structured Decision-Making Approach. Water, 12(2), 408.

UNDRR. (2019). Words Into Action Guidelines: Flood. Retrieved from https://www.undrr.org/publication/words-action-guidelines-flood

UN-Habitat. (2021). Flood Risk Management and Resilience in Unplanned Settlements: A Guide for Practitioners. Retrieved from https://unhabitat.org/books/flood-risk-management-and-resilience-in-unplanned-settlements-a-guide-for-practitioners

United Nations International Strategy for Disaster Reduction (UNISDR). (2009). UNISDR Terminology on Disaster Risk Reduction. Retrieved from https://www.undrr.org/publication/unisdr-terminology-disaster-risk-reduction

Van Eerd, M., Van Herk, S., & Zevenbergen, C. (2014). Structural Flood Risk Mitigation: A Cost-Benefit Analysis of Measures for Various Flood Hazard Scenarios in A Polder Area in the Netherlands. International Journal of Disaster Risk Reduction, 7, 56-66.

World Bank (2019). Flood Risk Profile for Greater Monrovia: Deliverable E - Final and Summary Report. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/681321639115215850/flood-risk-profile-for-greater-monrovia-deliverable-e-final-and-summary-report

World Bank. (2022). Building Resilience in Unplanned Settlements: Lessons from Bushrod Island, Liberia. Retrieved from https://www.worldbank.org/en/news/feature/2022/04/15/building-resilience-in-unplanned-settlements-lessons-from-bushrod-island-liberia

World Health Organization. (2021). Floods and Health: Responding to Health Impacts of Flooding. Retrieved from https://www.who.int/news-room/fact-sheets/detail/floods-and-health

Weather Spark. (2019). (Average Weather in Monrovia, Liberia, Year-Round) https://weatherspark.com/y/31914/Average-Weather-in-Monrovia-Liberia-Year-Round

Xu, W., Li, Y., Li, Z., & Fan, F. (2019). Quantifying The Effectiveness of Structural and Nonstructural Measures on Urban Flood Risk Mitigation: A case study of Beijing. Journal of Hydrology, 568, 372-381.

APPENDIX

Department of Disaster Management
School of Architecture, BRAC University
Mohakhali Dhaka, Bangladesh

Dear Participants,

I am a graduate student pursuing a Master of Science Degree in Disaster Management at the specified department and institution. Currently, I am conducting research on the effectiveness of structural and non-structural flood mitigation measures in the unplanned settlements of Bushrod Island.

The purpose of this research is purely academic and aims to fulfill the requirements for my degree. The questionnaire provided will assist me in gathering valuable and relevant information for the completion of this research. I assure you that all information shared will be treated with the utmost confidentiality and used solely for academic purposes.

I kindly request your participation in this exercise, which should take no more than 5 minutes of your time. Your input will greatly contribute to the success of this study.

Thank you for your cooperation and patience.

Abu Sumaila Kamara
Student Researcher

Socio-Economic Data for Research Participants

	Socio-Economic Characteristics	**YES**	**NO**
Section 1	**Age (%)**		
	18 – 25		
	26 – 33		
	34 – 41		
	42 – 49		
	50 – 57		
Section 2	**Gender (%)**		
	Male		
	Female		
Section 3	**Household Position (%)**		
	Head of Household		
	Member of Household		
Section 4	**Asset Ownership (%)**		
	Own House(s)		
	Tenant		
Section 5	**Employment Status (%)**		
	Employed with Job		
	Self-Employed		
	Not Employed		
Section 6	**Education Status (%)**		
	Not Educated		
	Primary Education		
	Secondary Education		
	Tertiary Education		
	Vocational Education		

Interview Questionnaires

Section One

1. Are you aware of the flood hazards in your area? YES/NO

2. How often does flooding occur?

3. Where does the floodwater come from?

- Rain
- River
- Ocean

4. What height does the floodwater reached here?

- Ankle
- Knee
- Waist
- Chest
- Other

5. What are the impacts of flooding in this area or community?

6. What is the source of flood disaster information?

- Family/friends
- Government Agencies
- Internet (social media)
- Radio/TV
- Newspaper
- International & Local NGOs

7. Who are the providers of floods disaster intervention?

- Government
- Neighbors/Community
- Local & International NGOs
- Self
- Don't Know

8. Which flood hazard(s) occur in this area?

- Pluvial
- Riverine/Fluvial
- Coastal

9. Are you aware of the flood vulnerabilities in the area? YES/NO

If yes, what are they?

Section Two

1. Experience with Floods

a. Have you ever experienced a flood in your area? YES/NO

b. If yes, how severe was the flood?

c. How often have you experienced floods in your area?

d. Have you taken any measures to mitigate flood risks in your area? YES/NO

e. If yes, which type of measures did you take?

- Structural Measures
- Non-Structural Measures

Section Three

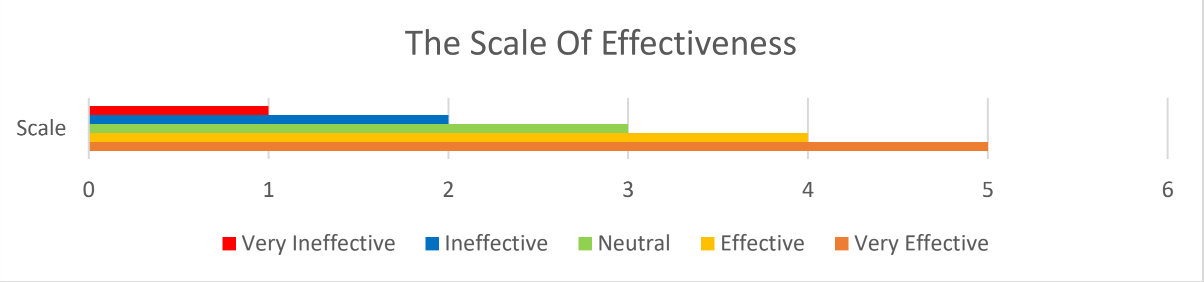
2. Structural Measures

a. Are you aware of any structural flood mitigation measures in your area? YES/NO

b. If yes, what are the structural measures in your area?

c. Are the structural measures effective in reducing flood risks in your area? YES/NO

d. If yes or no, how effective or ineffective are they on a scale of 1-5?



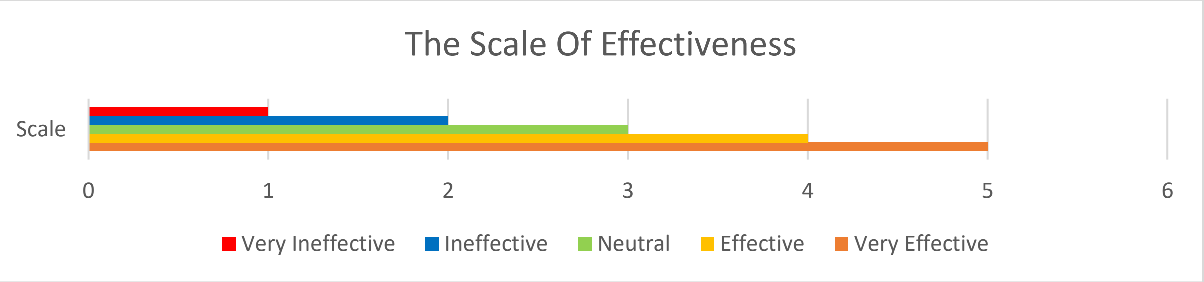
3. Non-Structural Measures

a. Are you aware of any non-structural flood risk mitigation measures in your area? YES/NO

b. If yes, what are the non-structural measures in your area?

c. Are the non-structural measures effective in reducing flood risks in your area? YES/NO

d. If yes or no, how effective or ineffective are they on a scale of 1-5?



4. Comparison of Structural and Non-Structural Measures

a. Which types of flood risk mitigation measure do you think is more effective?

- Structural
- Non-Structural
- Both

b. In your opinion, which type of measure is more practical for your area?

c. What factors would influence your decision in choosing between structural and non-structural measures?

d. What recommendations would you give to improve flood risk mitigation measures in your area?

5. Implementation

a. Is there any instances where the flood risk mitigation measures have failed?

b. What challenges have you faced in implementing or maintaining flood risk mitigation measures in your area?

c. Are the current mitigation measures in the area are sufficient? Why or why not?

d. What are factors affecting the effectiveness of both structural or non-structural flood risk mitigation measures?

e. What recommendations would you make to improve the flood risk mitigation measures in your area?

f. How can the current or new mitigation measures be improved in the area?

Interview Questions

Can you describe you or your entity role in flood risk management in the area?

What phase of the DRM Circle is you or your institution involve with?

  a. **Mitigation, b. Preparedness, c. Rehabilitation, d. Response e. Prevention**

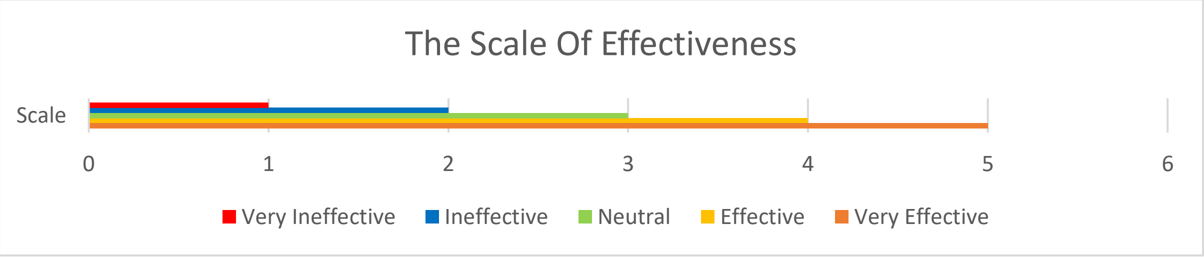
What do you think are the main causes of floods in the study area?

What is the flood hazard risks and vulnerabilities have you observed?

What are the current flood risk mitigation measures in place in the area? Can you describe them?

What are the factors affecting your work and involvement?

How effective have are the current flood mitigation measures in reducing flood risks in the area? On the scale of 1-5 below



General Awareness of Flood Hazards (Pluvial, Riverine & Coastal)

Response	**Frequency**	**Percentage**
Yes		
No		
Total		

Source of Information for Floods Risk Mitigation

Source of Information	Observations	Percentage
Family/friends		
Government Agencies		
Internet (social media)		
Radio/TV		
Newspaper		
International & Local NGOs		
Total		

Severity of Flood Effect

Level	Frequency	Percentage
Very Severe		
Severe		
Mild		
Not Severe		
Total		

Flood Vulnerability Level

Level	Frequency	Percentage
Very High		
High		
Moderate		
Low		
Very Low		
Total		

Sources of Floods Interventions

Expect Interventions from	Observations	Percentage
Government		
Neighbors/Community		
Local & International NGOs		
Self		
Don't Know		
Total		

Flood Water Height/Level

Response	Observations	Percentage
Chest Level		
Waist Level		
Knee Level		
Ankle Level		
Other Level		
Total		

Respondents' Floods Experiences in the Study Area

Response	Frequency	Percentage
1 Year		
3 Years		
5 Years		
7 Years		
9 Years & Above		
Total		

Comparison of Incidences of Loss of Lives & Properties

	2008 NDMA Data		2022 Field Data	
Response	**Frequency**	**percentage**	**Frequency**	**Percentage**
Yes				
No				
Total				

The Effectiveness of Structural Mitigation Measures

S/N	Structural Measure	Very Effective	%	Effective	%	Neutral	%	Ineffective	%	Very Ineffective	%
1.											
2											
3											

The Effectiveness of Non-Structural Mitigation Measures

S/N	Non-Structural Measure	Very Effective	%	Effective	%	Neutral	%	Ineffective	%	Very Ineffective	%
1.											
2											
3											