Nature-based Coastal Adaptation Approaches: Spatial Modelling and Community Perception of Barriers and Opportunities in Ghana

By

Frank Kwaku Aazore

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Members of the Supervisory Committee:

Approved: Dr. Danika van Proosdij
Supervisor
Department of Geography & Environmental Studies
Saint Mary's University

Approved: Dr. Patricia Matsumoto
Supervisory Committee
Department of Geography & Environmental Studies
Saint Mary's University

Approved: Dr. Edem Mahu
Supervisory Committee
Department of Marine & Fisheries Sciences
University of Ghana

Approved: Dr. Brent Doberstein
External Examiner
Department of Geography and Environmental Management
University of Waterloo

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Abstract

Ghana's coastal areas face increasing risks from coastal hazards. While conventional engineering approaches (seawalls and groins) have been the primary mitigation strategies, they often prove unsustainable. Adaptation planning efforts have widely failed to account for local community knowledge. As a result, this study explored community perceptions of risk to coastal hazards, assessing opportunities for nature-based coastal adaptation (NbCA) approaches using GIS, participatory mapping, and household surveys across three communities in Accra.

The study showed significant differences in perceived risk, with older age groups (60+) expressing higher vulnerability. Awareness of NbCA was uneven, with 72% of respondents in Bortianor reporting familiarity due to existing mangrove restoration, compared to Jamestown (37.5%) and Teshie (10%). Despite this, there was a high expression of support for NbCA. Furthermore, participatory mapping identified community-perceived high-risk areas, which showed spatial consistency with GIS risk models.

The findings emphasize the importance of inclusive, context-sensitive, and evidence-based adaptation planning.

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Chapter 1 – Introduction

1.1 Background

It is estimated that about 44 % of the global population lives within 100 km of the coastal zone (O'Leary et al., 2023). The dynamic and complex multi-functional coastal ecosystem is always evolving due to both natural and human-induced factors. These changes impact on a variety of frequently competing human socioeconomic activities in these areas. Rapid urban development has caused several direct and indirect impacts on coastal ecosystems, including damage and degradation (El-Shahat et al., 2021).

The most serious threats to coastal areas worldwide are urbanization, infrastructure development, overfishing, pollution, and climate change, all of which endanger the coastal systems including biological diversity, and environmental regulating functions (Parthasarathy & Natesan, 2015). Apart from the pressure produced by the growing coastal population, most coastal areas are increasingly affected by climate-induced coastal erosion (Mavromatidi et al., 2018) , which is caused by sea-level rise and potential changes in wind or wave conditions and storm regimes (Boateng, 2012; Spalding et al., 2014). Climate change makes coastal areas more vulnerable to risks (Dada et al., 2022).

Coastal communities around the world suffer most from hazards such as coastal flooding and sea-level rise, which most are attributed to climate change (Giardino et al., 2018). The total potential losses from coastal hazards are rapidly increasing in major coastal cities (Dada et al., 2022; Mavromatidi et al., 2018; Revell et al., 2021). While many cities and coastal communities have initiated adaptation to coastal hazards through planning and engineering efforts, others lack both the knowledge and resources to implement effective risk-reduction strategies (Chang et al., 2018).

Cities in the global south are expanding and have a high impact on key services provided by the natural environment (e.g, provisioning services) and destruction of natural landscapes through increased deforestation, habitat fragmentation, and soil erosion (Maharjan et al., 2020; Serdeczny et al., 2017). The impact of climate change and extreme weather events present more challenges in the sustainability of cities, as does the rising vulnerability of these cities to climate change (Mensah et al.,

2020). The fast-growing population and impact of climate change exacerbate cities' ability to accommodate population growth and offer necessary services for well-being (Nassary et al., 2022). Due to the rapid urbanization with a high degree of informality, city dwellers in some cities in the global south are perilously vulnerable to a variety of socio-ecological issues, including coastal hazards (Enu et al., 2024; Wake, 2020).

Climate change is projected to have a global impact; however, scientists agree that coastal cities in developing countries of the global south stand to be among the most climate-impacted in the world (Mycoo et al., 2021). Coastal cities in the Global South face a variety of severe coastal hazards, including erosion, flooding, and saltwater intrusion, leading to major socioeconomic consequences such as displacement and loss of livelihoods (Gisevius et al., 2023). According to Evadzi et al. (2018) hundreds of millions of people in developing countries will be displaced by sea-level rise within this century, with severe economic and ecological damage likely to follow (do & Adeyemi, 2013). Addo et al. (2011) also highlighted that the impact of sea level rise will be more pronounced in developing countries in Africa due to limited adaptive capacity. It is therefore necessary to assess coastal communities' awareness and responses to sea-level rise to improve adaptation planning.

Climate change estimates show that the West African coastal zone will be at risk of coastal hazards, especially flooding by 2080 (El-Shahat et al., 2021). The West African coast is regarded as being highly vulnerable to climate change and its associated sea-level rise due to the concentration of lower-income populations in potentially hazardous areas at risk (Addo & Adeyemi, 2013). Ghana's coast has developed in response to changes in its natural environment. Such changes have happened on various spatial and temporal scales and are currently influenced by human activities. The lateral changes in the coastline position have resulted in coastal erosion, which has destroyed the coastal environment and affected the socio-economic life of the local population, threatened cultural heritage, and hindered coastal tourism development (Addo, 2009; Codjoe et al., 2017; Osman et al., 2016).

Coastal erosion poses a severe threat to life and property in Ghana, as the coastal zone is home to 25% of the nation's population and hosts over 80% of the industrial institutions, including two international ports (Tema and Tarkoradi ports) (Avornyo et al., 2023). Previous studies including Addo (2013) and (2015), have reported on shoreline erosion in the Greater Accra region. Erosion is expected to endanger approximately 80% of the shoreline, with the remaining 20% stable or accreting. Despite this concern, past and contemporary management strategies have remained *ad hoc* and site-specific (Asumadu-Sarkodie, Owusu, & Jayaweera, 2015).

A study by Parthasarathy & Natesan (2015) suggested that the necessary intervention and policy design must be based on risk and vulnerability analyses, with vulnerable groups included in adaptation efforts. Understanding the causes of vulnerability can assist in determining where and how to reduce coastal vulnerability to hazards, as well as identify institutions able to facilitate adaptation (Chang et al., 2018). However, Addo et al. (2011) noted that, in Ghana, very little attention has been paid by the government to suggested policy implications and adaptation measures for protecting coastal communities. Coastal communities continue to suffer from coastal hazards including coastal erosion and flooding, which in many cases have resulted in the loss of infrastructure, thus posing an additional cost to Ghana's conventional development agenda (Addo, 2014; Dekongmen et al., 2021; Fitton et al., 2021).

1.2 Research Problem

Over the last few decades, researchers, government agencies, and local coastal communities have increasingly acknowledged the importance of adapting to sea level rise and associated coastal hazards. Communities, scholars, and coastal management agencies have long urged for the inclusion of adaptation planning in long-term urban planning frameworks, as a long-term way to prevent this *ad hoc*, emergency response form of coastal management (Revell et al., 2021). According to Slinger et al. (2021), effective coastal management necessitates the ability to plan the response to climate change

variations in both the short and long term, as any change in climate processes would eventually influence the coastal zone in some way (Boateng et al., 2017).

Until recent years, traditional engineering approaches, which rely mainly on constructed measures, were employed for risk mitigation. However, they have not always been effective, especially in the long term (Enu et al., 2024). Previously, attempts at coastal protection have relied mainly on 'hard' measures such as seawalls and bulkheads, especially for developed coastal areas with significant assets at risk. While such approaches might be valuable and highly effective, they can also be expensive to develop and maintain. Hard constructions can also fail, and there have been several reports of such structures aggravating coastal erosion or causing damage in adjacent areas (Spalding et al., 2014). Coastal hazard management efforts in Sub-Saharan Africa have mostly focused on "hard" solutions, however, they have not been wholly effective in controlling coastal hazards (Alves et al., 2020).

A paradigm shift towards living with, rather than managing nature has been encouraged, spurred by the increasing recognition of synergies between efforts to decrease risk, combat climate change, and address human development challenges through the utilization of ecosystems and their services (Anderson & Renaud, 2021). Nature-based Solutions (NbS) have thus attracted significant attention from both scholars and decision-makers, due to their potential to contribute to a sustainable and climate-resilient future (Hagedoorn et al., 2021). These solutions aim to protect, sustainably manage, and restore natural or modified ecosystems while providing benefits to human well-being and biodiversity. However, the uptake and success of NbS vary by region, reflecting differing environmental conditions and socio-ecological processes (Chee et al., 2021).

While the term "NbS" broadly refers to measures to preserve, reinstate and control the natural or altered ecological systems effectively and adaptively to address societal challenges (Cohen-Shacham et al., 2016), the term "Nature-based coastal adaptation (NbCA)" which is a subfield of NbS, focuses on coastal areas and incorporates ecosystem-based approaches to mitigate hazards such as flooding, erosion, and sea-level rise (Rahman et al., 2023). More recently, policymakers and researchers have

been exploring NbCA to highlight the unique physical dynamics, policy challenges, and socio-ecological contexts of coastal environments that conventional NbS literature may not fully cover (Morris et al., 2018; Rahman et al., 2023; van der Meulen et al., 2023). However, it appears to be most popular in high-income places and has been explored and implemented in a variety of ways (Rahman et al., 2023; Rahman et al., 2021) such as the living shorelines in the US and Canada (Bilkovic et al., 2016) and the sponge city concepts in China (Chan et al., 2018). In contrast, medium to low-income regions, including Sub-Saharan Africa and especially Ghana, present limited studies on NbS measures and even more so for NbCA (Asare et al., 2023).

Ghana's strategy to mitigate coastal hazards has traditionally relied on conventional engineering strategies such as dams, levees, storm drains, and sea walls (Amoako & Inkoom, 2018). While these strategies aim to adapt to climate change, they are not always sustainable, and the continued loss of natural areas underscores the need for alternative approaches, such as NbCA, which are currently underutilized (Asare et al., 2023). Despite the economic and ecological importance of coastal ecosystems, such as mangroves, Ghana lacks a holistic policy or integrated plan for coastal management. This gap has resulted in reactive, hard-engineering approaches that may address immediate concerns but often lead to long-term environmental degradation (Charuka et al., 2023) . The limited application of NbCA in Ghana, particularly in the context of coastal hazard mitigation, suggests a need for further exploration and understanding of these approaches.

Given the limited knowledge and application of these key approaches in sustainably managing coastal hazards and their use in Sub-Saharan Africa, this study seeks to explore community perceptions of risk to coastal hazards and understand the potential barriers and opportunities for implementing NbCA in the study area. This research addresses the gap in existing literature, which has predominantly focused on grey infrastructure solutions (human-made engineering approaches) and neglected the potential of NbCA in regions like Ghana.

1.3 Research Objectives

This study will specifically examine the Greater Accra regional coast, an area of critical importance due to its exposure to both high and medium wave energy and its status as the most developed part of Ghana's coastline. Prior studies on coastal management in Ghana have largely overlooked this region, focusing instead on other parts of the coast. By addressing this gap, the research aims to provide insights that will inform the sustainable management of coastal hazards in Accra through NbCA. To achieve this goal, the following research questions and objectives will be pursued:

1) What are the community perceptions of risk to coastal hazards in Accra?
    - *Objective 1: To assess variations in coastal hazards risk perceptions across different demographic and socioeconomic groups within the study communities*

2) Based on community risk perceptions and Geographic Information System (GIS) analysis of coastal hazards in Accra, where are the potential target areas for effective NbCA interventions?
    - *Objective 2: To conduct a comprehensive GIS analysis of risk factors to coastal hazards in Accra, integrating data on sea level rise, erosion, and other relevant variables and associate community perceptions of risk with GIS-based assessments.*
    - *Objective 3: To identify and prioritize potential target areas for effective NbCA interventions in Accra based on the findings from Objective 2.*

The study will be guided by the following hypotheses:

1) The community perceptions of risk to coastal hazards vary based on factors such as proximity to the coastline, cultural and socioeconomic status (age, gender, education, occupation income, religious affiliations), and past experiences or beliefs.

2) There is a spatial association between community derived coastal hazards risk areas and GIS assessment of coastal hazard risk areas the study communities, suggesting that areas with

perceived high-risk to coastal hazards align with regions identified as high-risk through GIS analysis.

1.3.1 Clarification of key terms

In this study, three key interrelated concepts are used to examine how stakeholders perceive and respond to climate-related threats in selected coastal communities in Ghana. These concepts include 'coastal hazards', 'risk' and 'vulnerability'. The terms are used in this thesis as below:

Coastal hazards refer to natural processes including flooding, storm surge, erosion, and salinization, that endanger to human lives, infrastructure, and livelihoods (Mukhopadhyay et al., 2012).

Vulnerability refers to the degree to which people, households, or communities are susceptible to harm from these hazards, considering factors such as location, income, housing conditions, and adaptive capacity (Adger, 2006; Chang et al., 2018; Turner et al., 2003).

Risk, in this thesis refers to 'perceived risk' (based on people's perception), which is defined as how people interpret or understand and evaluate the possibility and potential severity of harm from coastal hazards. This approach draws from social science lens, in which perceptions of risk are influenced not only by actual hazard exposure but also by socio-cultural and experience factors (Bubeck et al., 2012; Eboh et al., 2021). As a result, risk in this study is ***not statistically quantified*** but rather measured through survey responses that represent community attitudes, beliefs and lived experiences. This framing is critical because risk perceptions have a direct influence on public support for adaptation strategies (Eboh et al., 2021) and this includes nature-based coastal adaptation approaches. Understanding risk as perceived by the community members or residents assists in identifying both barriers and opportunities for local adaptation planning.

1.4 Literature Review

1.4.1 Coastal Hazards and Adaptation Planning

The coast is one of the most dynamic parts of the Earth's surface. About 23% of the world's population live within 100 km of the coast and about 10 % of the population live in extremely low-lying areas (< 10 m above mean sea level (Mukhopadhyay et al., 2012). Raub & Cotti-Rausch (2019) defines coastal communities as all stakeholders living and working in the coastal zone of the ocean and Great Lakes states and territories, such as people, municipal governments, businesses, and organizations.

Coastal regions have enormous social, economic and biological value. They provide important ecosystem services to human society, including food, energy, shoreline protection, tourism and coastal livelihoods, water quality maintenance, waste treatment, biogeochemical cycling, and regulating services, support for the green and blue economies, and most importantly, the maintenance of the basic global life support systems (Benveniste et al., 2020; Melet et al., 2020). The provisions of these services have been substantially affected during the 20th century due to both natural and human factors or processes such as increasing populations, urbanization, and development activities (Maanan et al., 2018). Additionally, there are several coastal hazards, such as coastal erosion, storm surges and flooding, which can impact coastal settlements. Rising sea levels and changes in the frequency and severity of storms due to climate change will likely exacerbate these hazards (Oteng-Ababio et al., 2011). Given this, several studies including Maanan et al. (2018) and Fitton et al. (2021) claim that coastal communities worldwide are becoming more vulnerable to a wide range of potential hazards including coastline erosion and coastal resource degradation. The problem is exacerbated by growing urbanization and the concomitant anthropogenic beach changes that influence coastal processes (Revell et al., 2021).

Coastal hazards are complex issues, as are the efforts required to adapt and build resilient communities. Key challenges in planning for coastal hazards include understanding and predicting the probability of the timing and severity of future events and assessing tolerance (Raub & Cotti-Rausch,

2019). Adapting to changing coasts is an extraordinary planning problem as coastal hazards, including those associated with climate change, influence all sectors of resource management (Mattah et al., 2023). If adaptation is not pursued, most low-lying islands, coasts and communities will encounter substantial risk from coastal hazards regardless of their level of development (Mycoo et al., 2021).

Urban coastal communities in the Global South are disproportionately affected by coastal hazards due to their increased exposure to environmental risks and limited adaptive capacity (Gisevius et al., 2023). In West Africa, climate change vulnerability is particularly high, as many low-income populations reside in hazard-prone coastal zones that are highly susceptible to sea-level rise and extreme climate-related events (Addo, 2013). The region faces a variety of potential climate-induced impacts, including shoreline erosion, saltwater intrusion, flooding of wetlands and estuaries, and threats to cultural heritage sites and critical coastal infrastructure (Yankson et al., 2017).

The ability of a coastal settlement to adapt is largely dependent upon access to climate, engineering, and management knowledge; access to accurate and reliable local-scale climate data; access to financial resources; local communities' participation; and political consensus (Fitton et al., 2021). As highlighted by Mattah et al. (2023), the adaptive capacity of a community may also vary concerning certain socio-economic variables such as experience with coastal hazards, skills, level of income, age, gender, and others. Whether or not there is a perceived need to adapt to coastal hazards is determined by risk perceptions and the processes and conditions that shape that risk. Communities' perceptions are rarely taken into consideration in coastal risk and adaptation analyses. Studies focusing on communities' perceptions generally explain them by reference to socio-economic and demographic factors (Friesinger & Bernatchez, 2010). Raub & Cotti-Rausch (2019) therefore concluded that in order to plan for the future, coastal communities confronted with coastal hazards must have access to risk information and knowledge at acceptable scales and degrees of reliability.

Recent studies including Benveniste et al. (2020) and Melet et al. (2020) suggested that monitoring the coastal zone is also a fundamental first step to protect the well-being of the large coastal

communities depending on its ecosystem. In this context, Melet et al. (2020) emphasized that satellite missions provide a cost-effective way to supply repeated, dense, and global observations of the essential variables representing the dynamics, health and trends of the coastal zone, as well as events leading to coastal hazards. However, Friesinger & Bernatchez (2010) argued that it has been shown that a gap between geospatial data and the perceptions of individuals concerning environmental change can reduce the resilience of coastal communities, even to a point where no adaptation strategy is implemented.

Furthermore, to improve coastal hazard adaptation planning, there is a need to determine the level of awareness of the key coastal hazards (e.g. sea-level rise) and responses in coastal communities (Evadzi et al., 2018), necessitating the need to assess people's perception. Understanding the social perceptions and the relative priorities given to coastal risk can help in the development of adaptive capacity and associated adaptation strategies, as perceptions tend to shape individual behaviour (Domingues et al., 2021) and management strategy preferences (Dada et al., 2022).

1.4.2 Coastal Hazards in the face of climate change

Climate change is widely acknowledged as a critical environmental concern that affects both natural and human systems around the world. Threatened environmental systems include coastal areas that are particularly exposed to a range of hazards connected to climate change (e.g., sea-level rise, increased levels of inundation and storm flooding, accelerated coastal erosion, seawater intrusion, and increased sea surface temperature), which can result in a suite of socioeconomic impacts on the coastal zone (e.g., loss of properties and coastal habitats and loss of tourism, recreation, and transportation functions) (Mattah et al., 2023; Vasseur, 2021).

In tropical regions, such as Africa, flooding is a significant problem due to strong and frequent rainstorms, which are projected to be exacerbated by climate change (Evadzi et al., 2018). Changes in built-up areas caused by urbanization can modify flood regimes, notably the timing of flooding, and natural channels can become clogged. These factors can speed up the movement of floodwaters

compared to natural conditions (Amoako & Inkoom, 2018). Additionally, coastal communities in Africa are amongst those facing the most pressure from inward migration, urbanization, resource extraction, pollution and industrialization (Bunce et al., 2010). Despite the numerous livelihood opportunities coastal inhabitants enjoy from the coast, the incidence of climate change has negatively impacted these opportunities and has threatened coastal livelihoods (Ankrah, 2018).

In Ghana, climate change impacts such as increasing storms, heavy and unexpected rainfall, flooding, and sea-level rise, are reported to have affected coastal residents and their socioeconomic activities (Addo, 2014). Accelerated sea-level rise poses a substantial coastal management problem to coastal communities in Ghana, where geospatial data is scarce (Boateng et al., 2017). Ghana's coast continues to suffer from coastal erosion and flooding, which has resulted in the loss of infrastructure in many cases, adding to the country's conventional development agenda (Yankson et al., 2017). According to the United Nations Environmental Program (UNEP), Ghana's coast is one of the "climate hotspots" in Africa, where natural disasters caused by climate change continue to wreak havoc (Twerefou et al., 2023). Ghana is also one of several West African countries with port cities that are vulnerable to sea-level rise and flooding (Amoako & Inkoom, 2018). Ghana's coastal regions have seen an increase in the frequency of climate risks during the past ten years, most notably flooding and submersion. Increased coastal erosion in Ghana has been attributed by Addo (2014) to unplanned physical infrastructure expansion, population growth, and growing tourism development in coastal zones. This means that, for building infrastructure, wetlands are drained, and coastal vegetation is destroyed (Darko et al., 2022).

According to Tasantab et al. (2020), coastal hazards risk management in Ghana, just like many countries across the world, is positioned in a reactive culture and is most definitely not indicative of such sustainable features. This is a result of the government prioritizing catastrophe relief over disaster risk reduction (Poku-Boansi et al., 2020). Generally, it is unclear how households in the flood-prone areas may be encouraged to improve their flood resilience in the future. Furthermore, it is not evident what

deters households from implementing individual flood precautions, which are essential for balancing flood sensitivity and exposure and, ultimately, damage (Christian et al., 2021). A household's decision to implement private precautionary adaptation may be influenced by a variety of factors, including socioeconomic and psychological ones like age, sex, educational attainment, and type of tenancy, or psychological ones like fear, perception of flood risk, and prior experience with flooding (Twerefou et al., 2019).

Effective coastal management necessitates the ability to plan responses to climate change variations in both the short and long term, because any change in climate processes will eventually influence the coastal zone (Addo, 2014; Dekongmen et al., 2021). As a result, assessing coastal vulnerability to climate change is critical to long-term coastal management. It is crucial to highlight, however, that predicting the future reaction of coastal zones to changes in sea level rise or storm strength requires knowledge of the coast's historical and current states (Adams et al., 2022). This information allows for an adequate response to the hazards posed by rising sea levels (Boateng et al., 2017) . The absence of proper information on coastal conditions has hampered awareness of the level of danger faced by various coastal towns in Ghana, as well as their ability to cope (Yankson et al., 2017).

To address the detrimental effects of climate change and the concomitant rise in sea levels, policymakers, coastal managers, and opinion leaders require evidence-based information on existing coastal vulnerability and predictions (Adams et al., 2022). Determining coastal vulnerability hotspots helps for proper long-term policy implementation, such as development restrictions in susceptible areas, as well as short-term resource allocation. According to Boateng et al. (2017), the vulnerability of the coast is determined by the sensitivity or susceptibility of coastal areas to erosion and the lack of capability to cope with and adapt to the occurrence. Estimates of the natural and socioeconomic values of the various coastal land-cover types threatened by coastal erosion can thus assist policymakers in anticipating coastal impacts and prioritizing management efforts to minimize risks (Addo, 2013b; Codjoe & Afuduo, 2015; Owusu-Ansah et al., 2019).

1.4.3 Climate change Impact on the coast of Accra, Ghana

Accra, the capital city of Ghana, is increasingly experiencing the effects of climate change and rapid urbanization, particularly in its low-lying coastal areas. The city is experiencing "double exposure", a convergence of socio-spatial pressures such as informal settlement expansion and environmental hazards linked to climate change, including sea-level rise, tidal inundation, coastal erosion, rising water tables, and the intensification of storms and cyclones (Christian et al., 2021). These impacts have increased coastal erosion, caused periodic flooding in susceptible areas, and increased threats to infrastructure and livelihoods along the coastline. Given this, Addo (2013) emphasized the importance of conducting a comprehensive coastal vulnerability assessment in the Greater Accra region to guide effective adaptation and risk reduction strategies. (e.g see Addo, 2009b; Addo & Addo, 2016; Amoani et al., 2012; Ishmael, 2021) have reported that eighty percent of Accra's shoreline is thought to be at risk from erosion, with the remaining twenty percent either stable or accumulating. In addition to endangering cultural assets and impeding the growth of coastal tourism, coastal erosion has an impact on the social and economic well-being of the local populace (Addo, 2013b). There is a dearth of information regarding the response to sea-level change and its integration into adaptation planning, despite the report by Armah (2005) identifying sea level rise in Ghana as having an impact on shoreline recession, flooding, and inundation of low-lying coastlands (Boateng et al., 2017).

Many cities in Ghana have grown rapidly without strictly adhering to development restrictions, making them vulnerable to a variety of climate change dangers (Codjoe & Afuduo, 2015). Building on waterways and paving of surface areas have encroached on these places, preventing rainwater from infiltrating into the soil. Areas intended for runoff detention (swamps and valleys) have been utilized for infrastructure development, which eventually contributes to floods (Tasantab et al., 2020). These areas were naturally designed for the retention of excessive runoff and overland flows, which aids in reducing the time of concentration of surface runoffs (Dekongmen et al., 2021).

In the Greater Accra region, three types of flood hazards can be identified: flooding caused by inadequate drainage, flooding caused by the overflow of streams, rivers, and lagoons, and coastal flooding caused by storm surges and tidal waves, all of which are directly or indirectly related to climate change (Twerefou et al., 2019). The natural breaks in the Greater Accra region's elevation patterns run between 4 and 130 m above mean sea level, giving the impression that Ghana's capital city is rather flat (Yankson et al., 2017). In general, the Greater Accra region has modest slopes up to roughly 22%. As a result of the low-lying nature of the Greater Accra, runoff from other municipalities in the Greater Accra is directed downwards to the city of Accra and its environs (Dekongmen et al., 2021).

The city is particularly prone to flooding in about 40% of its land area (out of 17,320 hectares) (Yankson et al., 2017). Therefore, it regularly experiences significant damage and loss due to perennial flooding (Amoako & Inkoom, 2018; Poku-Boansi et al., 2020). Notably, on June 3, 2015, severe flooding triggered an explosion at the Ghana Oil filling station, when floodwaters caused fuel leakage that ignited, leading to over 200 fatalities and costing over US$100 million in restoration expenses (Codjoe & Afuduo, 2015; Dekongmen et al., 2021). It was the most serious calamity to strike the city in recent times. A significant portion of the city was devastated, and the impact on livelihoods and well-being was significant. Although the disaster comprised both flooding and a subsequent explosion, hydrological evaluations classified the flooding alone as a ten-year flood event, implying an approximately 10% chance of such a flood occurring in any given year (Amoako & Inkoom, 2018). According to Adams et al. (2022), one of the key causes of Accra's devastating flood on June 3, 2015, was a barrier at the Odaw River's mouth, which prevented it from discharging freshwater into the sea. Between 2016 and 2019, several lives and properties were also lost due to repeated floods. Some researchers attribute these recurring foods in the Accra Metropolis to a variety of contested factors, including the city's low-lying area (Darko et al., 2022; Yankson et al., 2017), poor planning (Poku-Boansi et al., 2020), drainage networks (choke drains, underside drains, etc.), massive city expansion, increased impervious surface area, mismanagement of surface water resources through uncontrolled

rapid urbanization and the construction of residential and commercial structures on waterways (Dekongmen et al., 2021; Poku-Boansi et al., 2020).

Floods occur in communities in Accra along major rivers, as well as those near tributaries of these big rivers, in response to heavy rains. The issue of flooding has become a perennial event for the settlements (Owusu-Ansah et al., 2019). Despite perennial flooding events with devastating impacts, Ghana lacks efficient systems for flood prevention, mitigation, and recovery (Poku-Boansi et al., 2020). The National Disaster Management Organization (NADMO) visits flooded areas and distributes relief supplies to flood victims during the rainy season. It also frequently collaborates with senior government officials, including the president (Gough et al., 2019). Nonetheless, public authorities withdraw to their offices when flooding incidents cease to make news, while flood victims return to save their properties (Poku-Boansi et al., 2020). The annual flooding of Weija Township, which lies downstream of the Weija Dam and close to Ghana's capital, Accra, is a glaring example of this difficult cycle (Owusu-Ansah et al., 2019).

According to Owusu et al. (2019), lower-income households and businesses located in densely populated and economically important coastal zones in African cities are particularly vulnerable to the extreme impacts of climate change, such as increased flooding. To support sustainable urban management amid these growing risks, it is critical that stakeholders develop a comprehensive understanding of flood susceptibility and the adaptive capacities of different urban localities. In the context of Ghana, there is an urgent need for evidence-based insights into the relationship between climate change and urban flooding, as well as effective response strategies. Such knowledge is essential to lessen disaster vulnerability and subsequently enhance community resilience (Poku-Boansi et al., 2020).

1.4.4 Nature-based Adaptation Approaches

Developing strategies to adapt and manage the impacts of climate change in urban areas will become increasingly important as the global population becomes more concentrated in cities and climate

continues to change in ways that have potentially severe consequences for urban populations and infrastructure (Hobbie & Grimm, 2020). However, for a while, adaptation was mostly studied from a societal response perspective, with the belief that human activities need to adapt with little or no consideration for the rest of the natural ecosystem. As a result, adaptation and mitigation measures for coastal hazards have been both structural (built/grey/engineered) and non-structural (forecasting, early warning, and evacuation). Structural or gray approaches refer to the hard, engineered and built-up techniques to manage coastal hazard effects. For example, sea walls, groins, floodgates, tide gates, breakwaters etc. These human-made structures are often constructed by using traditional building materials such as concrete, steel, or other long-lasting materials. They are designed to prevent any form of ecosystem from flourishing on it and are not flexible, sustainable, or resilient to the on-going urbanization and climate change (Kumar et al., 2021).

From an ecological perspective, hard infrastructures often alter the morphological and hydrodynamic features of coastal ecosystems by modifying wave regimes, sediment dynamics and deposition processes, and squeezing out habitats that can bring coastal resilience to flood and erosion problems (Rahman et al., 2019). Additionally, Spalding et al. (2014) highlighted that once established, the hard infrastructures are difficult to modify, which eventually reduces adaptability to changing socio-economic and environmental demands. Considering these limitations, several scholars (e.g. see Meselhe et al. 2020; Schueler, 2017) have concluded that hard-coastal protection infrastructures may be 'maladaptive'. As a result, there is a growing scientific interest in exploring how natural processes can provide management solutions to resolve the vulnerability and degradation of coastal environments (Slinger et al., 2021; van der Meulen et al., 2023). In the past decade, the importance of the natural ecosystem in climate change adaptation has gained a new dimension, where it is not only just a question of ensuring that it can adapt, but also the recognition that it can be a vehicle for the social-ecological system to adapt (Vasseur, 2021).

There are multiple names for concepts that aim to integrate natural ecosystems into infrastructural designs and developments. This nature-based approach has been given different names, such as nature-based solutions (NbS) (Kabisch et al., 2017), building with nature (BwN)(van Slobbe et al., 2013), green infrastructure (GI) (European Union 2013), ecosystem-based (EbA) or ecological engineering and nature-based coastal adaptation (NbCA)(Rahman et al., 2019). All of them share the use of natural elements and processes that belong to the site to achieve varying objectives, including flood risk reduction, coastal hazard mitigation, ecological health, and recreation. The term "NbS" emerged in the late 2000s and has since been used in various international environmental documents and frameworks, with prominence as actions for addressing the climate change and biodiversity loss crises (Kabisch et al., 2017). A clear, universal definition of NbS does not exist. However, the International Union for Conservation of Nature (IUCN, 2015) defined NbS as "measures to preserve, reinstate and control the natural or altered ecological systems effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016; Tye et al., 2022). The European Commission also defined NbS as solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience (Davies et al., 2021). NbS therefore encompasses a broad range of actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits (Chausson et al., 2020; Cohen-Shacham et al., 2016). These solutions focus on harnessing the power of nature as a cost-effective answer to broad socio-environmental challenges (Chee et al., 2021).

NbS encourages sustainability values in the process, thereby not only solving the environmental or social obstacles but also inducing human mental and physical well-being by providing positive environmental externalities of increased biodiversity (Kumar et al., 2021; Kiss et al., 2022). Additionally, NbS also provides a host of co-benefits, including the provision of coastal defense to safeguard people and property, support of global economies through enhanced fisheries and tourism

activities, conserving and restoring nearshore habitats , creation of green jobs, and generally increasing the resilience of natural ecosystems to environmental disturbances (Chee et al., 2021; van der Meulen et al., 2023). Furthermore, NbS acknowledges that working with nature, rather than against it or without it, can lead to more effective, economical and culturally appropriate solutions to societal challenges while concurrently conserving or restoring biodiversity (Kiddle et al., 2021). In addition to the many benefits of NbS, in many cases, they present more efficient and cost-effective solutions than more traditional "hard" infrastructure and technical approaches (Baustian et al., 2020; Enu et al., 2023).

1.4.4.1 Nature-based Coastal Adaptation (NbCA)

Historically, coastal communities' economies have been built upon the exploitation of natural resources, which has shaped their socioeconomic growth. This has limited these communities' ability to adjust to climate change (Vasseur, 2021). Despite the high sensitivity to sea-level rise impacts, coastal populations and infrastructure have grown in both developed and developing countries, fuelling increasing demands for coastal protection and multiple ecological services. Sea levels are rising faster than ever, limiting the effectiveness of hard infrastructure-based coastal protection. Scientists and policymakers are exploring alternative adaptation approaches that use nature's capacity to buffer flooding and erosion, a strategy referred to as nature-based coastal adaptation (NbCA) (Rahman et al., 2023).

Recognizing the undesirable outcomes and limitations of hard infrastructure, coastal managers are turning to nature's capacities to reduce risks to coastal hazards through 'nature-based coastal adaptation' (NbCA) (Rahman et al., 2023). Rahman et al. (2019) defined NbCA as "any coastal adaptation approach that uses (i) ecologically available adaptation options (e.g., natural space, ecological process, and species planting) and (ii) socio-psychologically and socio-politically available opportunities (e.g., emotional and cultural acceptance, social values, policy, rules and regulations etc.) to (iii) allow for adjustment to coastal climate change impacts through enhancing and maintaining

natural coastal processes such as erosion and sedimentation for conserving or restoring coastal ecosystems, and (iv) considering societal demand for diverse ecosystem services (e.g., provisioning, regulating, cultural, and supporting) while (v) minimizing engineered construction as a supporting component wherever possible."

NbCA refers to all adaptation options that use the natural capacity of coastal ecosystems to adapt to coastal hazards and maintain multiple ecosystem services for sustainable coastal zone management (Rahman et al., 2021). Implementing NbCA necessitates context-specific knowledge, technical innovation, policy provisions, community involvement, land, and financial resources. It can be challenging to gather all these resources within the policy and institutional frameworks that are intended for hard protection measures. Thus, the adoption and implementation of NbCA as a coastal adaptation measure may call for institutional reform (Rahman et al., 2019).

Common approaches considered under NbCA include re-imagination (i.e., inventing new coastal landscape perceptions and usages considering the inevitable impacts of climate change); reinforcement (i.e., holding the existing line of coastal defense by greening shorelines or floodproofing coastal infrastructures); relocation (relocating homes, buildings and infrastructure from high-risk flood and erosion areas); restoration (i.e., creating a new line of defense by landward movement of existing hard protection infrastructures to accommodate floodwater in natural reservoirs like salt marshes) and restriction/reservation (i.e., imposing legal and institutional instruments to regulate coastal development and to help implement different NbCA approaches) (Sherren et al., 2024).

Reguero et al., (2018) concluded that coasts with essential ecological components such as salt marshes, mangroves, dunes, and coral reefs, lend themselves to applications of resilience principles for management. Indeed, in their view, NbS are central to achieving resilience, and they contend that this requires more than engineering alone (Slinger et al., 2021). Coastal ecosystems also protect people, infrastructure, and economic activities from flooding, erosion, and sea-level rise. Compared to hard infrastructure, which is often designed for a single purpose, natural systems can provide a variety

of benefits and livelihood opportunities (Schueler, 2017). Unlike engineered hard structures, natural landforms dynamically adjust to external drivers (e.g., wave and/or tidal energy). This adjustment means that natural landforms can potentially persist where engineered structures cannot. It also means that natural coastal protection requires more space than engineered defenses.

Although NbCA approaches are more sustainable than conventional hard infrastructure, they may not be able to cope with coastal hazards such as sea level rise forever. In the cases of extreme sea-level rise, more inland migration may be required, which can be limited by existing physical barriers creating coastal squeeze. Despite this limitation, NbCA approaches are preferred over hard infrastructure because of their flexibility, which can be modified relatively easily, and the additional co-benefits that they provide (Rahman et al., 2021).

1.4.5 Role of Community/Stakeholders in Nature-based Approaches

The multifunctionality of NbCA creates more opportunities for stakeholder participation but also increases the possibility of conflict (Hein et al., 2006; Santoro et al., 2019). Several authors emphasized the importance of accounting for community risk perception in risk management, arguing that the reality perceived influences stakeholders' decisions and may lead to failures in risk management actions. Social perception of natural hazards is subjective, and the risk associated with a particular natural hazard differs within and across communities (Santoro et al., 2019). However, Hino & Nance (2021) found that evidence from several flood risk management efforts shows that a thorough understanding of the primary physical phenomena to be addressed is frequently insufficient and must be combined with stakeholders' knowledge and community risk perceptions.

The effectiveness of flood risk management measures is particularly dependent on stakeholders' perceptions and attitudes, which play a significant role in how individuals and institutions operate (Santoro et al., 2019). Negative public perceptions are commonly considered a potential impediment to NbS adoption (Santoro et al., 2019). Therefore, policy-oriented NbS recommendations emphasize the importance of local stakeholder participation (Anderson et al., 2021). When faced with competing

social interests within their "host" communities (i.e. groups of local citizen stakeholders living and interacting with NbS), NbCA may be less effective in the short term than other measures, necessitating stronger long-term protection (e.g., conservation).

In terms of stakeholders' role in ensuring effective coastal protection, Rahman et al. (2019) emphasized the importance of communicating the scientific foundation of NbCA approaches to the residents and other local stakeholders of coastal communities. This is because community stakeholders frequently argue that scientists, technical experts, and decision-makers are unaware of communication and interpretive tools and techniques for explaining the complexities of coastal ecosystems and the efficacy of NbCA. Similarly, Gomez-cunya et al. (2022) supported this finding and highlighted the importance of considering the perspectives of people affected by the implementation of these approaches, especially when viewed from various angles. For example, restoring a coastal environment to improve biodiversity, mitigate climate change, and strengthen coastal protection may have a negative economic impact on certain stakeholder groups. In this regard, a successful NbCA implementation will require setting the action within the specific ecological and social context, involving stakeholders, considering potential outcomes and interactions with other interventions, balancing trade-offs, and prioritizing actions and outcomes (O'Leary et al., 2023).

In this study, the term "stakeholders" refers to persons, or individuals and groups who are affected by or can influence coastal adaptation responses in Ghana. These include local community members, traditional authority, non-governmental organizations (NGO's), and government actors. While the term "community" is commonly used to describe groups that share a geographic space, this study uses the term 'stakeholders' more broadly to refer to the numerous actors who influence or are influenced by NbCA. Nonetheless, data collection was predominantly focused on community household surveys, making community members and leaders the key stakeholder group in this study's analysis.

1.4.6 Risk Perception and Vulnerability to Coastal Hazards

Persons and agencies from different academic and professional backgrounds use the terms vulnerability and risk differently. In defining these concepts, social scientists move towards social structures and differential access to resources, while physical scientists are much more biased towards physical property and quantifiable entities (Boateng et al., 2017). The United Nations Development Programme (UNDP) defines vulnerability as a human condition or process resulting from physical, social, economic, and environmental factors that determine the livelihood and scale of damage caused by the impact of a given hazard (Osman et al., 2016). Additionally, Chang et al. (2018) defined vulnerability as attributes of communities that affect the potential for harm when hazard events occur. Moreover, Thomas et al., (2019, p.2) highlighted that vulnerability arises as "a function of the exposure (who or what is at risk) and sensitivity of the system (the degree to which people and places can be harmed)". The study further indicated that understanding vulnerability is integral to the process of determining actions that facilitate adaptation strategies.

Vulnerability assessment is a complex process that considers multiple dimensions of vulnerability, including both physical and social factors, as well as extensive datasets encompassing human and socioeconomic variables (Parthasarathy & Natesan, 2015). As a result, Maanan et al. (2018) recommended that coastal vulnerability assessment should integrate current and projected risks due to climate change or human impact. Vulnerability assessment serves as a valuable tool for researchers and decision-makers to gather information on the actual or potential damage that hazards can cause to any system. It also informs the decision-maker about the disaster risk from a particular type of hazard and how to mitigate, manage, or reduce this risk (Thi et al., 2018). Additionally, Mattah et al. (2023) highlighted that vulnerability assessment enables the development of location-specific adaptation strategies to reduce risk, exposure and vulnerability levels, influencing community preparedness, response, mitigation and restoration before and after disasters.

Coastal hazards and their associated vulnerability change dramatically throughout time and place (Maanan et al., 2018). Coastal geomorphology, urban growth patterns, affluence, and socioeconomic systems all influence how a coastal hazard event results in human losses, property damage, and economic disruption. To be effective, risk reduction and resilience measures must include the local hazard and vulnerability context, since solutions that are suited for one type of community may be ineffective for another (Chang et al., 2018).

Coastal vulnerability is the process of putting people who may be affected by a disaster or possible hazard at the center of analysis and strategic planning of coastal cities to avoid human, economic, and environmental losses (Mavromatidi et al., 2018). Coastal vulnerability assessments can provide information regarding the incidence of hazards and their impacts on people, property, and the ecosystem. The vulnerability of coastal systems to sea-level rise and to other drivers of change is defined by their sensitivity, exposure and adaptive capacity (Nicholls and Klein, 2005). A more extensive vulnerability assessment at the local scale allows for a better understanding of the complexities of the coastal system at a localized scale in a given area (Addo, 2013).

The terms ‘hazard’ and ‘risk’ are sometimes used interchangeably but must be distinguished fundamentally. While hazard refers to a natural or human-induced activity or situation that has the potential to cause injury or loss to humans and their property, the term risk also implies the likelihood of the hazard occurrence (Wachinger et al., 2013). Given the increasing relevance of flood mitigation in current and future flood risk management, there has been a renewed focus on individuals’ flood risk perceptions, which are likely to give significant insights for risk management and risk communication strategies (Bubeck et al., 2012).

The concept of 'risk perception' is well-established in the social sciences. The phrase refers to the process of gathering, selecting, and analyzing information concerning the unpredictable impacts of events, or activities. These signals can refer to direct experience (e.g., witnessing a flood event) or indirect experience (e.g., information from others, such as reading about a natural disaster in the

newspaper) (Wachinger et al., 2013). According to Eboh et al. (2021), risk perception has grown in importance in the field of risk analysis and is regarded as a crucial component in the context of flood risk management strategies. In other words, understanding people's risk perception is an important tool in modern flood risk management and mitigation measures (Ullah et al., 2020).

According to Ullah et al. (2020), risk perception (or perceived risk) refers to how people or communities interpret or understand and evaluate the possibility and potential severity of hard from coastal hazards. Similarly, risk perception is linked to people's awareness, behavior, and emotions with regard to hazards. Risk perception is also seen as a critical component of social vulnerability assessment and community resilience. As a result, risk perception has become an important aspect of disaster risk reduction (DRR) and climate change adaptation (Rana et al., 2020).

Risk perception is critical in motivating the public to take action to reduce or mitigate the risks associated with natural hazards (Bronfman et al., 2020). People take precautionary efforts to mitigate the risk they consider to be high. The logic behind the "motivational hypothesis" can be used to highlight the need for boosting awareness among the population at risk to reduce susceptibility by increasing the amount of private mitigation (Bubeck et al., 2012). Without accurate risk perception assessment, researchers may be unable to understand people's attitudes about reducing these risk (Ullah et al., 2020).

Given the importance of risk perception in disaster preparedness behavior, researchers have investigated this link in several studies. Overall, these studies show that individuals who report a higher level of risk perception are more likely to take preparedness steps. However, in other circumstances, increased risk perception does not imply increased desire to engage in preparedness and mitigation activities (Bronfman et al., 2020). Risk perception demonstrates the acceptability of risk and, to some extent, predicts community responses, which can help create suitable and appropriate public education programs and risk communication strategies (Rana et al., 2020). Perceptions also have a

significant impact on encouraging people to take action to avoid, mitigate, adapt to, or even ignore risks (Wachinger et al., 2013).

The term **"risk"** in this study is used to refer to the perceived risk to coastal hazards, including flooding, storm surge and erosion, as understood and experienced by residents in the selected coastal communities in the Greater Accra region of Ghana. This thesis takes a social science approach, examining how individuals perceive and respond to potential threats, rather than the commonly used technical definition of "risk" as a quantifiable probability of harm typically expressed as *Risk = Hazard × Vulnerability × Exposure* (IPCC, 2014). This approach is consistent with well-established literature (see Bubeck et al., 2012; Eboh et al., 2021; Wachinger et al., 2013), which acknowledges that perceptions of risk are shaped by personal experiences, local knowledge, socioeconomic conditions, and trust in institutions, all of which are important when assessing community responses and adaptation to climate-related hazards. In this study, 'risk' is defined as the perceived likelihood and severity of harm caused by coastal hazards, where as 'Vulnerability' is defined as the degree to which different stakeholders are susceptible to these hazards, based on factors such as location, income, housing quality, and awareness. These are ***not based*** on quantitative models, but rather through household surveys and qualitative feedback.

Chapter 2 – Study Area

2.1 The Greater Accra Region

2.1.1 Geography and Demography

Ghana, a coastal country on the West African coast with an approximate shoreline of 550 km, is not immune to the difficulties and transitions that coastal communities face around the world. Ghana's coastal zone of Ghana is home to more than a quarter of the country's population and account for over 80% of the country's annual marine catch, with a coastline classified primarily as high-energy (World Bank, 2018). Ghana's coastlines of Ghana are under threats from both anthropogenic and natural factors that cause changes in shoreline movements.

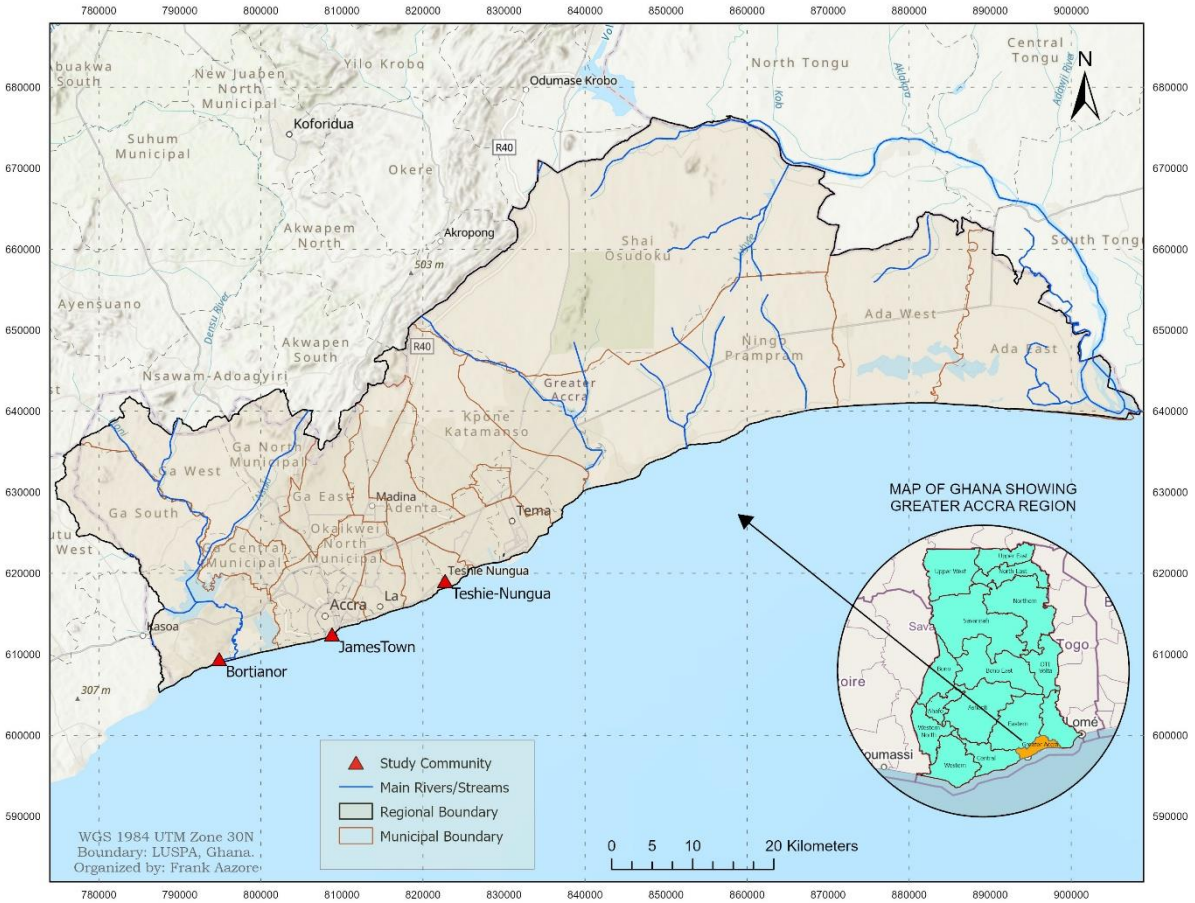

Figure 2.1 Location of study communities in the Greater Accra region

The Greater Accra Region is the smallest of Ghana's 16 administrative regions. It occupies a total land area of 3,704 square kilometers (km^2) (Addae & Oppelt, 2019a), which is 1.4% of Ghana's total land

area. According to the Ghana Statistical Service (GSS) (2021) report, the region has a population of 5,455,692, consisting of 49.1% (2,679,063) men and 50.9% (2,776,629) women. It is hence the most populous area and makes up 17.7% of Ghana's total population. It is also the most urbanized area in the country, with approximately 87% of the people residing in urban centers. Accra, the capital city of Ghana, serves as the hub of the Greater Accra Region. The GSS (2021) reported a population of above 2 million in Accra. The city's sustained population increase has contributed to its identification as one of the most rapidly growing metropolises in Africa (Korah et al., 2019). Ghana's literacy rate, according to the GSS (2021), is 69.8%. People who can read and write in any language and are at least six years old are included in the data. The Savannah Region recorded the lowest percentage at 32.8%, while the Greater Accra Region had the highest percentage at 87.9%. The same GSS (2021) reports a religious breakdown of 77.8% Christians, 16.2% Muslims, 1.4% traditional faith and 4.6% other (unspecified) for the Greater Accra region of Ghana.

Greater Accra's coast is located between the Eastern and Central coasts of the entire coast of Ghana. Thus, it shares the characteristics of the geomorphology of the Eastern and Central coasts, with a blend of sandy shorelines and/or rocky headlands (Adu-Boahen et al., 2020). The coastal zone is divided into three geomorphic regions, namely 'western' (14.3 km from Bortianor to Jamestown), 'central' (12.7 km from Jamestown to Teshie), and 'eastern' (11.3 km from Teshie to Sakumo lagoon) (Addo, 2009). The coastal zone is underlain by a gentle, mature topography that slopes towards the shore (Addo, 2015). Sagoe-Addy and Addo (2013) reported that the western and eastern regions of the coastline are more susceptible to coastal erosion than the central region. Accra's sea level is projected to rise by approximately 3 mm per year. This is comparable to the recent global average rate of sea level rise. According to the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5), the global mean sea level rose at an average rate of 3.2 mm per year between 1993 and 2010 (IPCC, 2023). This acceleration is due to factors such as ocean thermal expansion and increased melting of glaciers and ice sheets. Projections show that, under high-emission scenarios, global sea levels could rise by up to 0.98 meters by 2100 (Calvin et al., 2023).

The coastal zone of Greater Accra is inhabited by twelve percent (12 %) of Ghana's total population and has a growth rate of about 3% per year as compared to the national growth rate of 2.5 % (Darko et al., 2022). This area is home to a variety of economic activities, including ports and harbors, manufacturing companies, fishing, agricultural activities and recreation (Avornyo et al., 2023) . Despite the economic benefits gained in the coastal area, it faces several challenges including pollution, erosion, habitat and biodiversity loss (Addo, 2015).

2.1.2 Climate and Vegetation

The Greater Accra region falls within a dry, coastal, equatorial climate zone, which is classified as 'Aw' (Tropical Savanna) under the Köppen-Geiger system - characterized by two distinct rainy seasons each year (Addae & Oppelt, 2019b). Annual rainfall varies from about 635 mm near the coast to 1,140 mm in the northern areas. The first rainy season typically occurs from April to June, while the second runs from September to mid-November, with rainfall peaks in June and October (Osei-Yeboah et al., 2020). These seasons are critical for agricultural activities in the region. Temperatures remain consistent throughout the year, ranging between 20°C and 30°C, due to the region's proximity to the equator, which results in minimal temperature fluctuations both daily and annually (Frimpong et al., 2022). The region is drained by important rivers such as the Volta and Densu. The region is also distinguished by seasonal streams that flow from the Akwapim Ridge through different lagoons into the sea. Some of these wetlands and lagoons are particularly important ecologically, yet they are heavily contaminated due to human activity such as illegal mining (Maria konda, 2016).

The vegetation in the Greater Accra region primarily consists of coastal savannah, with scattered shrubs and thickets. Grasses in this area grow sparsely, rarely exceeding a height of 1 meter, while the tallest trees reach around 5 meters. The loss of dense forests in the region is attributed to both climate change and human activities such as agriculture and urbanization (Tuffour-Mills et al., 2020). Mangrove forests, particularly red mangroves (Rhizophora) and black mangroves (Avicennia) flourish at the western and eastern ends of the Greater Accra coastline. These species are well-suited to the saline,

frequently flooded coastal soils (Alves et al., 2020). However, they are under significant threat from coastal pollution, overharvesting, salt production, and sand mining (Nunoo & Agyekumhene, 2022). The region also supports other vegetation, such as seagrasses, shrubs, and forested areas.

The Greater Accra region has been the subject of recent studies (Codjoe & Afuduo, 2015; Dekongmen et al., 2021; Owusu-Ansah et al., 2019; Twerefou et al., 2023)due to the high incidence of coastal erosion and flooding from storm surges and tides, exacerbated by relative sea-level rise. The expanding coastal population has increased pressure on the coastal environment and resulted in increased coastal erosion through the unsustainable use of coastal resources (Addo, 2013). The clearing of coastal vegetation to build shelters for the growing population and the expanding coastal tourism business has resulted in increased competition for limited land resources ('land squeeze'). This situation limits the available lands for ecological conservation, disturbs natural coastal buffers, and intensifies land-use conflicts (Addo, 2013). A significant percentage of the population has lost properties due to increased flood erosion. Asumadu-Sarkodie et al. (2015) indicated that increased erosion has recently threatened recreational activities, industry, and a major Ramsar wetland reserve (Darko et al., 2022).

2.2 Study Communities

The study focused on three selected coastal communities in the Greater Accra region. The study communities were purposively selected due to two main factors: proximity to the shoreline and frequent exposure to coastal hazards such as flooding/storm surges, and erosion. Through livelihood activities such as fishing and the growth of informal settlements along the coast, these communities also demonstrate high levels of interaction between residents and coastal ecosystems. The first community (Bortianor), located in the Ga South Municipality of the Greater Accra Region, is a traditional fishing community with an estimated population of 5,446 and is in the western part of the coast of Accra. The second community (James Town), is another fishing community with deep cultural ties to the coast, situated in the central part of the coastal region. Lastly, Teshie-Nungua, located in the

eastern part of the coast, was also selected because of its direct exposure to the Gulf of Guinea and residents' reliance on fishing and other coastal-based livelihoods, making it an appropriate site for assessing vulnerability to coastal hazards. for this study.

The selection of study communities was based on the literature (Addo, 2015b; Boateng, 2012), indicating that low-lying coastal areas in Greater Accra are particularly susceptible to climate-induced coastal hazards. Additionally, these communities reflect a combination of formal and informal urban growth patterns, alongside varying levels of government intervention in coastal protection, making them suitable for assessing local adaptation options and stakeholder perceptions.

2.2.1 Study Area 1 (Bortianor)

Bortianor is a coastal community located on the western outskirts of Accra, Ghana. It is geographically located 332 kilometers southeast (146°) of the approximate center of Ghana and 13 kilometers west (254°) of Accra and is known for its beaches and serene environment (Oteng-Ababio et al., 2011). The socio-economic profile of Bortianor is diverse, with a mix of indigenous Ga-Dangme natives and newer residents who have moved to the area for affordable housing near the coast. The community is characterized by a mix of traditional coastal livelihoods, such as fishing and salt production (Ishmael, 2021), alongside emerging residential developments catering to Accra's expanding population. The majority of community members depend on the sea for their livelihood. The town located in the coastal savannah belt, which receives seasonal rainfall with two peaks in June and September. The average mean annual rainfall for the area is 800 mm, with an average annual temperature of 26°C (Ishmael, 2021). The vegetation in this area is primarily shrub and grassland (Sarfo et al., 2019). The Densu River feeds the wetland and has been dammed a few kilometres upstream (Weija dam) to supply water to several areas in Accra.

Bortianor's coastal location makes it particularly susceptible to coastal hazards, including erosion, flooding, and the impacts of sea-level rise. These risks are compounded by the community's rapid urbanization, which has led to unplanned development and increased pressure on local infrastructure

(Ishmael, 2021). The coastal zone in Bortianor is facing significant environmental challenges, including the degradation of natural coastal defenses like mangroves and wetlands, which traditionally helped mitigate the effects of coastal hazards (Amoani et al., 2012; Oteng-Ababio et al., 2011).

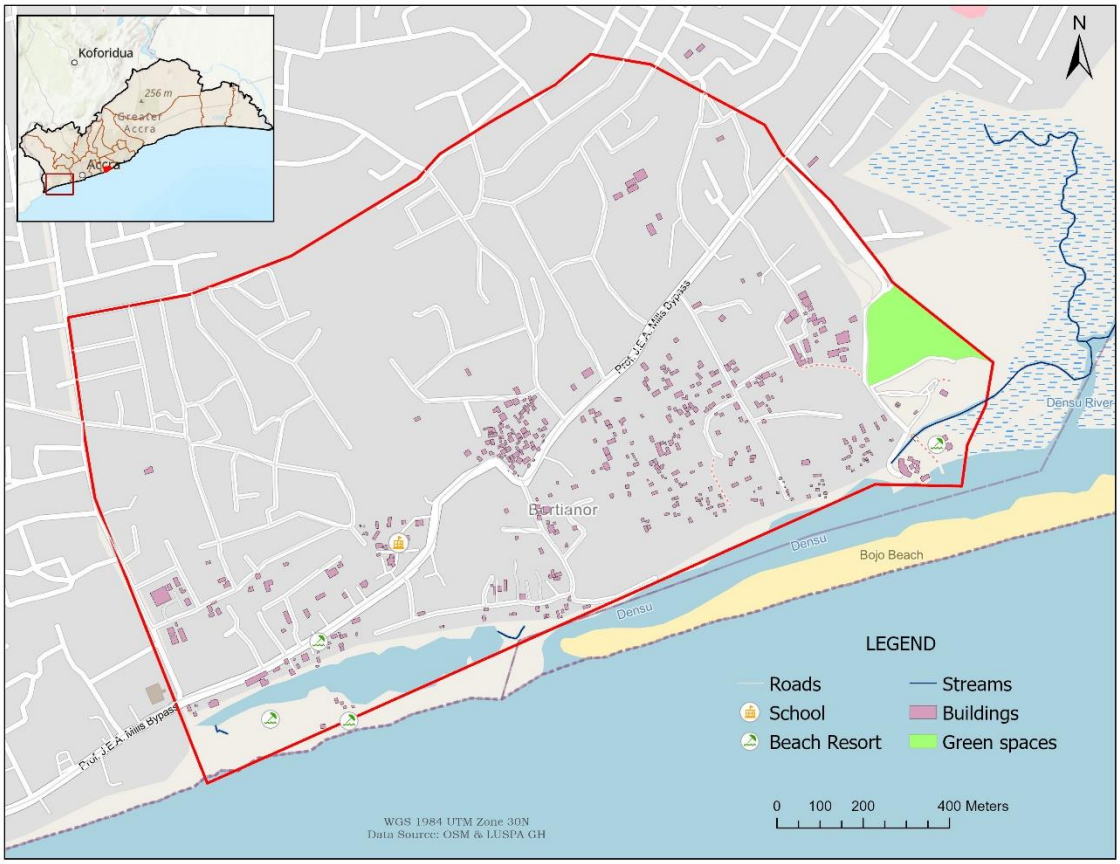

Figure 2.2 Location of Study Area 1 (Bortianor)

2.2.2 Study Area 2 (JamesTown)

James Town is one of the oldest and most historically significant coastal communities in Accra, Ghana. Located in the center of the city, the community is distinguished by its unique cultural heritage and strong sense of community. It is a fishing community populated by the Ga people, who have been in the area for generations. It is a famous attraction for tourists interested in Ghana's colonial history. According to Larbi Ayisi et al. (2023), Jamestown is known mainly for fishing. Thus, fishing is the major occupation and source of livelihood for the people in the community.

As a coastal community, James Town is particularly vulnerable to various coastal hazards, including erosion, flooding, and the impacts of sea-level rise. The community has a diverse socio-economic

landscape, with a mix of low-income households and small businesses (Tutu et al., 2017). The community faces challenges such as overcrowding, poor sanitation, and limited access to basic services (Sarfo et al., 2019), all of which contribute to its vulnerability to coastal hazards. The community's proximity to the ocean exposes it to these risks, which are exacerbated by climate change, unplanned urban development, and inadequate coastal management. The community's infrastructure, including homes, roads, and public spaces, is at risk, making the community a critical case study for exploring the potential for NbCA.

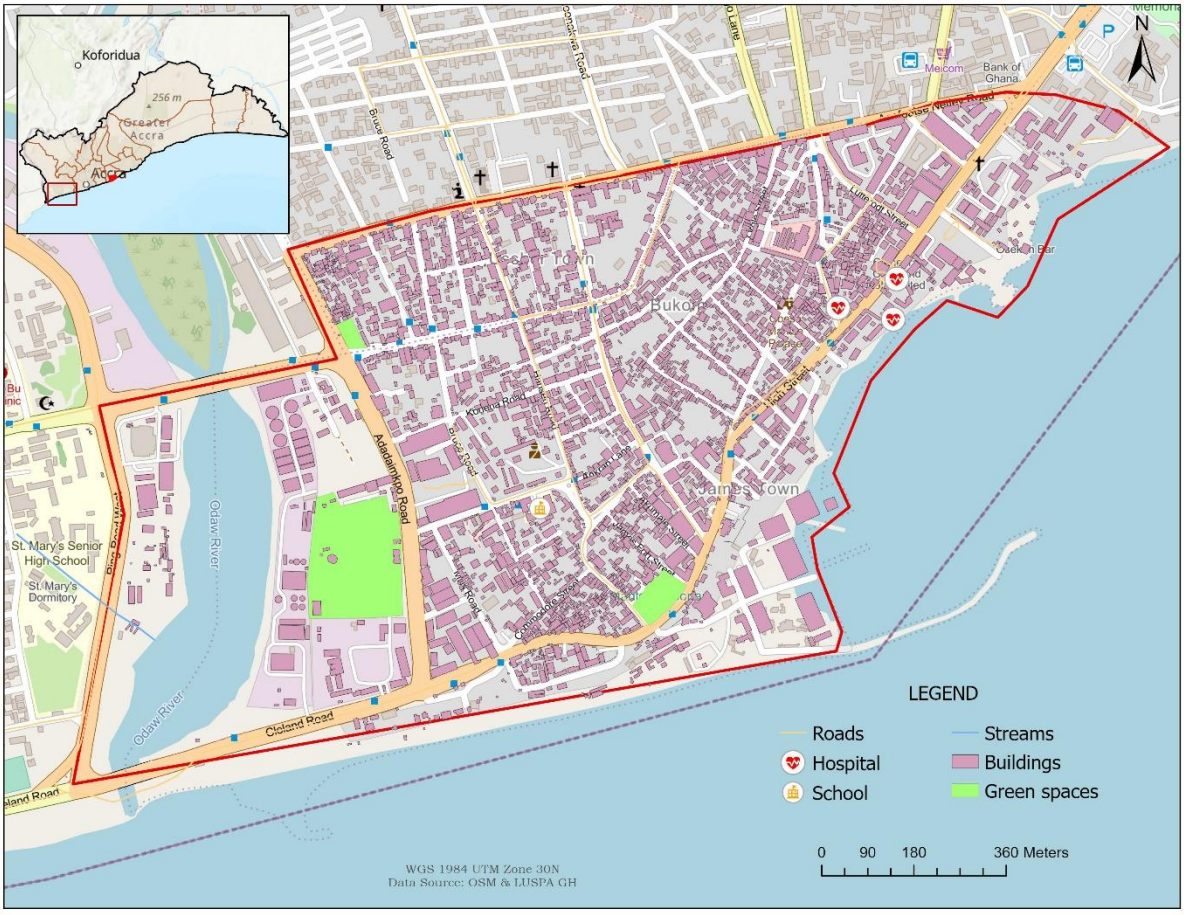

Figure 2.3 Location of the Study Area 2 (JamesTown)

2.2.3 Study Area 3 (Teshie-Nungua)

Teshie-Nungua is a densely populated coastal area located in the eastern part of Accra, Ghana. The community is a combination of two historically significant towns ("Teshie" and "Nungua"), each with deep-rooted cultural heritage and traditions. Over the years, Teshie-Nungua has experienced rapid

urbanization, transforming from a collection of fishing villages into a dense urban hub with a diverse population engaged in a range of economic activities, including fishing, trade, and small-scale manufacturing (Miller et al., 2020). The area is a Coastal Grassland province with a maximum of two rainy seasons in a year. The rainfall in the area, which usually comes with serious storms and lasts a little while, has an annual average rainfall of 730 mm (GMet, 2024).

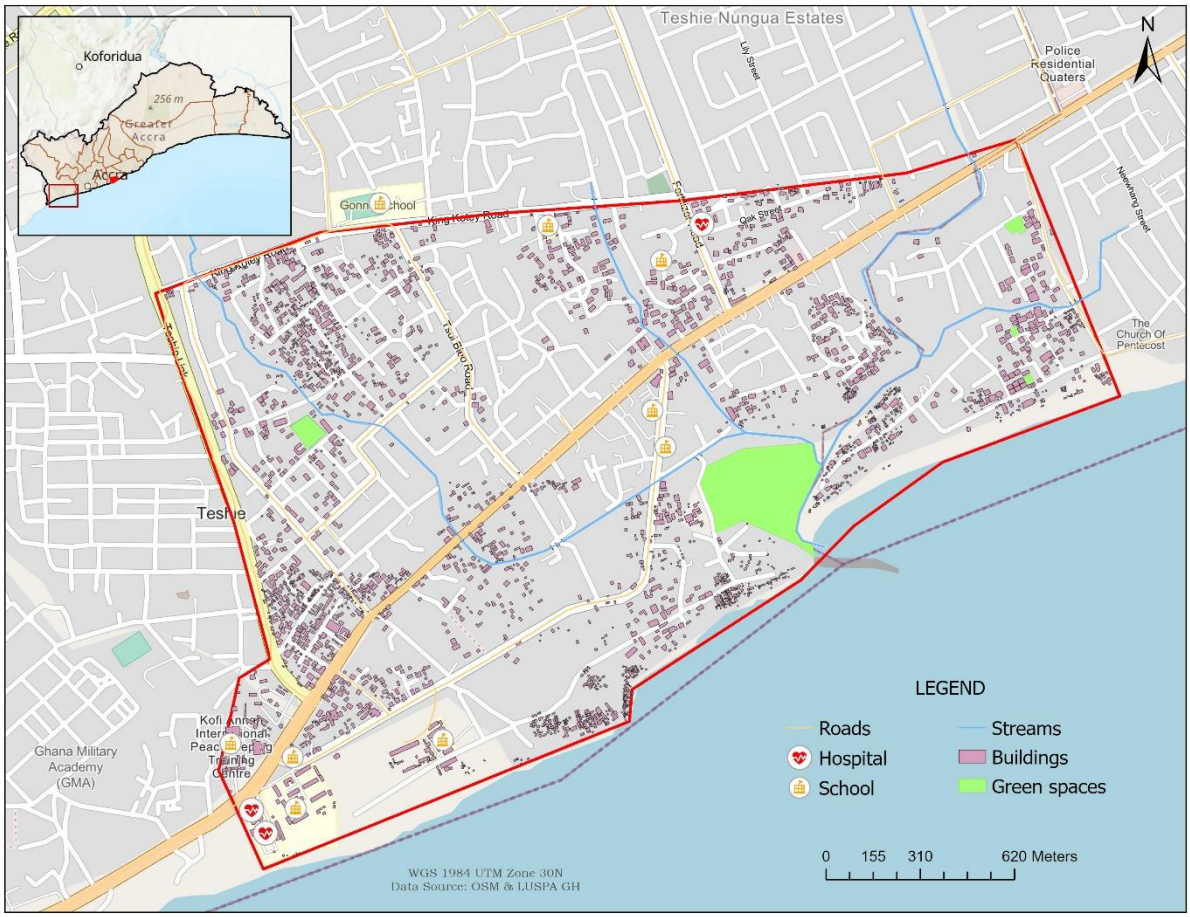

Figure 2.4 Context map of the Study Area 3 (Teshie-Nungua)

Teshie Nungua is Ghana's ninth most populous settlement, inhabited by the indigenous Ga people of Accra. The places are irregularly built and crowded and often get muddy during the rainy season due to poor drainage. The coastal location of Teshie-Nungua makes it highly vulnerable to a range of coastal hazards, including erosion, tidal flooding, and the impacts of sea-level rise. The area's rapid urban growth has led to significant environmental challenges, such as the loss of natural coastal defenses, increased pollution, and pressure on existing infrastructure. Informal settlements are common along

the coast, where homes and businesses are often constructed without adequate planning (Gaisie et al., 2022), making them particularly susceptible to the effects of coastal hazards.

In conclusion, these three communities collectively represent a cross-section of coastal communities in the Greater Accra Region, with differing socio-economic conditions, exposure to coastal hazards, and community-level interventions. These differences are expected to provide diverse perceptions of risk, vulnerability, and adaptation, all of which are essential to the research objective of exploring stakeholders' perspectives on coastal adaptation strategies. Previous studies (Belay & Fekadu, 2021; Gisevius et al., 2024; Rehman et al., 2023) have shown that local contexts, such as differences in livelihood options, infrastructure, institutional presence, and historical engagement with government adaptation initiatives, can greatly influence how communities perceive environmental risk (Schneiderbauer et al., 2021). By capturing these variations, the study design allows for a more comparative analysis, which enhances the understanding of the barriers and opportunities for implementing NbCA across distinct coastal communities in Ghana.

Chapter 3 - Methodology

3.1 Research design & approach

In this research, I adopted a case study approach because it allows for an in-depth exploration of real-life issues within a specific jurisdiction (Alam, 2021). In this case, I examined coastal hazards and NbCA-related matters in Accra, Ghana, focusing on three coastal communities, namely Bortianor (Tsokomey), Jamestown (Chorkor), and Teshie. The study communities were selected for their proximity to the shoreline and frequent exposure to coastal hazards such as flooding/storm surges, and erosion, as well as their socio-economic and environmental challenges. To ensure a comprehensive understanding, a mixed-method approach was used, which combined qualitative and quantitative data collection techniques. This approach was adopted because it allows for a carefully designed combination of both quantitative and qualitative methods to provide a comprehensive understanding of the topic (Schoonenboom & Johnson 2017).

Natow (2020) also emphasized that mixed methods use triangulation, which involves the use of more than one approach in data collection and analysis for research to increase confidence in the findings. In this regard, methods such as spatial mapping/analysis and statistical and thematic analysis were used to come up with in-depth findings in this study. Additionally, Dawadi et al. (2021) described mixed methods to portray how both qualitative and quantitative approaches can complement each other in explaining a phenomenon, for example, in this study's context, understanding the people's perception of the quantitative associations or output of the spatial analysis.

3.2 Data sources & collection procedure

Both primary and secondary data sources were used to answer research questions and achieve the research objectives. In terms of primary data, a household survey and a participatory mapping activity were used to gather data on respondents' levels of knowledge of NbCA and perceptions/opinions on coastal hazard risks and vulnerability. According to Dada et al. (2022), the 'household' has been identified as a valuable unit of analysis for perceptions of risks. This is because it is a unit of action that

exists between individuals and society, in which personal values, societal norms, and institutional needs intersect. To assess community awareness of NbCA, the field survey did not solely rely on technical terminology. Given the possibility that participants were familiar with the practices but not the formal terminology, the questionnaire included a brief explanatory introduction, followed by the specific question on awareness (*see Q14 in Appendix*), which clarified the concept by providing examples such as mangrove restoration and referring to "natural measures" alongside the formal term "Nature-based Adaptation approaches." This framing was meant to reduce confusion and ensure that responses reflected true familiarity with the concept, even if participants described it in different local terms.

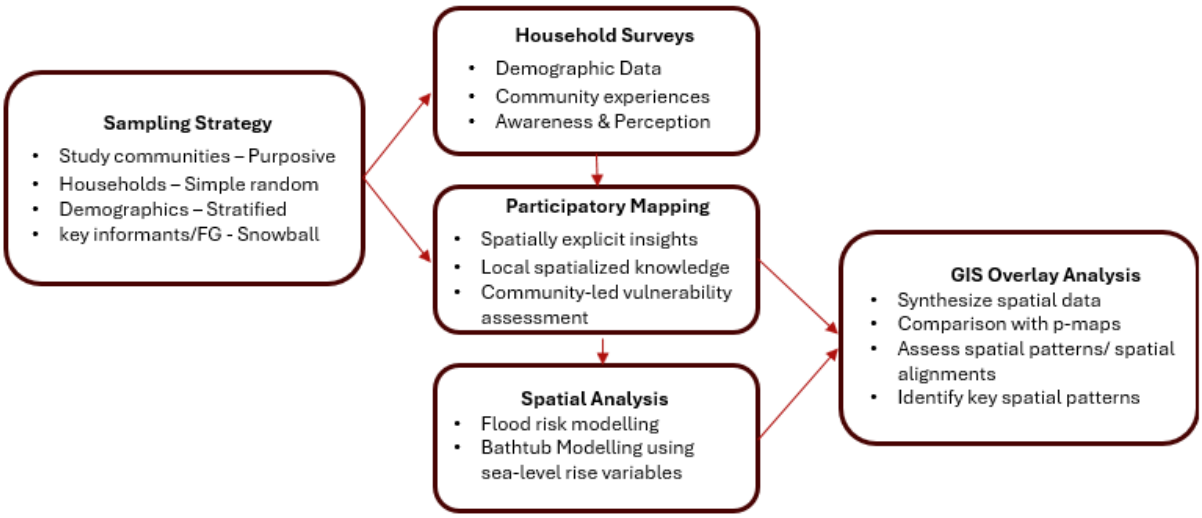

Figure 3.1 Methodological flow of the research

Secondary data was obtained from published government reports and scholarly literature retrieved from academic databases such as Google Scholar and Web of Science, accessed via the Saint Mary's University library system, as well as organizational reports from the Municipal Assemblies in Ghana and open data portals. The secondary data also includes Census data, GIS data: Esri products – Sentinel 2-10m Landuse/cover data, precipitation data (2010 to 2022), and a 30m Digital Elevation Model (DEM) (see Table 3.1). Additionally, GIS vector data of the study area boundary representing the administrative region, together with the road network datasets, were obtained from the Centre for

Settlements Studies (CSS) based at the Kwame Nkrumah University of Science and Technology (KNUST). These data sources were selected to directly address the research questions by providing critical information on socio-economic and environmental conditions. For instance, GIS datasets were used to analyze risk to coastal hazards, while census data were utilized to assess demographic and socio-economic factors influencing risk perception and adaptation capacity.

Table 3.1 Summary of Data and Data Sources

Secondary Data		
Data	**Format**	**Source**
Digital Elevation Model (DEM) – 30m	Raster	CERSGIS, University of Ghana
Census data	PDF	Ghana Statistical Service Online
Greater Rainfall/precipitation data	CSV	Ghana Meteorological Agency (GMeT), (2010-2022) - 8 Stations
Study Area Boundary	Vector	CSS, LUSPA, Ghana
Primary Data		
Collated Household Survey	Excel,	Fieldwork
Google basemaps for Participatory mapping	PDF	Google Earth

3.2.1 Interviews

Given the multilingual nature of the study communities, language considerations were an important component of the fieldwork design. The study communities are predominantly Ga-speaking, while some residents also communicate in Ghanaian Pidgin English. To ensure accurate communication in data collection, field research assistants from the Marine Biogeochemistry Lab at the University of Ghana were recruited. These assistants were fluent in both the local Ga language and English, and they provided critical support in real-time translation of survey questions and interview responses. To acquire relevant information from households, semi-structured (closed- and open-ended questions) interviews were used. The questions were prepared with KoBoToolbox and the questionnaires were administered with the KoBoCollect App. Kobo Toolbox is a free open-source tool used for data

collection. It is mostly used in remote areas or where internet access is uncertain or unstable. This toolbox stands out for its advanced features, such as repetitive questions and the skip logic method, as well as its advanced mode of questions, which include images, audio, video recordings, and GPS coordinate collection, all of which will be essential for this research (Poloju et al., 2022). Before data collection, this study obtained ethical approval from the Saint Mary's University Research Ethics Board (REB) (REB Certificate No. 24-096), ensuring that all procedures followed ethical guidelines for research involving human participants (*See certificate attached in Appendix B*).

3.2.2 Participatory Mapping

A participatory mapping exercise was conducted using seven key informants, specifically community leaders, who were randomly sampled based on availability and willingness to participate. In Ghana, assembly members play a crucial role in local governance. As elected representatives of their communities, they hold a central position within district assemblies, responsible for key policy and decision-making processes. Their mandate requires them to make strategic decisions that significantly influence the performance of their districts (Agomor et al., 2019). As community members themselves, they possess deep local knowledge, making them well-positioned to provide insights into the challenges and vulnerabilities within their areas.

Social participatory mapping is a valuable analytical approach in coastal hazard perception research that engages local communities in mapping and expressing their understanding of coastal hazards (Cochrane & Corbett, 2018). This method involves collaboration between researchers, community members, and stakeholders to collectively create spatial representations of local knowledge, perceptions, and concerns related to coastal hazards. To act as a backup, data from participatory mapping was recorded with a digital voice recorder and documented in a field notebook. As highlighted by Yulianti (2021), focus group discussions and mapping have the advantage of allowing participants to interact and highlight their perspectives and experiences. It also allows participants to

participate, highlighting the language they use about a topic as well as their values and opinions about a scenario.

Figure 3.2 Pictures of participatory mapping and focus group discussion with community representatives for Teshie (A) and Bortianor (B).

For the field mapping in Ghana, printed aerial basemaps from Google Earth were used, with pre-drawn boundaries for each of the three research communities. Participants were asked to draw responses on these maps based on their local knowledge, highlighting specific areas within their communities that are susceptible to hazards such as flooding, storm surge, and coastal erosion. They were also asked to identify areas where coastal solutions or adaptation measures currently exist. The original plan was to engage two assembly members from each community in the participatory mapping activity. However, due to field challenges, including participant concerns about the change in government, several prospective participants declined. All invited assembly members in Jamestown eventually declined to participate. Two assembly members from Teshie participated as planned. In Bortianor, two assembly

members and four community leaders took part. At the end of each session, field notes were compiled, and group discussions were summarized.

3.3 Study Population & Data Analysis

According to Taherdoost (2016), a research population includes all occurrences of entities or elements that meet a specific condition. It can also refer to a broader group of people, an institution, or an object with one or more characteristics that is the focus of the study (Berndt, 2020). Understanding the population allows researchers to precisely define the interest group and establish the relevance range for their conclusions. Population and sample are important in research because they allow for meaningful and reliable inferences about a wider group of interest(Ahmad et al., 2023). The target population for this study consisted of all key community members, including household heads and community leaders who live in the study communities.

As emphasized by Lakens (2022), an important step when designing an empirical study is to justify the sample size that will be collected. The fundamental aim of a sample size justification for such studies is to demonstrate how the obtained data is expected to provide valuable information given the inferential goals of the researcher. By studying the sample, researchers can draw meaningful conclusions that can be generalized to the larger population, making research more feasible, cost-effective, and time-efficient. The accuracy and dependability of the findings depend on the quality of the sample and its ability to mirror the population's characteristics (Ahmad et al., 2023).

In this study, a multi-stage sampling approach was employed to select both study sites and participants. First, **purposive sampling** was used to select three coastal towns or communities within Accra that represent diverse demographics, socioeconomic statuses, and levels of exposure to coastal hazards. Within each community, a combination of simple random sampling, stratified sampling, and snowball sampling techniques was utilized to recruit participants. **simple random sampling** was used to select individual households for survey administration, ensuring that each household had an equal

chance of being chosen and minimizing selection bias (Etikan, 2017). According to Berndt (2020), while simple random sampling may have research biases, its benefits far outweigh its setbacks, since it offers the researcher quick access to samples, requires little movement for data collection, and is associated with low cost. Additionally, **stratified sampling** was used to ensure representation across different demographic groups (e.g gender, age and religious groups), enhancing the validity of the findings by reflecting variations within the research population (Taherdoost, 2016).

Finally, **Snowball sampling** was employed and used selectively during key informant interviews/focus group recruitment, particularly when community leaders or prior respondents recommended others with relevant knowledge or experience. This was a method beneficial for reaching communities that are not easily accessible (Naderifar et al., 2017).

Table 3.2 Target Sample size for Field survey

Study Community	Targeted Sample Size	Respondents interviewed	Estimated number of respondents approached	Response rate (%)
Bortianor	40	40	42	95%
Jamestown	40	40	53	76%
Teshie-Nungua	40	40	46	86%
Total	**120**	**120**	**141**	**85%**
Total participants for Participatory Mapping	6 total participants	7 for Botianor & Teshie-Nungua 0 participants from Jamestown		

To achieve the overall goal of the study, different analytical methods were utilized under each specific objective. These are summarized in **Table 3.3** (see below).

Table 3.3 Data analysis and tools

Research Questions	Method of analysis	Data	Software/tools
Objective 1: Understand variations in risk perceptions across different demographic and socioeconomic groups within the study communities			
Q1: What are the community perceptions of risk to coastal hazards in Accra?	-Basic descriptive analysis (charts/graphs/tables) -Exploratory factor analysis -Binary logistic regression -Ordinal logistic regression	-Field data, -Responses from the household survey -Base Maps (Participatory maps)	SPSS, MS Excel
Objective 2: To conduct a comprehensive GIS analysis of coastal hazard risk factors in Accra, integrating data on sea level rise, erosion, and other relevant parameters and correlate community perceptions of risk with GIS-based assessments. ***Objective 3:*** To identify and prioritize potential target areas for effective NbCA interventions in Accra based on the findings from Objective 2.			
Q2: Based on community risk perceptions and GIS analysis of coastal risk in Accra, where are potential target areas for effective NbCA interventions?	-Digitizing & Georeferencing -Hazard susceptibility/risk mapping -Simple Bathtub Modelling	Esri land cover maps (2017-2022) -DEM, coastal topography (slope, watershed, aspect, rainfall data etc.) -Participatory map – field output	Esri products ArcGIS Pro

3.4 Analyzing Participatory Maps

Participatory maps developed with community stakeholders were scanned to obtain high-resolution digital versions for spatial analysis. These maps were created using participant input to highlight perceived high-risk zones as well as areas with existing or proposed coastal adaptation measures. The scanned photos were imported into ArcGIS Pro software and *georeferenced* using identifiable landmarks and boundaries, buildings and coastline features matched with basemap layers to align the

images with real-world coordinates using the coordinate system *WGS 1984 UTM Zone 30N*. After georeferencing, the participant-identified features were *digitized* into vector data using polygon and point shapefiles. Key elements were grouped into feature classes such as *perceived high-risk areas, existing nature-based solutions/coastal adaptation (NbS/NbCA), hard infrastructure* and *preferred locations for future adaptation.* Each feature was labeled and attributed based on field notes and community responses. This technique allowed for the integration of local knowledge into the GIS environment (Chambers, 2006a), as well as spatial comparison with technical flood risk models.

3.5 Quantitative/Statistical Analyses

To achieve the study's objectives and effectively analyze the primary dataset on risk perceptions, awareness and factor relationships, several statistical analyses were employed. These include basic descriptive statistics, chi-square tests, cross-tabulation analysis, exploratory factor analysis (EFA), and binary logistic regression analysis. These methods were used to test key socio-economic variables against responses related to coastal hazards, allowing for a comparison of variations in risk perceptions across the study communities, and to understand both awareness, challenges, and general perceptions about coastal hazards and NbCA.

3.5.1 Normality test

The distribution of the dataset (continuous variables used in statistical analysis) was tested for normality using both the Shapiro-Wilk and Kolmogrorov-Smirnov tests to determine whether the data was parametric and to validate the statistical methods used in the quantitative analysis. According to Khatun (2021), normality tests generate a normal probability plot and conduct a hypothesis test to determine whether the observations follow a normal distribution. The hypothesis consists of two parts: a) H0: the data follows a normal distribution, and b) Ha: the data does not follow a normal distribution. In this case, a P-value will be calculated and the null hypothesis evaluated for validity. For the data to be considered normal, the sig. (p-values) must be higher than 0.05. The normality test showed that all p-values were less than < 0.05, rejecting the null hypothesis of normality for all

variables. This suggests that the collected data were not normally distributed. As a result, the quantitative data was analyzed using non-parametric tests.

3.5.2 Reliability Analysis

The reliability of a questionnaire is concerned with the consistency, stability, and dependability of the scores. The Cronbach alpha coefficient test was computed to analyze the reliability of the Likert scale questions. It provides a simple way to measure whether a score is reliable or not. It is used under the assumption that multiple items are measuring the same underlying factor (Shrestha, 2021). The Cronbach alpha coefficient ranges in value from 0 to 1, where higher values of alpha are more desirable. Govindasamy et al. (2024) argued that Cronbach's alpha value higher than 0.6 is considered acceptable. A high level of alpha shows the items in the test are highly correlated with an acceptable level of internal consistency (Bujang et al., 2024).

Table 3.4 indicates that Cronbach's alpha values for obstacles and willingness to implement NbCA are 0.933 and 0.950 respectively, implying adequate data reliability.

Table 3.4 Cronbach's alpha reliability statistics

Reliability tests for obstacles to implementing NbCA	
Cronbach's Alpha	N of Items
.933	15
Reliability tests for willingness to support the application of NbCA	
Cronbach's Alpha	N of Items
.950	13

3.5.3 Exploratory Factor Analysis (EFA)

An Exploratory Factor Analysis (EFA) was employed to analyze factors related to obstacles and willingness to support NbCA implementation. According to Gie Yong & Pearce (2013), EFA is one of a family of multivariate statistical methods that attempts to identify the smallest number of hypothetical constructs (also known as factors, dimensions, or internal attributes) that can explain the covariation observed among a set of measured variables. That is, to identify the common factors that explain the

structure and order among measured variables. The EFA was used to identify underlying factors related to obstacles in implementing NbCA, grouping items into general factors including "Financial and Economic Barriers," "Community and Cultural Barriers," "Technical and Knowledge Barriers," and "Policy and Governance Barriers," depending on how responses cluster. Similarly, the EFA was used to uncover the underlying factors of willingness to support the application of NbCA, grouping items into factors including "Active Participation," "Financial Support," and "Advocacy and Promotion". EFA was an effective method to summarize and interpret underlying relationships and patterns in the data. This is most appropriate when there are no expectations about the quantity of similar factors, or which measured variables would be affected by the same common factors (Gaskin & Happell, 2014).

The EFA was preceded by a Kaiser–Meyer–Olkin (KMO) and Bartlett test of sphericity to confirm sampling adequacy and population matrix identity, respectively, to assure the trustworthiness and reliability of factor analysis results (Shrestha, 2021). The KMO test for both perceived obstacles and willingness to support resulted in 0.922 and 0.927 respectively. These values are well above the recommended threshold of 0.6000 (King et al. 2024), indicating excellent sampling adequacy. This confirms that the patterns of correlations in the data are sufficiently compact, and that the dataset is highly sufficient for factor analysis.

Table 3.5 KMO and Bartlett's test

KMO and Bartlett's Test for Obstacles		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.922
Bartlett's Test of Sphericity	Approx. Chi-Square	1103.257
	df	105
	Sig.	<.001

KMO and Bartlett's Test for Willingness to Support NbCA		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.927
Bartlett's Test of Sphericity	Approx. Chi-Square	796.952
	df	36
	Sig.	<.001

Communalities refers to the variance or squared factor loadings of variables (*see table 3.6 and 3.7*). This explains the proportion of variability explained by factors, and its value remains constant regardless of whether unrotated or rotated factor loadings are used. The eigenvalues range from zero to one. A score close to one (1) indicates that the components adequately describe the variable (Panda et al., 2021). Eigenvalues greater than one (1) were considered significant and were used to explain the variance obtained by a factor. According to Shrestha (2021), eigenvalues of less than one (1) are considered insignificant; hence, communalities extracted from each variable were assessed, retaining only values nearer 0.5 or more before conducting the principal component analysis.

These communalities of the variables tested (see Tables 3.6 and 3.7) represent the proportion of variance in each variable explained by the extracted factors. The items are presented in their original order as used in the survey instrument to maintain consistency and traceability. Extracted values for the communalities are not interpreted as measures of importance rather as diagnostic tools used during factor retention.

Table 3.6 Communalities for Obstacles to NbCA Implementation

	Initial	Extraction
Lack of awareness on NbCA benefits	1.000	.626
Insufficient funding/financial resources	1.000	.638
Limited technical expertise	1.000	.573
Resistance to change/skepticism	1.000	.533
Lack of political will	1.000	.571
Competing land use priorities	1.000	.525
Insufficient community engagement	1.000	.587
Inadequate regulatory frameworks	1.000	.781
Land tenure/ownership issues	1.000	.577
Environmental hazards	1.000	.679
Limited access to relevant data/info	1.000	.801
Lack of stakeholder collaboration	1.000	.823
Economic instability	1.000	.793
Cultural or traditional practices	1.000	.731
Lack of clear benefits or community incentives	1.000	.603

Table 3.7 Communalities for Willingness to support NbCA

	Initial	Extraction
Participate in community activities	1.000	.827
Attend educational workshops	1.000	.861
Financial contribution	1.000	.838
Support public education/awareness campaigns	1.000	.812
Promote social media engagements	1.000	.783
Volunteer for project planning	1.000	.801
Provide technical expertise or skills	1.000	.871
Make kind donations	1.000	.670
Participate in research/data collection	1.000	.815

Extraction Method: Principal Component Analysis.

Tables 3.8 and 3.9 show the eigenvalues and total variance explained for samples 1 (obstacles to NbCA implementation) and 2 (willingness to support NbCA application), respectively. Before extracting for sample 1, fifteen linear components were identified in the dataset. After extraction and rotation, the data set has three different linear components with eigenvalues greater than 1. Three components are retrieved, accounting for 65.6% of the total variance (Table 3.9). Similarly, before extraction for sample 2, nine linear components were identified in the dataset, and three different components were selected following the extraction and rotation. The three components extracted account for 80.8% of the total variance (Table 3.10). According to Shrestha (2021), it is suggested that the proportion of the total variance explained by the retained factors should

be at least 50%.

Table 3.8 Total Variance Explained (Obstacles to NbCA Implementation)

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**5.959**	**66.211**	**66.211**	**5.959**	**66.211**	**66.211**	**2.919**	**32.435**	**32.435**
2	**.787**	**8.741**	**74.952**	**.787**	**8.741**	**74.952**	**2.187**	**24.301**	**56.736**
3	**.534**	**5.931**	**80.883**	**.534**	**5.931**	**80.883**	**2.173**	**24.147**	**80.883**
4	.450	5.001	85.884						
5	.351	3.905	89.790						
6	.326	3.627	93.416						
7	.212	2.356	95.772						
8	.202	2.246	98.019						
9	.178	1.981	100.000						

Extraction Method: Principal Component Analysis.

Table 3.9 Total Variance Explained (Willingness to support NbCA application)

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	7.905	52.702	52.702	7.905	52.702	52.702	3.884	25.895	25.895
2	.992	6.613	59.316	.992	6.613	59.316	3.393	22.622	48.517
3	.944	6.295	65.611	.944	6.295	65.611	2.564	17.094	65.611
4	.904	6.028	71.638						
5	.760	5.067	76.706						
6	.560	3.731	80.437						
7	.531	3.542	83.979						
8	.453	3.020	86.999						
9	.430	2.867	89.866						
10	.367	2.447	92.313						
11	.316	2.107	94.420						
12	.263	1.754	96.174						
13	.237	1.583	97.757						
14	.200	1.331	99.088						

15	.137	.912	100.000						

Extraction Method: Principal Component Analysis.

3.5.4 Regression Models (Binary and ordinal logit)

This study employed two types of regression models to examine key relationships between variables. First, a binary logistic regression was employed to examine the relationship between some key socioeconomic variables (education, income, tenure residency), NbCA awareness, risk perceptions, and willingness to support the NbCA implementation. Binary logit regression models are effective for evaluating the likelihood of one of two categorical outcomes of a dichotomous variable (Niu, 2020). The binary logistic regression model is particularly suited for this analysis, as it incorporates a binary response dependent variable, which takes one of two possible outcomes (e.g., "yes" or "no"). A binary regression seeks to identify the model that best explains the connection between the dependent and independent variables and is closest to reality (Sze et al., 2014). The dependent variable was binary (1 = willing to support, 0 = not willing), and predictor variables included key socio-economic characteristics (education, income, and residency tenure), as well as awareness of NbCA and perceived risk from coastal hazards. The model followed the general formula as below:

$$\log(p / (1 - p)) = \beta_0 + \beta_1 \cdot \text{Education} + \beta_2 \cdot \text{Income} + \beta_3 \cdot \text{ResidencyTenure} + \beta_4 \cdot \text{Awareness\_NbCA} + \beta_5 \cdot \text{RiskPerception} + \ldots + \beta_n \cdot X_n$$

where **p** is the probability of willingness to support NbCA,

$\boldsymbol{\beta_0}$ is the intercept, and;

$\boldsymbol{\beta_1 \ldots \beta_n}$ are the coefficients for each predictor variable.

What distinguishes binary logistic regression is that the outcome variable is binomial, and the model attempts to forecast whether it will happen or not.

Secondly, an Ordinal logistic regression analysis was employed to investigate the influence of socio-economic characteristics and the existence of coastal adaptation measures on perceived vulnerability to coastal hazards over the next 10 years. The dependent variable was a four-point Likert-type scale (1 = not vulnerable to 4 = highly vulnerable) on respondents' perceived level of vulnerability. Predictor variables included socio-economic characteristics and the existence of adaptation measures in the area. The logit link function was used, and the assumption of proportional odds was tested using the Test of Parallel Lines. SPSS Version 29.0.2 was used for all the regression analysis in this study.

3.6 Hydrological Analysis for Flood Risk Mapping

As emphasized by Sampurno et al. (2023), future flood risk needs to be accurately assessed for sustainable planning and coastal protection as more people move closer to the sea. However, this is rarely the case in developing countries, where forecasting tools and in-situ data collection are scarce. To achieve this study's objectives, a hydrological analysis was conducted using the ArcGIS Pro software to generate all datasets needed to produce a flood risk map for the study region. Flood risk mapping primarily focused on identifying the zones particularly vulnerable to flood hazards. Floods in different regions with distinct characteristics have varied effects (Brunner et al., 2021). The comprehensive hydrological analysis was conducted using the 30-meter Digital Elevation Model (DEM) obtained from Center for Remote Sensing and Geographic Information Services (CERSGIS), Ghana. The following steps outline the general methodological flow followed to generate the necessary output.

3.6.1 Data Acquisition and Preparation

Elevation data has a wide range of applications in studies related to topography. The DEM takes an important part in hydrological and hydraulic modeling, especially in flood risk mapping (Chen et al., 2018; Munoth & Goyal, 2019). This is because the pattern of a landform determines floodwater behaviour (Roostaee & Deng, 2020). For most flood risk mapping projects, DEM has been the major satellite image/data for modelling elevation, and it has proved to be very reliable (Munoth & Goyal, 2019). This study used a 30-meter resolution DEM of the Greater Accra Region obtained from CERSGIS

at the University of Ghana. The purpose of the DEM data was to determine the elevation, drainage density and slope of the study area's terrain.

According to Rincón et al. (2018) rainfall is the leading cause of river flooding. Heavy rainfall can cause flooding when the streams are unable to carry excess water. As runoff is proportional to precipitation, higher precipitation increases the amount of runoff. Therefore, higher precipitation increases the risk of flooding (Nguyen et al., 2019).

To incorporate rainfall as a critical factor in the flood risk analysis, average annual rainfall data for 10 years (2012–2022) was obtained from the Ghana Meteorological Agency (GMET). The dataset consisted of raster layers representing average rainfall for each year within the 10 years. These rasters were processed in ArcGIS Pro using the ***Raster Calculator tool*** to compute a composite raster, representing the spatial mean of precipitation over the 10-year period. This raster provided a spatially continuous surface of long-term rainfall patterns across the study area. The resultant precipitation map was then reclassified on a scale from 1 (low rainfall) to 5 (high rainfall), based on the equal interval classification method, aligning with the standardized risk scale used for other hydrological parameters in the study (see ranges and actual values in the appendix). The equal interval method divides the data range into equal segments to ensure predictable and equal class ranges (Ayalew et al., 2004; Brewer, 2006). This makes it suitable for precipitation values as they are often distributed across a relatively uniform range. It ensures that each class represents an equal portion of the data value range, making it simple to understand rainfall distribution patterns (Khosravi et al., 2016; Kose & Turk, 2019; Nandi & Shakoor, 2010), to identify places with significantly lower or higher amounts of precipitation. *Figure 3.2* gives an overview of the methodological flow employed to generate the flood risk map.

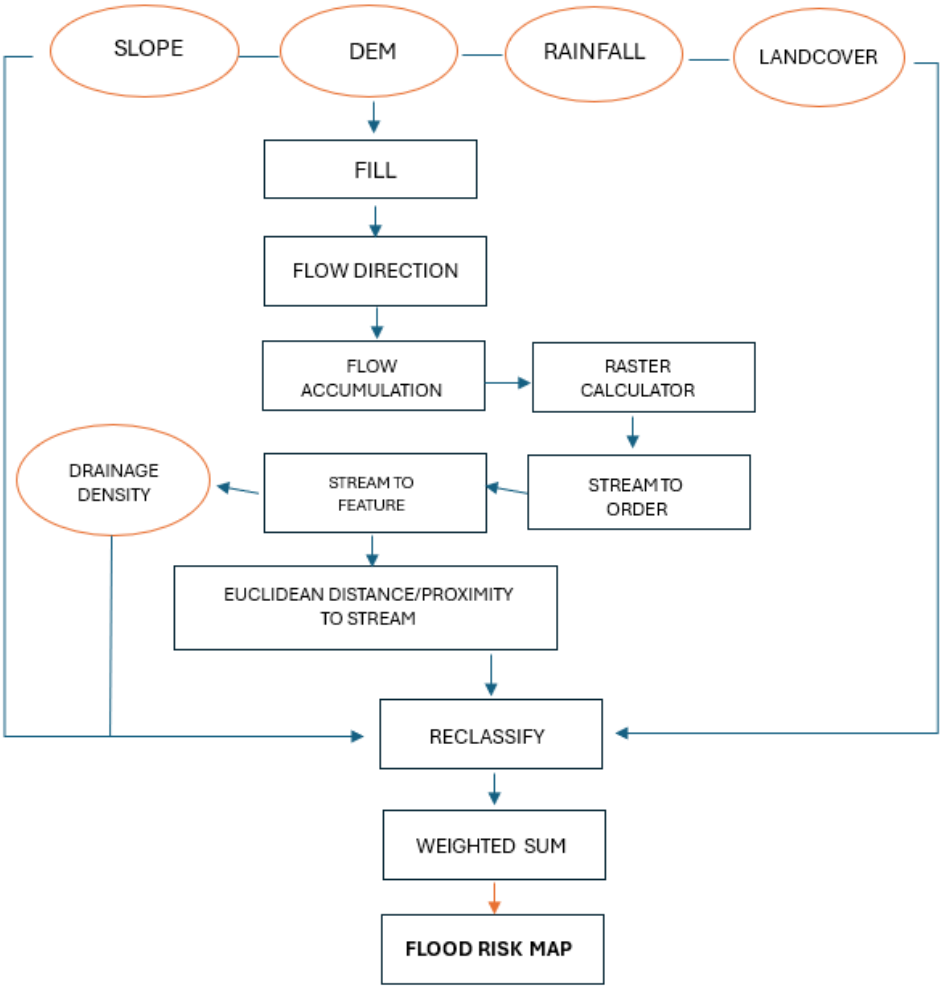

Figure 3.3 Methodological flow of the GIS analysis.

3.6.2 DEM Processing and Hydrological Modeling

The DEM was pre-processed to ensure accurate hydrological analysis. This involved filling depressions or sinks in the DEM using the ***Fill*** tool in the Spatial Analyst toolbox of ArcGIS Pro 3.3.1. Sinks are areas of the DEM that artificially impede water flow and filling them ensures a continuous flow path across the terrain. According to Munoth & Goyal (2019), hydrological modeling is one of the numerous environmental techniques that greatly benefit from elevation data. Elevation data provides the opportunity to analyze and present phenomena associated with topography and other surfaces and can help determine where water will flow and accumulate, making it easier to identify places that are at risk of flooding (McClean et al., 2020). Using the 'Reclassify' spatial analyst tool in ArcGIS Pro

software, the DEM data values were reclassified into five classes based on the Natural Breaks (Jenks) classification method, with 5 (high risk of flooding) assigned to low elevation values and 1 (low risk of flooding) to high elevations. The natural breaks method was appropriate because it groups the data based on similarity and has been widely utilized by scholars in comparable studies (Kadapa, 2024; Li et al., 2021; Vojtek et al., 2021). This method takes into account data discontinuities so that the variance of different categories is the greatest and the variance of the same category is the smallest to optimize classification, ensuring that elevation zones with the most similar flood risk characteristics are grouped, resulting in a more accurate classification for assessment (Bhagya et al., 2023).

3.6.3 Flow Direction and Flow Accumulation

The **Flow Direction** tool in ArcGIS Pro software was applied to the filled DEM to determine the direction of water flows across each cell in the elevation model. This indicates how water would naturally move across the landscape. On the elevation model, the flow direction indicates the potential direction of water runoff. The drainage basins were delineated to determine basins and watershed boundaries. A flow accumulation threshold of 5 was applied to generate the stream network, drainage basins, and flow direction using the filled DEM as input. The accumulation of water flow within each cell was then calculated using the Flow Accumulation tool, which helped to identify possible locations where water would naturally converge or accumulate. As indicated by Ozkan & Tarhan (2016) and Cai et al., (2019), these steps are critical in identifying high-risk flood zones where water could potentially flow in large volumes.

3.6.4 Stream Network and Proximity to Streams

The ***Raster Calculator*** was used to generate a stream network from the flow accumulation raster, with streams in the study region with a substantial flow greater than 500m being run as ("Flowaccumulation > 500") in the raster calculator. This threshold was chosen based on visual inspection and trial runs with varying thresholds (i.e 300, 800, 1000). The 500 provided the most hydrologically realistic stream network compared with satellite imagery from google maps. Following that, the *Stream Order* tool was

applied to the stream network and flow direction, and a Stream Order raster layer was generated using the Strahler method in the ArcGIS pro software. This helped in generating a stream network based on the hierarchy of streams. Proximity to streams was then calculated.

The measure of proximity to streams plays an important role in analyzing areas susceptible to flooding (Rincón et al., 2018). The zones closest to rivers are the most affected by floods. The ***Euclidean Distance*** spatial analyst tool was applied to the stream network to determine the proximity of various locations to the nearest water channels. The reclassification was based on assigning a value of 5 (to areas farthest from streams), and a value of 1 (to areas near various streams). The data distribution for proximity to streams showed a strong right-skewness (*see graph in Appendix A*), indicating that flood risk is concentrated in near-stream areas. The Natural breaks (Jenks) classification method was therefore used to reclassify the values for proximity to streams. This proximity analysis helps assess flood risk based on the distance of each cell to the nearest stream or river channel. This proximity analysis assesses flood risk based on the distance between each cell and the nearest stream or river channel.

3.6.5 Slope

The slope is the most important component for floods since it has a direct impact on surface runoff in watersheds. The slope influences the velocity with which water is transported through the drainage channel and watershed. Furthermore, the steeper the slopes, the higher the runoff, and hence, higher peak discharges will be generated (Rincón et al., 2018). As highlighted by Janizadeh et al. (2021), the impact of slope on the occurrence of severe floods is proportional to runoff speed. As a result, on steep slopes, the rate of water penetration is substantially slower, increasing the speed and flow of water (Nkeki et al., 2022). The slope of the study area was generated from the DEM using the ***Slope*** tool to understand the gradient and potential runoff velocity. The output produced a slope map layer that depicted the spatial distribution of slope landforms by degree. The slope layer was methodically reclassified into five classes ranging from 5 to 1, using the Equal interval method. The area with the

greatest degree of rise (steepest slope) was ranked 1, indicating very low flood risk potential. In contrast, the area with the least degree of rise (flattest slope) was ranked 5, indicating extremely high flood risk potential zones with slopes of ≤2° and 2°- 2.5° were classed as very high and high flood risk potential zones due to their relatively flat slope. ***Table 3.10*** shows the detailed classification based on the equal interval method. Even though the data distribution is right-skewed (*see graph in Appendix A*), the equal interval was suitable because it divides the slope range into evenly spaced classes, making it easier to identify areas with similar slope characteristics, and helping to differentiate between areas of low, moderate, and steep slopes, which is crucial for identifying flood-prone areas based on how terrain influences water flow (Vojtek et al., 2021).

3.6.6 Land Use/Land Cover

A land use map of the study area was incorporated to account for variations in surface characteristics that influence water absorption and runoff. This consist of different land use types (e.g., urban, agricultural, and forested areas) classified based on existing literature to reflect their role in flood risk assessment. Land use, as an indicator of flood risk, has a substantial impact on the recharging process. It has a direct impact on the surface runoff and infiltration rates of metropolitan areas. Several scholars have identified land use as a primary contributor to urban floods, which can aid in tracking the effects of urbanization on flooding (Nkeki et al., 2022; Rincón et al., 2018). Land use/land cover (LULC) is critical to floods and has an impact on several hydrological processes such as permeability, evapotranspiration, and runoff. When it rains in a basin, the amount of rain that falls into the rivers is determined by the area's characteristics, terrain, and LULC (Sugianto et al., 2022). The obtained LULC data, originally in raster format, was reclassified using the Natural breaks (Jenks) method to align with flood risk levels by assigning values based on land cover types (e.g., built-up, vegetation, water). The dataset had seven categories, but for the purpose of flood risk mapping, the dataset was simplified and reclassified into five broader categories that were most relevant to flood exposure in the study area, hence rocks and cloud cover were excluded. The aggregated five classes included water, built-up, croplands, bare lands, and vegetation (*see **Table 3.10***). It was reclassified into 5-1, with 5 representing

very high flood risk potential since it promotes rainfall-runoff and 1 depicts very low flood risk potential. As highlighted by scholars including Muriithi (2016) and Vojtek et al. (2021), the Jenks Natural Breaks method is the best suited for classifying land use in flood risk mapping because it groups similar land cover types based on their natural variation in the dataset, ensuring that areas with similar surface characteristics, such as impermeable surfaces that contribute to flooding and permeable vegetation that aids in water absorption, are appropriately classified.

3.6.7 Reclassification and Weighted Sum

The flood risk analysis was conducted using six factor layers: land use/land cover (LULC), drainage density, average annual rainfall, slope, proximity to stream channels, and elevation (DEM). Each layer was reclassified based on its impact on flood susceptibility and standardized to a common risk scale ranging from 1 (no risk/low risk) to 5 (very high risk). A weighted overlay was then created in ArcGIS using the *Weighted Sum tool*, with each factor assigned a weight indicating its relative contribution to flood risk. The weights were based on existing literature and expert assessment from previous flood risk studies in similar low-lying contexts (e.g., Enomah et al. 2023; Meral & Eroğlu, 2021; Roopnarine et al., 2018; Towfiqul Islam et al., 2021).

The final weights used were: LULC (30%), rainfall (25%), drainage density (20%), slope (10%), proximity to channels (10%), and DEM (5%). LULC and rainfall were given higher weights because of their major impact on surface runoff and infiltration capacity. Slope, proximity to streams, and elevation were assigned lower weights due to their moderate influence on the topography of the study area. Table 3.10 shows the weighted sum of the derived layers/factors.

Table 3.10 Reclassification and weighting factors

Factors (reclassified)	Domain	Risk Rank	Assigned weight	%
Land cover (LULC)	vegetation	1 - very low	0.30	30
	Croplands	2 - low		
	Barelands	3 - moderate		
	Water	4 – high		
	Built up	5 – very high		
Drainage Density (km/km^2)	0 – 17.47	1 - very low	0.20	20
	17.47 – 37.26	2 - low		
	37.26 – 56.48	3 - moderate		
	56.48 – 78.60	4 – high		
	78.60 – 148.47	5 – very high		
Average annual rainfall (mm)	541 – 643.04	1 - very low	0.25	25
	643.04 – 705.66	2 - low		
	705.66 – 732.33	3 - moderate		
	732.33 – 765.96	4 – high		
	765.96 – 836.69	5 – very high		
Slope (degree)	17.40 – 55.45	1 - very low	0.10	10
	8.92 – 17.40	2 - low		
	4.35 – 8.92	3 - moderate		
	1.96 – 4.35	4 – high		
	0 – 1.96	5 – very high		
Proximity to channel (m)	2494.43 – 4930.85	1 - very low	0.10	10
	1856.32 – 2494.43	2 - low		
	1295.56 – 1856.32	3 - moderate		
	638.11 – 1295.56	4 – high		
	0 – 638.11	5 – very high		
Elevation (m)	170.18 - 410	1 - very low	0.50	5
	88.46 – 170.18	2 - low		
	47.6 – 88.46	3 - moderate		
	20.95 – 47.6	4 – high		
	-43 – 20.95	5 – very high		

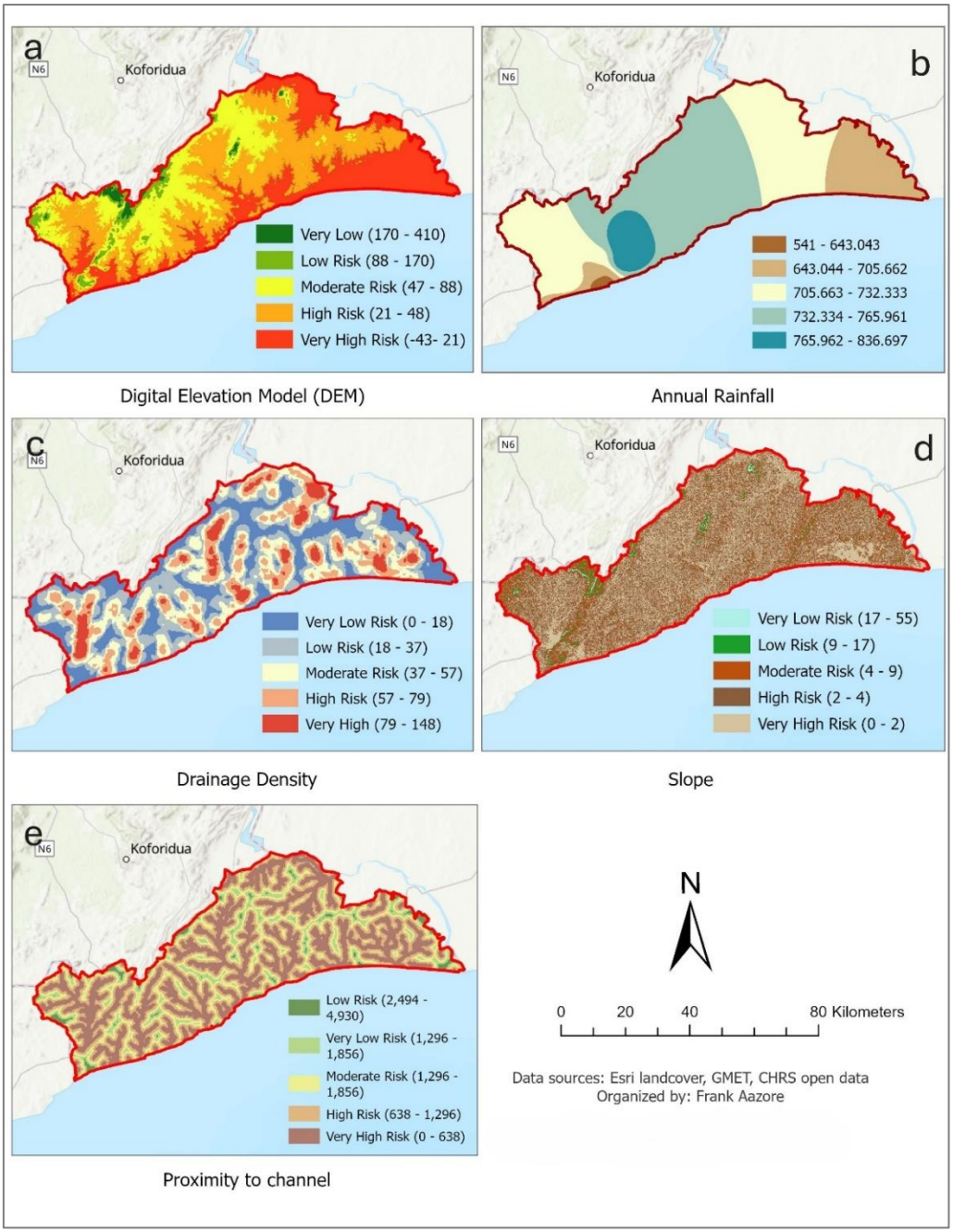

Figure 3.4 Classified indicators for flood risk mapping*; (**a**) Elevation using the Natural Breaks (Jenks) reclassification method; (**b**) Annual Average Rainfall using the Equal interval method; (**c**) Drainage density using the Natural Breaks (Jenks) method; (**d**) Slope using the Equal Interval; (**e**) Proximity to stream channels using the Natural Breaks method*

3.7 Bathtub Flood Risk Model

An elevation-based technique was used to extrapolate flood-inundation models for the Greater Accra Region to support the flood risk model with coastal factors to assess the flood risk to sea-level rise and storm surge. The simple Bathtub method (sBTM) is a GIS technique that indicates the areas below a specific elevation level as being flooded like a “bathtub” or single-value water surface (de Lima et al., 2021). Flooding areas are identified using a simple computational technique in a GIS environment in which the elevation in each cell of a DEM is compared to a predicted sea level, and all cells with values less than the predicted sea level are considered inundated (Yunus et al., 2016). According to Kasmalkar et al. (2024) bathtub models, in contrast to hydrodynamic models, provide a computationally inexpensive alternative for modeling coastal floods on global and regional scales. This approach requires only one input: a high-resolution and highly accurate Digital Elevation Model (DEM) (Williams & Lück-Vogel, 2020). As a result, bathtub models prioritize computational scalability over complex water flow dynamics processes. This method maps land next to the sea that is below a particular elevation threshold to project inundated areas. The mapping process uses a deterministic line to indicate inundation in relation to sea-level rise and ground elevation (Fitchett et al., 2016). As only elevation data are required for its application, it allows estimations when comprehensive hydrological data is missing or limited (Yunus et al., 2016).

The GIS-based sBTM was used to generate a flood extent map based on the predicted water levels in the study area. Using the ArcGIS Pro software, the elevation in each cell of the 30 m DEM of the study area was compared to the projected sea level rise. The zero elevation in the DEM was associated with the local mean sea level, and flood elevations were added to the surface. The cells in the DEM with lower values than the projected sea level were flooded. The potential flood risk from storm surge was mapped using a 3.5-meter storm surge elevation threshold, as recently observed during the most recent storm surge recorded on the east coast (Keta) (Brempong et al., 2023; Tumawu et al., 2024), under current and future sea-level rise projections of 1.1 meters by 2100 (IPCC 2021)(Avornyo et al.,

2023; Dada et al., 2023). The bathtub model was used to map flood zones with communities and infrastructure that could be vulnerable to a future 4.6-meter rise in water level. This is based on the recent benchmark storm in the east coast which produced a record 4-meter storm surge and a 1.1-meter projected sea-level rise under high emission scenarios.

3.8 Spatial Overlay Analysis

To assess spatial alignment and differences between the flood risk map and the participatory map of community-perceived risk zones, a visual overlay analysis was conducted in ArcGIS Pro. The flood risk model, which classified areas into Very low, Low, Moderate, High and Very high risk was first clipped to the boundary of each of the two study communities (where participatory mapping was conducted) using the *Clip Raster tool*. The resulting layer from the flood risk map displayed areas classified as *high risk* and *very high risk*, while lower risk categories (*very low*, *low*, and *moderate*) were not found within the boundaries of both Bortianor and Teshie. The community-perceived high-risk zones were derived from participatory mapping exercises and digitized as polygon shapefiles. These represented areas participants identified as most vulnerable to coastal hazards (flooding, erosion and storm surge). The digitized participatory maps were then overlaid on the clipped GIS flood risk layers. The transparency and symbology settings were adjusted for both layers to enable visual comparison of overlapping and non-overlapping areas.

3.9 Limitations

The study encountered some level of limitations. Some of the key expected limitations include the following:

The primary constraint of this research stems from the limited availability of data, particularly GIS datasets. The absence of an officially recognized National geodatabase hindered the comprehensive assessment of diverse GIS datasets essential for conducting this study. Consequently, the study was compelled to rely on datasets sourced from individual studies and those locally generated with the collaborative support of resources from research centers and labs including the Center for Remote

Sensing and Geographic Information Services (CERSGIS) at the University of Ghana, as well as the Maritime Provinces Spatial Analysis Research Centre (MP_SpARC) and the Wicked Problems Lab (WPL) at Saint Mary's University. While this study relied on variables such as elevation (DEM), rainfall, drainage density, slope, land use/land cover, and proximity to streams, other important GIS datasets commonly used in coastal hazard modeling were not available for the study area. Examples of such include: historical shoreline change data, Soil permeability and infiltration rates, Tide gauge and wave height data, etc.

Additionally, this research project was conducted within a limited budget, with essential funding secured from the Faculty of Graduate Studies and Research (FGSR) to support key aspects of the study. Given the international scope of the study and the need for collaboration with key resource persons within the study communities, the limited budget posed challenges in obtaining the necessary support. This limitation impacted the extent of both input and output achievable within the research, potentially influencing the depth and breadth of the study's findings.

Furthermore, a key limitation was the language barrier between me as the researcher and some of the study participants. While I am Ghanaian, I cannot speak and understand the Ga language, which is predominantly spoken in the study communities. As a result, trained field assistants who are bilingual in both Ga and English were hired to assist with translation for the household surveys and interviews. Although efforts were made to ensure the accuracy and meaning of responses, the use of interpretations may have affected certain expressions interpreted.

In conducting this research, I recognize the importance of positionality and reflexivity in guiding the research process. As a Ghanaian researcher, my national identity and prior knowledge of the cultural and environmental context of coastal hazards in Ghana provided both advantages and challenges, which were noted throughout the research process. While I share a national identity with the study participants, I do not speak the Ga dialect, which is commonly spoken in the study area. To ensure that participant voices were accurately represented, this required the use of trained research assistants

who translated questions and responses between English and Ga. However, I acknowledge that the use of interpreters, coupled with differences in social background and educational levels, may have influenced the depth of some responses. Efforts were made throughout the research to remain reflexive and aware of power dynamics, local sensitivities, and the importance of clarity in communication.

Chapter 4 – Results

4.1 Socio-Demographic Profile of Respondents

The household survey obtained a total of 120 valid responses, with 40 from each of the three study communities. Not all individuals approached agreed to participate. Although the precise number of participants approached during the household survey was not recorded, it was estimated based on the number of completed interviews and the response rate for each community. Based on this, about 141 individuals were approached across the three study communities, resulting in an overall response rate of 85%. In the few cases that individuals declined to take part, the field assistants used a replacement approach by continuing to nearby households until the target number of participants was met. Data collection occurred on a near-daily basis over one week in each community, reflecting a consistent level of field effort to reach the target sample size. *Table 4.1* shows the socio-economic characteristics of the final sample.

Six key factors were used to analyze socioeconomic characteristics. These included gender, age, educational level, religious affiliation, employment status, and annual household income. Additionally, residency tenure and historical ties to the communities were taken into consideration. These variables were selected based on their demonstrated influence on risk perception in existing literature. Studies have shown that 'gender' can influence risk perception, with women frequently reporting higher levels of concern about environmental hazards compared to men (Kellens et al., 2011; Wachinger et al., 2013). 'Age' can also influence how people interpret risk, with older persons often reporting higher risk due to increased vulnerability (Kellens et al., 2011). 'Education' has been associated with improved understanding of hazards and preparedness, which is often associated with high adaptive behaviour (Cerulli et al., 2020; Paton, 2005).

'Religious affiliation' and historical ties to a place can influence people's willingness to relocate or support adaptation strategies (Adger et al., 2011; Gaillard & Texier, 2010). 'Income and employment status' also affect people's ability to respond to coastal hazards, where those with lower income may

perceive more vulnerability due to fewer resources (Cutter et al., 2003). 'Tenure of residency' is typically related with enhanced local awareness of hazards but can also reduce perceived risk due to familiarity (Ali et al., 2022; Cutter et al., 2003).

Results from respondents' socio-economic analysis indicate that the majority of respondents were women (58%), with men accounting for 42% of the total sample. This is consistent with the recent 2021 Ghana Statistical Service population and Housing census (Ghana Statistical Service, 2021), which reported that females (2,776,629) outnumber males (2,679,063) in the Greater Accra Region. The age distribution was skewed toward middle-aged adults, with 43% of all respondents aged 30–45, followed by 27% aged 18–29, 19% aged 46–59, and only 11% reporting an age of 60 or older across the three study communities.

With regards to religious affiliation, Christianity was the dominant religion among respondents, constituting 74%, while 17% reported being affiliated with the traditional faith. Respondents identifying as Muslim and those who did not identify with any religion were 2% and 7%, respectively.

In terms of educational level, 31% of respondents reported having no formal education. A majority (53%) had attained at least a basic education (primary, middle, or junior high school). Additionally, 15% had completed secondary school, and only 1% had attained tertiary education.

Further analysis revealed that the majority of respondents were self-employed (61%), while 22% were employed and 17% were unemployed. Annual household income levels varied among the study communities, with 40% identified as medium income, 31% as high income, and 12% as low income, while 17% reported no household income. Annual household income was based on the daily minimum wage of GH₵19.97 (Donkor, 2024).

Table 4.1 Socio-demographic characteristics of respondents

Gender	***Frequency***			**Total (%)**
	Bortianor	***Jamestown***	***Teshie***	
Woman	22	28	19	69 (58%)
Man	18	12	21	51 (42%)
Other (specify)	0	0	0	0
Age	***Frequency***			**Total (%)**
	Bortianor	***Jamestown***	***Teshie***	
18-29	13	7	13	33(27%)
30-45	22	17	12	51(43%)
46-59	4	10	9	23(19%)
60 or older	1	6	6	13(11%)
Educational Background	***Frequency***			**Total (%)**
	Bortianor	***Jamestown***	***Teshie***	
No formal education	7	10	20	37(31%)
Basic (Primary, Middle or Junior High)	23	22	19	64(53%)
Secondary (Senior High)	9	8	1	18(15%)
Tertiary	1	0	0	1(1%)
Religious Affiliation	***Frequency***			**Total (%)**
	Bortianor	***Jamestown***	***Teshie***	
Christianity	28	34	27	89(74%)
Islam	0	1	1	2(2%)
Traditional faith	9	2	9	20(17%)
None	3	3	3	9(7%)
Employment Status	***Frequency***			**Total (%)**
	Bortianor	***Jamestown***	***Teshie***	
Employed	9	13	5	27(22%)
Unemployed	4	1	15	20(17%)
Self-employed	27	26	20	73(61%)
Annual household income	***Frequency***			**Total (%)**
	Bortianor	***Jamestown***	***Teshie***	
High income	11	16	11	38(31%)
Medium income	20	22	6	48(40%
Low income	6	1	7	14(12%
None	3	1	16	20 (17%
Total	**120**			**100%**

Table 4.2 Residency Tenure/Historical Ties

	None	More than two generations	One generation	Two generations	Total (%)
5 to 10 years	9	1	6	6	22 (18%)
Less than a year	2	0	1	0	3 (3%)
More than 10 years	3	39	16	37	95 (79%)
Total (%)	14 (12%)	40 (33%)	23 (19%)	43 (36%)	120

Table 4.2 is a cross-tab analysis that explores how long respondents have resided in the community and whether they have historical ties to it. The data reveals that residents who have lived in their community for more than 10 years are much more likely to have multigenerational ties. As a result, more than 80% of them reported having at least one generation of family history. Out of 95 people who have lived in the community for over 10 years, 39(41%) have family relationships that go back more than two generations, 37(38%) have ties for two generations, and only 3(3%) have no historical ties. In contrast, newer residents (less than 10 years) were predominantly those without such ties. Short-term residents (5 to 10 years) were more evenly distributed, whereas out of 3 recent residents (less than 1 year), 2 had no ties and 1 had ties going back to one generation.

4.2 Community Perceptions of Risk and Vulnerability to Coastal Hazards

4.2.1 Community Experience with Coastal Hazards

Respondents were asked about the coastal hazards they believed to be at risk. *Figure 4.1* presents the perceived coastal hazard risks across the study communities. ***Flooding and storm surge*** were frequently identified as the most serious hazards by respondents in Jamestown and Teshie. 97.5% of respondents in Bortianor similarly reported ***flooding*** and 92.5% reported ***erosion***, whilst 80% perceived being at risk to ***storm surges***. On the other hand, 82.5% of respondents in JamesTown reported a high concern for ***'Other'*** risks, which a couple of them attributed to declining fish stocks, as well as tides entering the community. Two responders from JamesTown and Teshie, who reported ***'Other'*** on the field survey, expressed the following:

[Original in Ga]: *"Nii mli hewalɛ, tsɔɔ mli lɛ, shɛɛ nɔ ni tsui ke hewalɛ lɛ… ɛyɛ akɛ gbo lɛ yɛ shi, anaa ni yɛ baa yɛ lɛ… Eyi lɛ yɛnitsɔɔ mli lɛ."*

[Translation in English]: *"These days, even in the season, the fish don't come like at first…. its like the sea is shifting or something is happening….That's our biggest problem right now."*

-Respondent A, Chorkor (Jamestown area)"

[Original in Ga]: *"Kpoji lɛ nɔɔ nyɛ gbɛi ni shibaa lɛ ni kpɔkpɔ. Nɔ ni yɛkɛ advice lɛ, lɔlɔi kɛ nyɛyɛ hewalɛ lɛ baa akɛ onɔ lɛsho. Nii mli lɛ, ɛyɛ akɛ amɛhee lɛ yɛ daadaa nɛɛ, ni onɔ lɛsho kɛ ji… shishi yɛnitsɔɔ mli lɛ, kɛ tourists kɛ visitors kɛ ehaaa wɔ".*

[Translation in English]: *"The beach is full of dump and toilet waste now. When we advise, most of the people here say there is nothing wrong. Now it's like a cultural thing that happens and no one cares, but it disturbs most of us and even the tourists and visitors."*

-Respondent B, Teshie

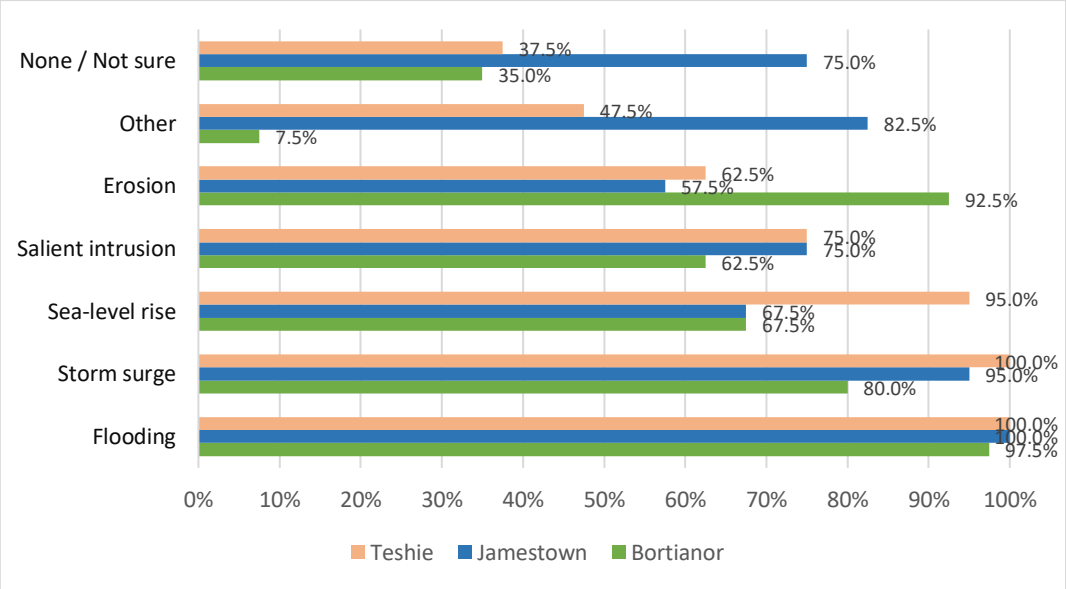

Figure 4.1 Distribution of risk perceptions to coastal hazards across study communities

A cross-tabulation was conducted to examine how residents perceived the main contributing factors to coastal hazards in their communities (***see Table 4.3***). The majority of respondents in the study communities attributed coastal hazards to a combination of ***both*** human activities and natural factors. This constituted 52.5% of responses from Teshie, 47.5% from JamesTown, and 40% from Bortianor. Perceptions of ***human activities*** were mostly reported in JamesTown (15%), compared to Bortianor (12.5%) and Teshie (7.5%). Meanwhile, Bortianor (47.5%) had the highest percentage of hazards attributed to ***natural factors***, followed by Teshie (40%), and JamesTown (37.5%). These findings suggest that while many respondents understand the interaction of natural and human causes to coastal hazards, community-level differences may reflect local experiences and exposure to specific risks.

Table 4.3 Cross-tab of the main perceived contributing factors for Coastal Hazards

Communities	*Both*	*Human activities*	*Natural factors*	Total (n)
Bortianor	40%	5 (12.50%)	19 (47.50%)	40
Teshie	52.5%	3 (7.50%)	16 (40%)	40
JamesTown	47.5%	6 (15%)	15 (37.50%)	40
Total (n)	56	14	50	120

4.2.2 Level of risk to coastal erosion

Respondents were asked to indicate their level of risk to coastal erosion, which was classified as low, moderate, high, or very high. Responses varied throughout the study communities (*see figure 4.2*). Respondents from Bortianor perceived higher risks of coastal erosion, with 35% reporting a ***High risk*** and 48% indicating a ***Moderate risk***. Bortianor was the only community with 5% of respondents reporting risk to coastal erosion as ***Very High***. Only 12.5% of Bortianor respondents perceived risk to coastal erosion as ***Low***. In contrast, most respondents in Teshie-Nungua reported risk to coastal erosion as ***Moderate*** (55%) or ***Low*** (42.5%), with only 2.5% indicating a ***High risk*** and none reporting ***Very High***. Similarly, 52.5% of respondents in JamesTown perceived the risk of coastal erosion as Low, and only 12.5% perceived it as ***High***; ***no respondents*** reported Very High.

The findings indicate that, among the study communities, respondents in JamesTown have the lowest perception of risk of coastal erosion, Teshie-Nungua has a moderate perception of risk, and Bortianor has the highest perception of risk of coastal erosion. This can be attributed to variations in perceptions because of differences in exposure and visibility of coastal impacts.

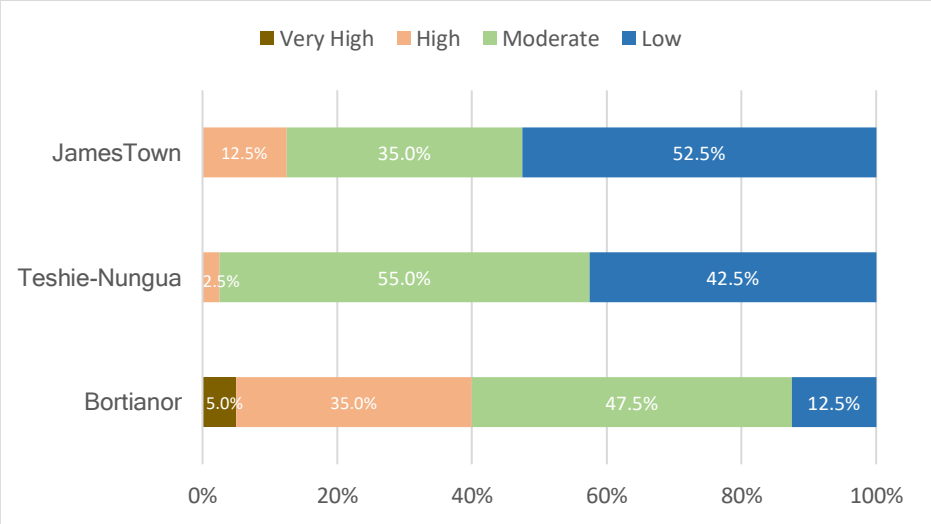

Figure 4.2 Comparison of perception of the level of risk to coastal erosion

A Kruskal-Wallis H test was used to examine differences in perceived risk of coastal erosion across the study communities. As shown in ***Table 4.4***, the test indicated that there was no statistically significant difference in perceptions between the groups. Pairwise comparisons using Dunn's test with Bonferroni correction revealed no statistically significant differences in perceived risk of coastal erosion between any of the three communities (all p-v > 0.05). However, the comparison between JamesTown and Teshie-Nungua approached significance (adjusted p=0.214), indicating a possible trend.

Table 4.4 Pairwise Comparisons of Study Area (Kruskal-Wallis H test)

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
JamesTown-Bortianor	2.913	7.184	.405	.685	1.000
JamesTown-Teshie	12.950	7.184	1.803	.071	.214
Bortianor-Teshie	-10.038	7.184	-1.397	.162	.487

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

4.2.3 Level of risk to Flooding/Storm surge

Respondents were asked to report how frequently their communities experience flooding/storm surges. The majority of respondents (42.5%) in Bortianor reported experiencing flooding ***frequently***, and 20% reported ***always***, indicating a higher perceived exposure to flood hazards. In Teshie-Nungua, 47.5% of respondents indicated that flooding occurs only ***occasionally***, while 50% indicated ***rarely/never***, and none reported ***always***. Similarly, in Jamestown, 60% of respondents reported flooding as ***rarely/never*** occurring, while 27.5% selected ***occasionally***. Based on the findings (see *figure 4.3*), Bortianor experiences more frequent flooding compared to Teshie-Nungua and Jamestown, where respondents perceive flooding less often.

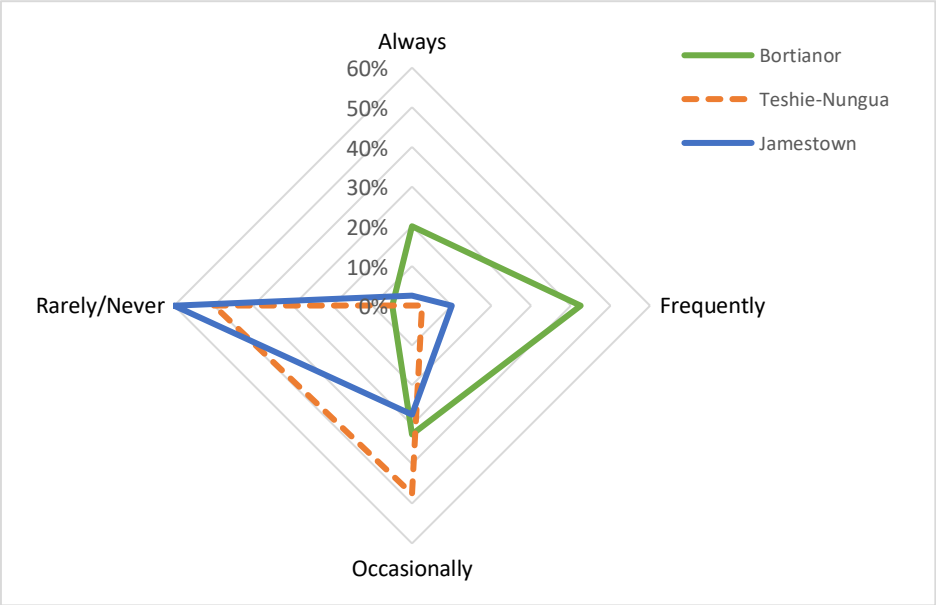

Figure 4.3 Frequency of flooding/storm surge experience by community

Respondents were asked to indicate their level of risk to flooding/storm surge, classified as low, moderate, high, or very high (see *figure 4.4*). Responses from Bortianor were skewed toward higher categories, with 40% of respondents indicating a ***High risk*** and 10% reporting a ***Very High risk***. Additionally, 42.5% of respondents perceived risk to flooding/storm surge as ***Moderate***, while only 7.5% indicated it as ***Low risk***. In contrast, in Teshie-Nungua, 55% of respondents reported ***Moderate*** and 45% reported ***Low risk*** to flooding/storm surge. ***None*** of the respondents in Teshie-Nungua perceived risk to flooding/storm surge as High or Very High.

In JamesTown, 62.5% perceived risk to flooding/storm surge as ***Low***, while 27.5% reported ***Moderate risk***, and only 10% reported ***High risk***. None of the respondents reported a ***Very High risk***. These findings indicate that the perceived risk of flooding or storm surge is highest in Bortianor, moderate in Teshie-Nungua, and lowest in JamesTown.

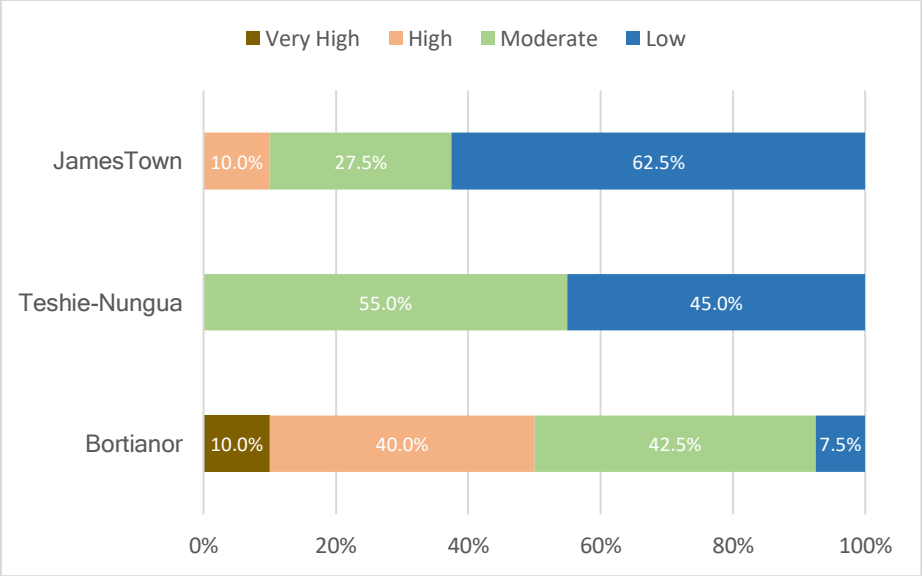

Figure 4.4 Comparison of perception of the level of risk to flooding/storm surge

A Kruskal-Wallis H test was used to assess differences in perceived risk to flooding/storm surge across the study communities. As shown in ***Table 4.5***, the results showed a marginally non-significant difference ($\chi^2(2) = 5.495$, *p-value = 0.064*). Pairwise comparisons following the Kruskal-Wallis test revealed a marginally significant difference in perceived flooding risk between JamesTown and Teshie-Nungua (adjusted p-value = 0.068). No significant differences were observed between Bortianor and the other two communities (all adjusted $p > 0.05$).

Table 4.5 Pairwise Comparisons of Study Area (Kruskal-Wallis H test)

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
JamesTown-Bortianor	4.800	7.241	.663	.507	1.000
JamesTown-Teshie	16.500	7.241	2.279	.023	.068
Bortianor-Teshie	-11.700	7.241	-1.616	.106	.318

4.2.4 Community Vulnerability to Coastal Hazards

Respondents were asked how vulnerable they feel to coastal hazards in the next ten years. Varied responses were received across the study communities (see *figure 4.5*), with the majority of respondents reporting ***moderate*** or ***low vulnerability*** levels. In Teshie-Nungua, 47.5% perceived themselves as ***moderately vulnerable***, while 40% perceived experiencing ***low vulnerability***. In contrast, 30% of responses from Jamestown indicated ***moderate*** vulnerability, 27.5% reported ***low vulnerability***, 22.5% reported ***high vulnerability***, and 20% reported ***extreme vulnerability***. In Bortianor, 42.5% reported ***moderate vulnerability***, 25% reported high or ***extreme vulnerability***, and only 7.5% perceived ***low vulnerability***.

The findings indicate that respondents in Bortianor feel the most vulnerable, with the lowest percentage indicating low vulnerability and the largest percentages reporting high or extreme vulnerability levels. Meanwhile, respondents in Teshie-Nungua generally perceive less vulnerability, with 87.5% indicating moderate or low vulnerability.

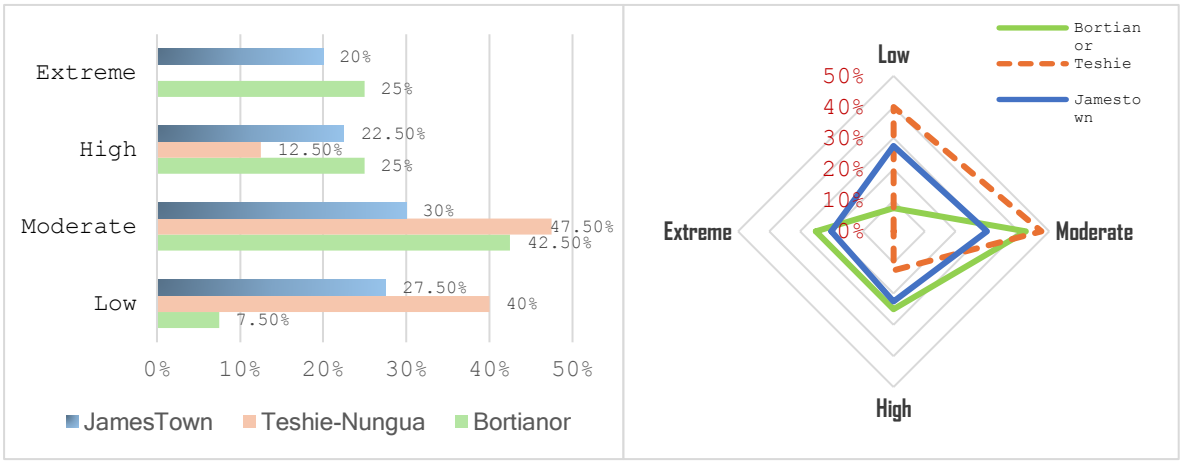

Figure 4.5 Perceived vulnerability to coastal hazards

An ordinal logistic regression model was conducted to determine whether socio-economic characteristics and the perceived presence of adaptation measures predicted respondents' perceived vulnerability to coastal hazards over the next 10 years (***see Table 4.6***). Several factors proved statistically significant, including *study communities, age, tenure residency, and existing adaptation*

measures. The findings indicate that respondents from Bortianor were considerably more likely to express higher perceived vulnerability than respondents from Teshie (B = 1.46, p-value = 0.002). Conversely, respondents from Jamestown were substantially less likely to perceive themselves as vulnerable than respondents from Teshie (B = -1.15, p = .024). Younger respondents aged 18–29 reported considerably lower levels of vulnerability compared to the oldest age group (60 or older) (B = -2.66, p-value < 0.001).

Furthermore, respondents who had resided in the community for 5 to 10 years were more likely to feel higher vulnerability than those who had lived for more than 10 years (B = 2.75, p-value = 0.024). Respondents who reported no adaptation measures in their community were more likely to perceive higher vulnerability than those who were aware of existing measures (B = 0.93, p-value = 0.037).

Table 4.6 Ordinal Logistic Regression on Socio-economic characteristics and perceived Vulnerability

Variables tested	Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
*Area 1 - Bortianor	1.455	.476	9.358	1	.002	.523	2.387
*Area 2 - JamesTown	-1.147	.509	5.069	1	.024	-2.146	-.149
Area 3 - Teshie	0[a]	.	.	0	.	.	.
Gender = Man	-.061	.378	.026	1	.871	-.803	.680
Gender = Woman	0[a]	.	.	0	.	.	.
*Age = 18-29	-2.664	.755	12.438	1	<.001	-4.145	-1.184
Age = 30-45	-1.028	.656	2.457	1	.117	-2.314	.258
Age = 46-59	.221	.681	.106	1	.745	-1.113	1.556
*Age = 60 or older	0[a]	.	.	0	.	.	.
No formal education	-.016	1.889	.000	1	.993	-3.718	3.686
Basic/Primary	.619	1.920	.104	1	.747	-3.144	4.381
Secondary	1.858	1.956	.902	1	.342	-1.977	5.692
Tertiary	0[a]	.	.	0	.	.	.
Residency [less than a year]	-.212	.489	.188	1	.665	-1.171	.747
*Residency [5 to 10 years]	2.754	1.222	5.080	1	.024	.359	5.149
Residency [More than 10 years]	0[a]	.	.	0	.	.	.
*Adaptation Measures [Yes]	.927	.446	4.333	1	.037	.054	1.801
Adaptation Measures [No]	-.967	.531	3.318	1	.069	-2.007	.073
Adaptation Measures [Not sure]	0[a]	.	.	0	.	.	.

4.3 Awareness of Coastal Protection and Adaptation

Respondents were asked about the coastal adaptation measures they are familiar with or believe are currently being used in their community. To assess the types of adaptation measures familiar to residents, responses were grouped into five groups based on structural, ecological, or a combination of both. These are 1) Hard Infrastructure (Rock armouring, seawalls, groins, land reclamation), 2) Hybrid (built structures with natural systems), 3) Nature-based Coastal adaptation (mangroves/swamps, sand dunes, beach nourishment), 4) Planned Retreat, and 5) No Awareness (none/not sure).

As shown in *Figure 4.6*, a majority of respondents in Jamestown (52.5%) and Teshie-Nungua (30.0%) indicated familiarity with ***Hard Infrastructure*** strategies such as seawalls and groins, whereas only 12.5% of respondents in Bortianor reported the same. In contrast, respondents in Teshie-Nungua (62.5%) and JamesTown (37.5%) were more familiar with ***Hybrid*** strategies than in Bortianor (32.5%). Notably, 40.0% of respondents in Bortianor indicated familiarity with NbCA such as mangrove restoration and beach replenishment, but none responded in Teshie-Nungua or JamesTown. All communities had minimal familiarity with ***Planned Retreat***, with 15% reporting in Bortianor and 7.5% in Jamestown. A small percentage of respondents reported ***no awareness*** or uncertainty regarding the adaptation measures, with Teshie-Nungua reporting the highest at 7.5%, followed by Bortianor and Jamestown at 2.5% each.

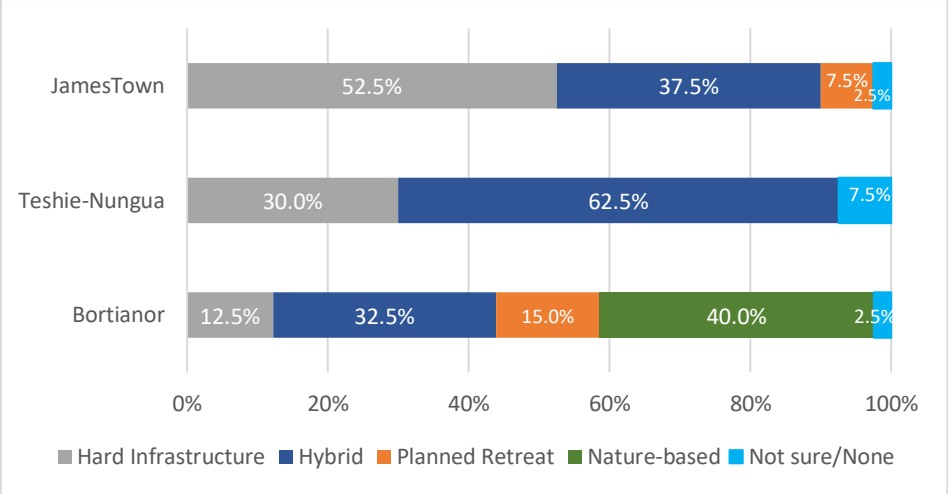

Figure 4.6 Existing Coastal Adaptation Measures across study communities

Field observations and community engagements revealed that each of the three study communities had different forms of adaptation measures in place. In Bortianor, there were mangrove plantations along parts of the coast (see *figure 4.7*), which the community leaders claimed were planted as part of a community-based restoration project led by the West African Coastal Areas Management (WACCA) program (Foli et al., 2022). The mangrove plantation serves as a natural buffer against flooding and erosion.

Figure 4.7 Existing Mangrove and coconut plantations at Bortianor

Source: Field survey, January 2025

In Jamestown, the current adaptation measure includes a sea defense wall (see *figure 4.8*), but many community residents are concerned about its effectiveness, particularly in terms of continued erosion and overtopping during high tides. Meanwhile, in Teshie-Nungua, groins have been constructed to trap sand and reduce erosion indirectly through sediment accumulation; however, residents have expressed dissatisfaction with their effectiveness, claiming that the structures have changed natural sediment movement and may have exacerbated erosion in surrounding areas. During the field visit to Teshie and Jamestown, no nature-based measures were noticed.

Figure 4.8 Hard Infrastructure (seawall and groins) constructed at JamesTown and Teshie

Source: Field survey, January 2025

Respondents were asked to identify if they had any of the following concerns regarding current adaptation strategies in their communities (see *Figure 4.9*); 'no concerns', 'not effective', 'causing financial loss/burden', 'causing more damage', and any 'other'. The most frequently selected concern across all study communities was that current measures were ***not effective in protecting the coast***, 45% of respondents in Teshie-Nungua, 35% in Bortianor, and 32.5% in Jamestown. A smaller percentage of respondents, 12.5% in Bortianor and 10% in Jamestown, expressed concern about the ***financial burden of*** current measures.

Additionally, 10% of respondents in both Teshie-Nungua and Jamestown reported that current measures cause ***more damage to the environment***, whereas only 2.5% of respondents in Bortianor supported this concern. Notably, 57.5% of respondents in Bortianor and 52.5% in both Teshie-Nungua and Jamestown indicated that they had ***no concerns*** about existing coastal adaptation measures. Notably, in Jamestown, 20% of respondents selected ***'Other'*** as a concern. Although these concerns were not specified in the questionnaire, field notes and follow-up comments suggest that respondents were concerned with issues such as restricted beach access for fishers, poor maintenance of the sea defense wall, and insufficient community consultation.

A respondent from JamesTown who reported 'Other' on the field survey, expressed the following:

> **[Original in Ga]:** *"Amɛbiko wɔ loo amɛkɛ wɔ wooo mli. Amɛ (nɔyeli lɛ) ba ni amɛ kɜ wɔ susuuu he. Amɛkɛɛ ŋaalɔi lɛ le jogbaŋŋ, no hewɔ lɛ wɔna tsɔnei kɛkɛ ni amɛba ni amɛje nitsumɔ shishi. Agbɛnɛ tɛi lɛ miiye wɔ lɛlɛi lɛ awui. Wɔnyɛŋ po wɔkɛ wɔlɛlɛi lɛ aba ŋshɔ lɛ naa mlɛo dɔɔŋ . Tɛi lɛ yɛ wɔgbɛ lɛ nɔ. Nɔyeli lɛ kɛ nɔ fɛɛ nɔ tsu maŋkwramɔŋ saji babaoo yɛ biɛ, ni wɔteŋ mɛi pii bɛ he miishɛɛ."*
>
> **[Translation in English]:** *"They didn't ask us or involve us. They (the government) came without any consultation. They said the technicians know best, so we just saw machines come and start work. Now the stones are causing harm to our boats. We can't even bring our canoes to shore easily anymore. The stones are in our way. The government did too much politics with everything here, and most of us are not happy with it."*
>
> *-Respondent C, Chorkor (Jamestown area)"*

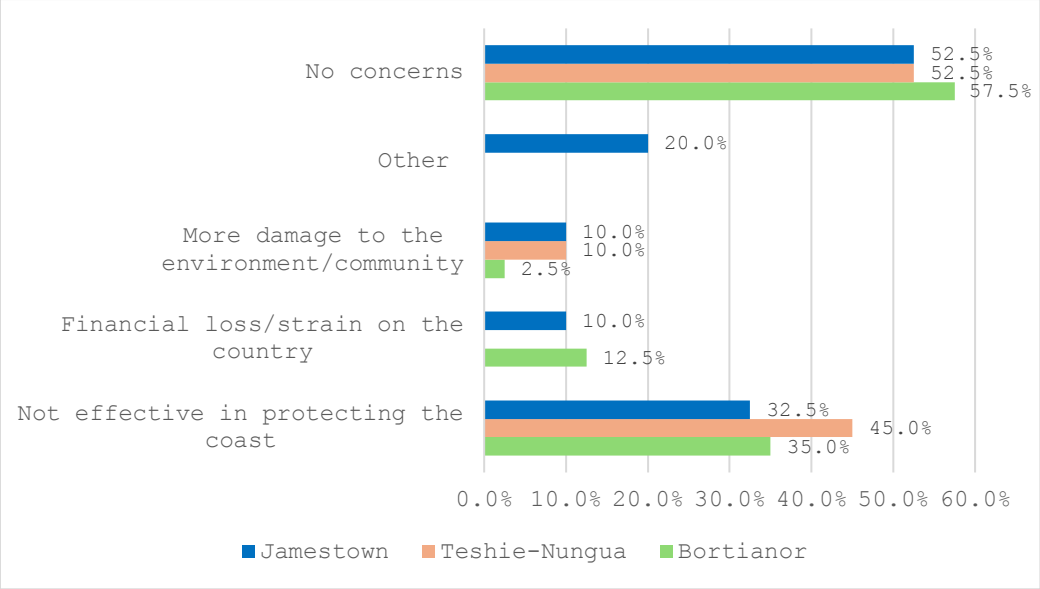

Figure 4.9 Concerns about coastal adaptation measures across study communities

Respondents were asked to indicate their level of satisfaction with the government's support in addressing coastal hazards in their communities (see *Figure 4.10*). 'Government support' in this context refers to actions such as the building of coastal defense structures (e.g., sea walls and groins), conducting public education campaigns, providing post-disaster relief, and community engagement in adaptation planning.

The findings indicate that a majority of respondents (35%) in Bortianor reported being ***neutral***, with 27.5% ***very dissatisfied*** and 12.5% dissatisfied. Only 22.5% of Bortianor respondents reported being ***satisfied***, with 2.5% being ***very satisfied***. In Teshie-Nungua, dissatisfaction was more prevalent, with 45% of respondents reporting dissatisfaction, and another 25% indicating they were ***very dissatisfied***. Only a small percentage expressed satisfaction, with 2.5% selecting ***'satisfied'*** and another 2.5% very satisfied, while 25% reported being ***neutral***. In Jamestown, 50% of respondents selected ***'neutral'*** for government support. An additional 20% were dissatisfied, while 2.5% were very dissatisfied. 20% reported satisfaction, and 7.5% indicated they were ***very satisfied***.

Overall, ***dissatisfaction*** was more prominent in Teshie-Nungua, whereas ***neutral*** responses dominated in Jamestown, and satisfaction levels varied more in Bortianor.

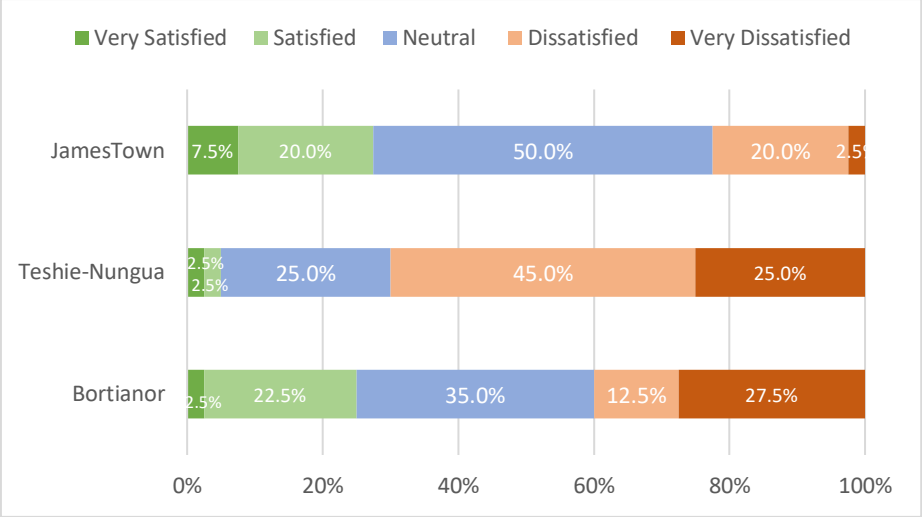

Figure 4.10 Community satisfaction with government support

4.4 Awareness and Perception of Nature-based Coastal Adaptation (NbCA)

Respondents were asked about their level of awareness of NbCA across the study communities. A chi-square test analysis of responses revealed a statistically significant relationship ($\chi^2(2, N = 120) = 46.70$, $p < 0.001$) in terms of awareness of NbCA interventions among the study communities. In general, 44% of the total study sample (120) reported being aware of NbCA while 56% reported not being aware or have never heard about NbCA. As shown in Table 4.10, Bortianor had the highest level of awareness with 85% (n=34) of respondents reporting knowledge of NbCA. Teshie-Nungua had the lowest level of awareness, with only 4 respondents (10%) reporting awareness. Jamestown showed moderate levels of awareness, with 37.5% (n=15) reporting knowledge of NbCA and 62.5% (n=25) reporting being unaware. The findings (*see* ***table 4.7***) indicate strong community-level disparities in exposure to, or understanding of, nature-based coastal adaptation approaches.

Table 4.7 Community awareness of NbCA

		Aware of NbCA?		
		No, I am not aware	**Yes, I am aware**	Total
Study Area	Bortianor	6 (15%)	34 (85%)	40
	Teshie-Nungua	36 (90%)	4 (10%)	40
	JamesTown	25 (62.5%)	15 (37.5%)	40
Total		**67 (56%)**	**53 (44%)**	**120**
		Value	df	P-value
Pearson Chi-Square		46.702[a]	2	<.001
N of Valid Cases		120		

The relationship between awareness of NbCA and willingness to support their implementation in the study communities was examined using a chi-square test of independence. The analysis revealed a significant association between awareness and support ($\chi^2(1, N = 120) = 6.49$, $p = .011$). As shown in ***Table 4.8***, 85% (n=102) of the total sample (120) expressed willingness to support the application of NbCA, while only 15% (18) expressed not willing to support. Out of this, 94% of respondents ***who were aware*** (53) of NbCA expressed willingness to support its application. Similarly, 78% among those ***who were not aware*** (67) also expressed willingness to support its application once explained to them. This suggests that residents who are already familiar with NbCA in these communities are much more likely to approve and support their use in coastal protection efforts. However, most people who are not aware are still willing to support its application provided it yields positive benefits.

Table 4.8 Awareness and willingness to support NbCA

		Willing to support the application of NbCA to protect the coast?		
		No	**Yes**	Total
Aware of NbCA?	No, I am not aware	15 (22%)	52 (78%)	67 (56%)
	Yes, I am aware	3 (6%)	50 (94%)	53 (44%)
Total		18 (15%)	102 (85%)	120
		Value	df	P-value
Pearson Chi-Square		6.494[a]	1	.011
N of Valid Cases		120		

4.4.1 Factor Analysis (FA) of Perceived Obstacles to NbCA Implementation

Table 4.9 shows the varimax-rotated FA of underlying dimensions of perceived obstacles to implementing NBCA in the study communities, using the Principal Component Analysis (PCA) on a 15 Likert-scale questionnaire. The rotated component matrix was selected because it may generate a clearer and more interpretable structure, which aids in identifying and understanding the underlying factors (Panda et al., 2021). It is important to note that all the extracted components contained more than one variable, indicating that the results are acceptable and free from intricate structures. The results indicate the evaluation of the likely interrelationships among the variables contained in each component. Initial eigenvalues suggested a three-factor solution, with all three components having eigenvalues greater than 1. Together, the three factors explained 65.61% of the total variance. The principal factors include ***a) Factor 1 (Awareness, Governance, and Institutional Capacity)***, which consists of items such as lack of awareness of NbCA benefits (.754), insufficient funding (.728), limited technical expertise (.622), resistance to change (.515), competing land use priorities (.525), lack of political will (.571), and inadequate regulatory frameworks (.778). ***b) Factor 2 (Coordination and Information Access)***, which comprised environmental hazards (.776), limited access to data (.772), lack of stakeholder collaboration (.770), economic instability (.579), lack of incentives (.562), insufficient community engagement (.536). ***c) Factor 3 (Socio-cultural and Tenure)***, consisting of cultural or traditional practices (.806) and land tenure or ownership issues (.693). All communalities were greater than 0.5, suggesting each item shared a substantial amount of variance with the factors.

Table 4.9 *Rotated Component Matrix*[a]

	Component			
	1	2	3	Factors
Inadequate regulatory frameworks	.778			**Factor 1**: (Awareness, Governance, and Institutional Capacity)
Lack of awareness on NbCA benefits	.754			
Insufficient funding/financial resources	.728			
Limited technical expertise	.622			
Resistance to change/skepticism	.515			
Competing land use priorities	.525			
Lack of political will	.571			
Environmental hazards		.776		**Factor 2:** (Coordination and Information Access)
Limited access to relevant data/info		.772		
Lack of stakeholder collaboration		.770		
Economic instability		.579		
Lack of clear benefits or community incentives		.562		
Insufficient community engagement		.536		
Cultural or traditional practices			.806	**Factor 3:** (Socio-cultural and Tenure)
Land tenure/ownership issues			.693	

4.4.2 Factors predicting willingness to support NbCA Implementation

A binary logistic regression was conducted to examine the extent to which socio-demographic and risk perception variables predicted respondents' willingness to support the application of NbCA strategies to protect the coast. *Table 4.10* shows the result and summary including the variables tested, with B representing the partial regression coefficient and Exp (B) as the regression ratio, standard error (SE), wald statistic, degree of freedom (df) and significance. The dependent variable was a dichotomous response to the question: *"Are you willing to support the application of NbCA to protect the coast in your community?"* (coded as 1 = Yes, 0 = No). The independent variables were socio-demographic factors including gender, age, religious affiliation, educational level, income (based on minimum wage), tenure of residency, perceived level of risk to coastal erosion, perceived level of risk to flooding/storm surge, perceived vulnerability to coastal hazards over the next 10 years, and awareness of NbCA.

Overall, the model was statistically significant (*p-value* < 0.05), indicating that the set of predictors reliably distinguished between those who were willing and unwilling to support NbCA. Among all

predictors, only "***awareness of NbCA"*** significantly contributed to the model (*p-value <0.05*), indicating that those who were aware of NbCA had 4.2 times higher odds of being willing to support its application (Odds ratio=4.2), compared to those who were not, holding all other variables constant. All other predictors including age, gender, religion, education, income, or risk perceptions (for all) recorded *p*-value > 0.05, hence were not statistically significant predictors of willingness to support NbCA application to protect the coast in the study area. These findings suggest that awareness of NbCA plays a critical role in shaping community support for their implementation, more so than demographic background or perceived exposure to coastal risks

Table 4.10 Binary regression analysis for willingness to to support NbCA

		B	S.E.	Wald	df	P-value	Exp(B)/OR
Step 1[a]	Gender	.727	.636	1.307	1	.253	2.069
	Age	-.317	.325	.947	1	.330	.729
	Religious Affiliation	-.045	.249	.032	1	.857	.956
	Education	.172	.429	.160	1	.689	1.187
	Income (Minimum wage)	-.222	.280	.629	1	.428	.801
	Tenure Residency	.142	.383	.137	1	.712	1.152
	Level of risk to coastal erosion	1.141	.768	2.211	1	.137	3.131
	Level of risk to flooding and/or storm surge	-.779	.730	1.139	1	.286	.459
	Vulnerability to CHz over the next 10 years	-.351	.336	1.089	1	.297	.704
	***Awareness of NbCA**	**1.443**	**.711**	**4.125**	**1**	**.042**	**4.235**
	Constant	-1.368	2.855	.230	1	.632	.255

Signifacance level p-value < .05, OR (Odds Ratio)

4.4.3 Factor Analysis of Ways Willing to Support NbCA Application

Table 4.11 shows the varimax-rotated FA of a 9 Likert-scale items measuring willingness to support the application of NbCA in the study communities. The results indicate the evaluation of the likely interrelationships among the variables contained in each component and the factor loadings resulting in the classification into three main components. The three factors emerged with eigenvalues above 1, explaining 80.88% of the total variance. The principal factors include ***a) Factor 1 (Active Participation)***, which captures direct, hands-on community involvement in the adaptation efforts. It

includes activities such as attending educational workshops (.844), supporting public education/awareness campaigns (.766), participating in research or data collection (.698), and participating in community activities (.670). These items reflect a willingness to be actively present and involved in the implementation and outreach processes of adaptation strategies. ***b) Factor 2 (Technical and Voluntary engagement)***, which represents a form of support that requires specialized knowledge or voluntary time commitments. This includes providing technical expertise or skills (.862) and volunteering for project planning (.619). These forms of engagement suggest a more organized and skill-based involvement. ***c) Factor 3 (Material and Financial Support)***, which includes forms of indirect but tangible support such as financial contribution (.886), In-kind donations (.596), and promoting social media engagements (.561). These actions reflect a willingness to support adaptation without necessarily being physically involved, focusing instead on providing resources or advocacy to enable implementation. All items had strong communalities, ranging from 0.67 to 0.87, and the internal consistency for the overall scale was considered high.

Table 4.11 Rotated Component Matrixa

	Components			
	1	2	3	Factors
Attend educational workshops	.844			**Factor 1:** (Active Participation)
Support public education/awareness campaigns	.766			
Participate in research/data collection	.698			
Participate in community activities	.670			
Provide technical expertise or skills		.862		**Factor 2:** (Technical and Voluntary engagement)
Volunteer for project planning		.619		
Financial contribution			.886	**Factor 3:** (Material and Financial Support)
Make In-kind donations			.596	
Promote social media engagements			.561	

4.5 Participatory Spatial Insights on Nature-based Coastal Adaptation in Bortianor and Teshie

The digitized map outputs based on the participatory mapping exercises conducted in Bortianor and Teshie involving a total of seven participants (community leaders) are shown in *Figures 4.11 and 4.12*. The maps capture community perceptions of areas with high risk of flooding and erosion, current coastal protection measures, and suggested locations for future interventions. Participants in Bortianor (*see Figure 4.11*) indicated two main high-risk areas: one along the floodplain adjacent to the Densu River, and another toward the southwestern coast. These zones were attributed to Densu River, ocean backflow during storm surges, and the occasional release of water from the Weija Dam, which has been reported in previous research (e.g., Addo, 2015; A. B. Owusu et al., 2023) as a contributor to seasonal flooding in the area. Areas with existing NbCA measures were also identified. These were primarily mangrove plantations and coconut buffers. However, the preferred locations for new NbCA were along the beach front, reflecting residents' concern about coastal erosion and a desire for solutions such as mangrove restoration, which they are quite familiar.

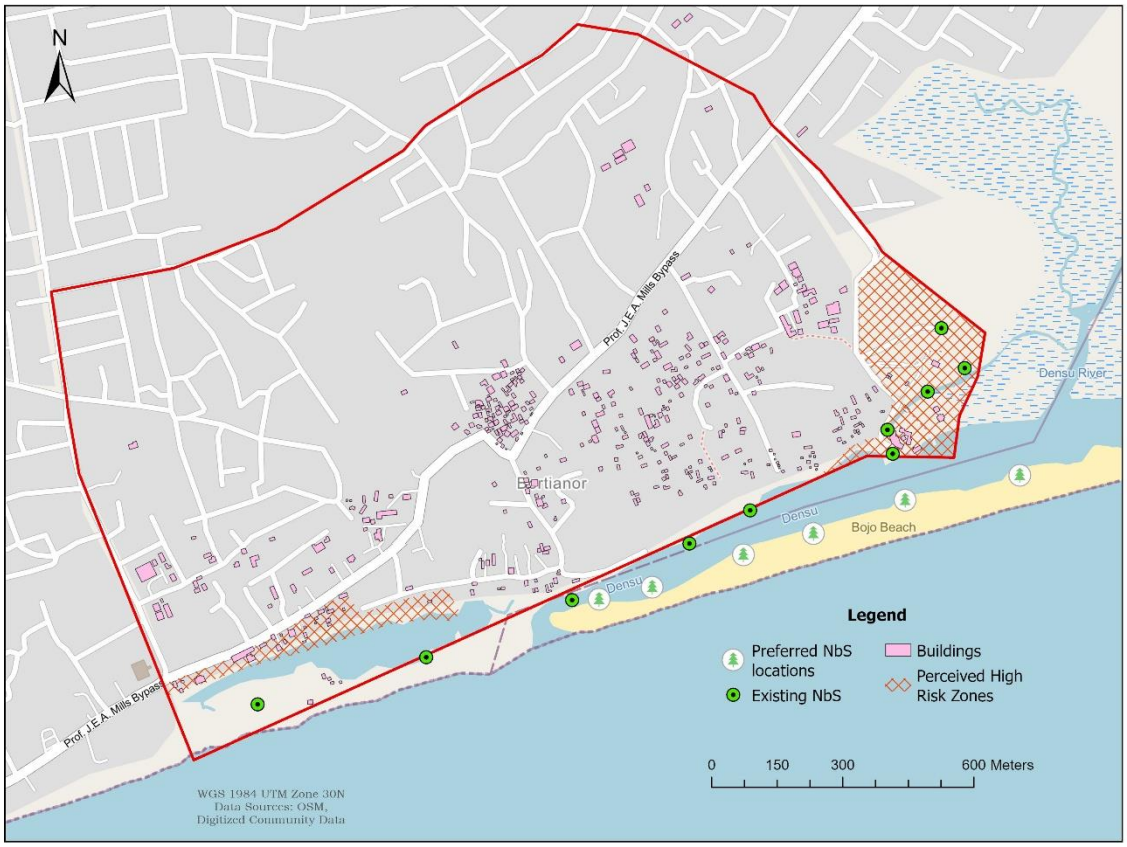

Figure 4.11 Participatory mapping output for Bortianor, showing perceived coastal hazards high-risk zones, existing nature-based solutions, and preferred locations for future NbCA, as identified by community stakeholders

In Teshie (*see Figure 4.12*), participants identified a much broader area as high risk, particularly along the river corridor and the central eastern coastline strip. Field responses suggest that these areas experience frequent flooding and poor drainage, which some respondents attribute to blocked channels and runoff from uphill developments. Participants also identified areas of existing NbCA locations, which are primarily coconut and vegetation buffers. Participants indicated several preferred future NbCA locations, which were spatially aligned with flood risk zones and existing hard infrastructure (groins and sea walls). These responses may reflect residents' dissatisfaction with the groins implemented along the shoreline, which were perceived as ineffective and unevenly distributed.

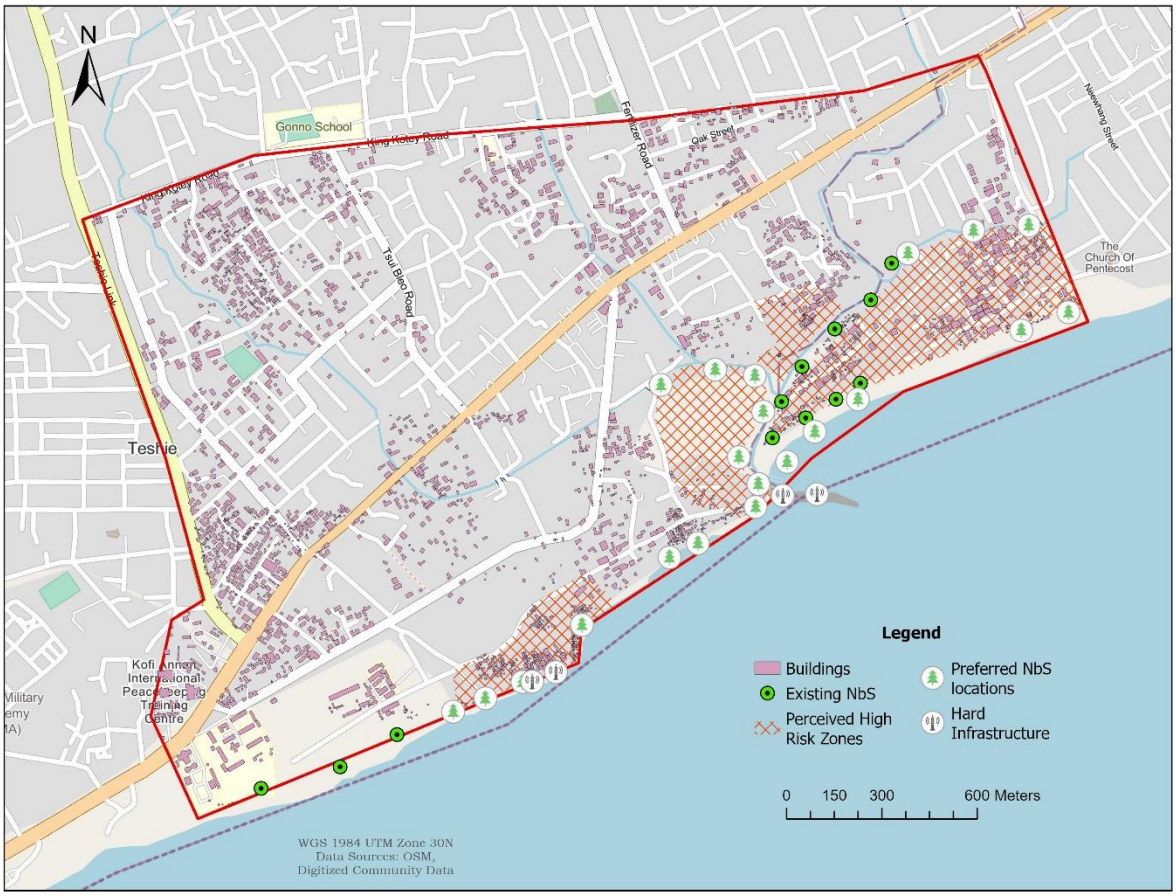

Figure 4.12 Participatory mapping output for Teshie, showing high-risk zones, existing solutions, and preferred locations for future NbCA, as identified by community stakeholders

4.6 Flood Risk Assessment

The flood risk analysis, using elevation, rainfall, drainage density, slope and proximity to channels, revealed that 30% (1,142.1 sq km) of the total land area (3,704.6 sq km) is at no or low flood risk. In contrast, 52% (2,562.5 sq km) of the region is classified as high-risk flood zones, predominantly located in low-lying coastal areas and urbanized zones (*see **figure 4.13***), with inadequate drainage systems. The remaining 18% (667.5 sq km) falls into moderate-risk zones, often in peri-urban regions where urban expansion meets natural landscapes. This suggests a significant vulnerability to flood hazards, predominantly driven by poor drainage infrastructure and urban encroachment on natural floodplains. The findings highlight critical zones for targeted interventions, including the prioritization of NbCA interventions such as wetland restoration and mangrove planting to absorb floodwaters and reduce runoff.

Table 4.12 *Flood Risk Land Area Inventory*

Risk Rank	Land Area (km^2)	Risk Area in %
Very low risk	276.60	7%
Low risk	865.50	23%
Moderate risk	803.10	22%
High risk*	945.20	26%
Very high risk*	814.20	22%
Total Land (km^2)	**3,704.60**	**100%**

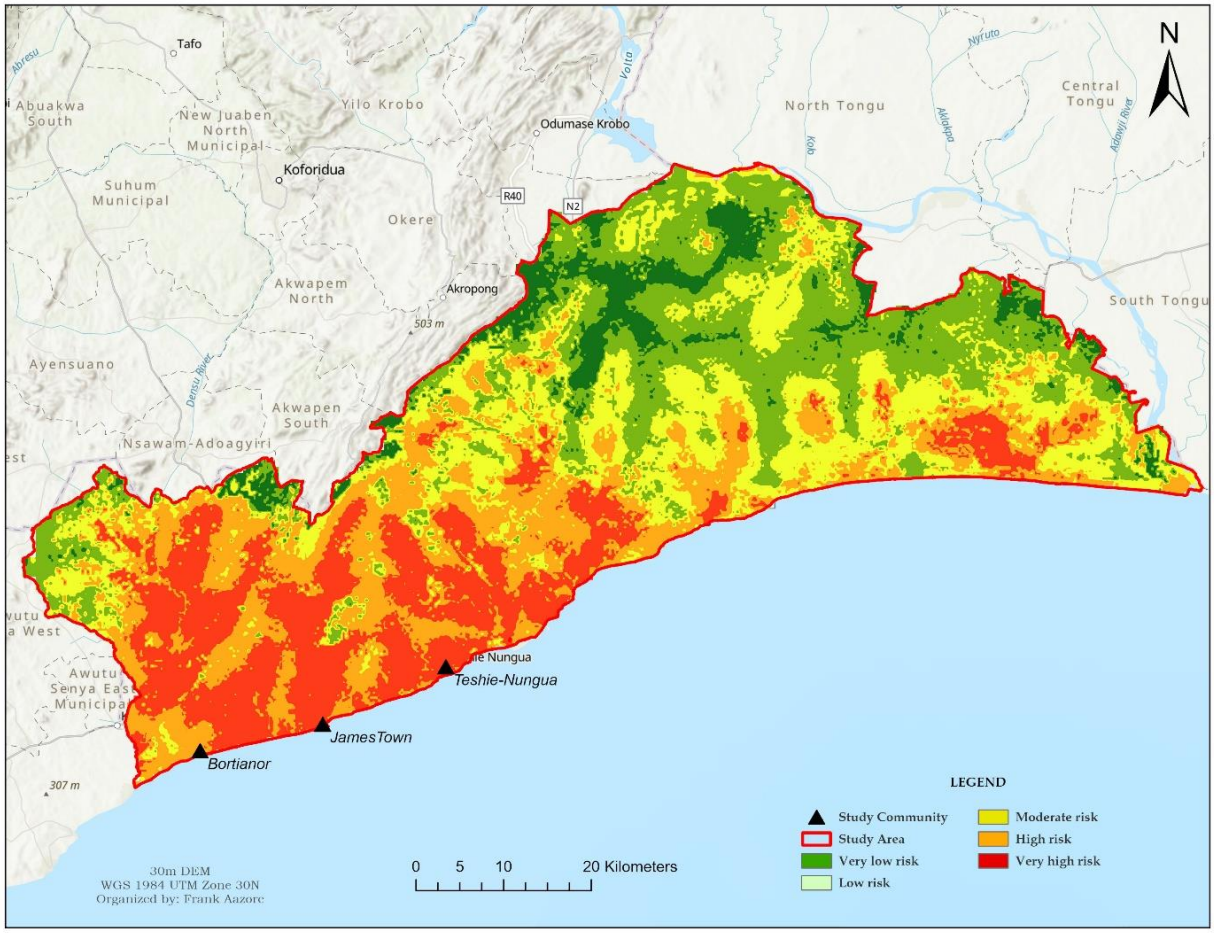

Figure 4.13 Flood risk map of Greater Accra region

4.6.1 Simple Bathtub Model (sBTM) Flood Risk Analysis

The sBTM revealed that 391.91km^2 (constituting 11%) of the total land area of the Greater Accra region has the potential to be flooded by a 4.6 m storm surge and increase in water level under high emission sea-level rise projections by 2100 (*see Figure 4.14*). In this scenario, a total of 1,807 (0.6%) buildings out of a total of 288,147 existing buildings in the region are estimated to be flooded by a 4.6m storm surge and sea-level rise (see ***Table 4.13)***.

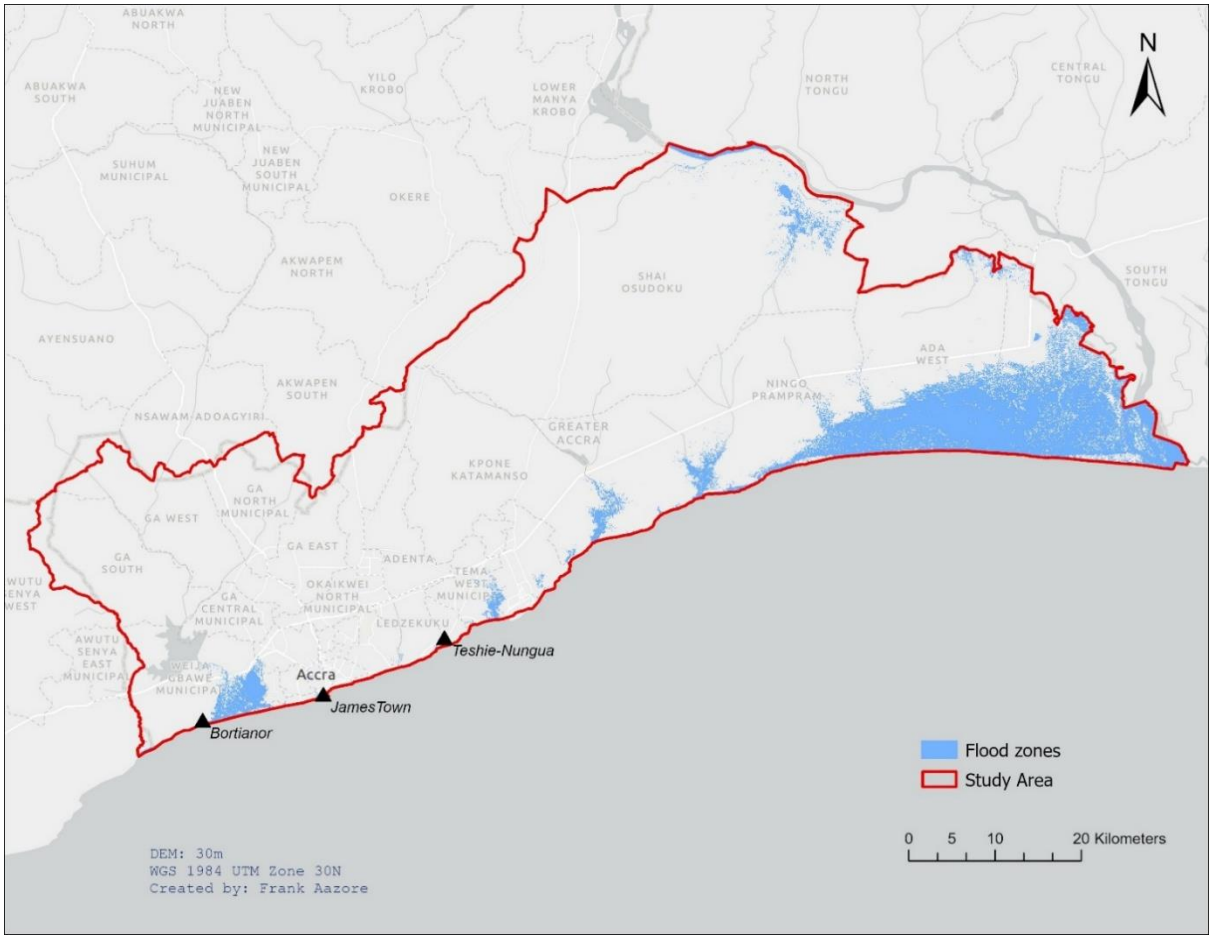

Figure 4.14 Bathtub Model of flood risk zones in Greater Accra regio*n*

Table 4.13 Coastal Hazard Impact Assessment

Study Areas	Total number of Buildings at risk	Percentage (%)
	Benchmark historical surge (3.5m) + IPCC sea-level rise 2100 projection (1.1m)	
Bortianor	44	0.02%
JamesTown	14	0.80%
Teshie-Nungua	113	6.30%
Total Flooded Buildings / Total Buildings in Region	**1,807 / 288,147**	**0.01%**
Total Flooded Land / Total Land Area	391.75 km² / 3704.60 km²	10.58%

Table 4.13 shows that 1,807 of the 288,147 existing buildings in the Greater Accra region are expected to be impacted by the sBTM future hazard scenario. This accounts for around 0.6% of all building structures in the region. The flooded land area is estimated at 391.75 km², whereas the total land area is 3,704.60 km². This implies that around 10.6% of the region's land area is vulnerable to flooding under this combined surge and sea-level rise scenario.

4.7 Spatial Overlay of Risk Models and Participatory Maps

Figure 4.15 shows the GIS flood risk model overlayed with the participatory map of community-perceived high-risk zones for Bortianor. The analysis revealed that the entire area within the Bortianor boundary was classified under either ***high*** or ***very high risk*** based on the GIS flood risk model. No areas within the boundary fell under *very low*, low, or *moderate risk*.

The results of the community participatory mapping, indicated by hatched polygons, revealed two separate ***perceived high-risk zones***. The first community ***perceived high-risk zone*** is in the eastern section of Bortianor between the Densu River and Bojo Beach, marked in red crisscross (hatched) lines

(see figure 4.15). This area overlaps with the ***very high risk*** areas from the GIS model. This consistency highlights both technical and local awareness of the area's susceptibility to coastal hazards. The community residents attributed this risk to frequent river flooding and the blocking or slowdown of river discharge during high tide or storm surge, which frequently causes upstream flooding. This perception aligns with the bathtub model results (see Figure 4.14), which illustrate the potential for low-lying areas close to the river mouth to retain water during extreme tide or storm surge, even in the absence of direct overland flow. The bathtub model enhances understanding of the inland inundation risks and provides some validation to community observations.

This overlap confirms both technical and local awareness of this area's susceptibility to river flooding and ocean backflow, which is consistent with seasonal flood events noted during fieldwork and previously highlighted by Oteng-Ababio et al. (2011). The second ***perceived high-risk zone*** is in the southwestern coastal area and *does not overlap* with the GIS model's ***very high risk area,*** but falls entirely within the GIS model's ***high-risk area***. Participants identified this zone as vulnerable due to frequent flooding, which is likely exacerbated by tidal overflow and a lack of protective infrastructure.

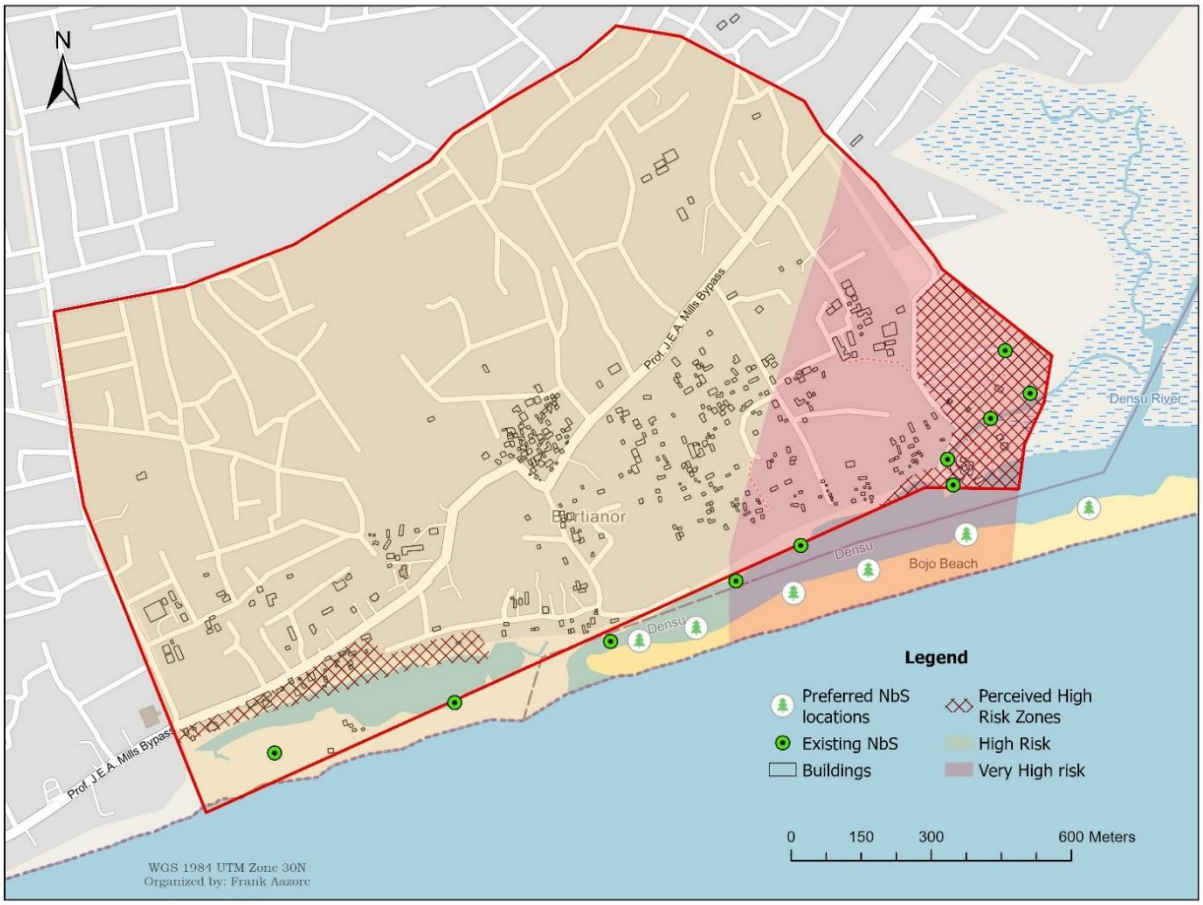

Figure 4.15 Overlay of GIS-modeled flood risk areas and community-perceived high-risk zones in Bortianor

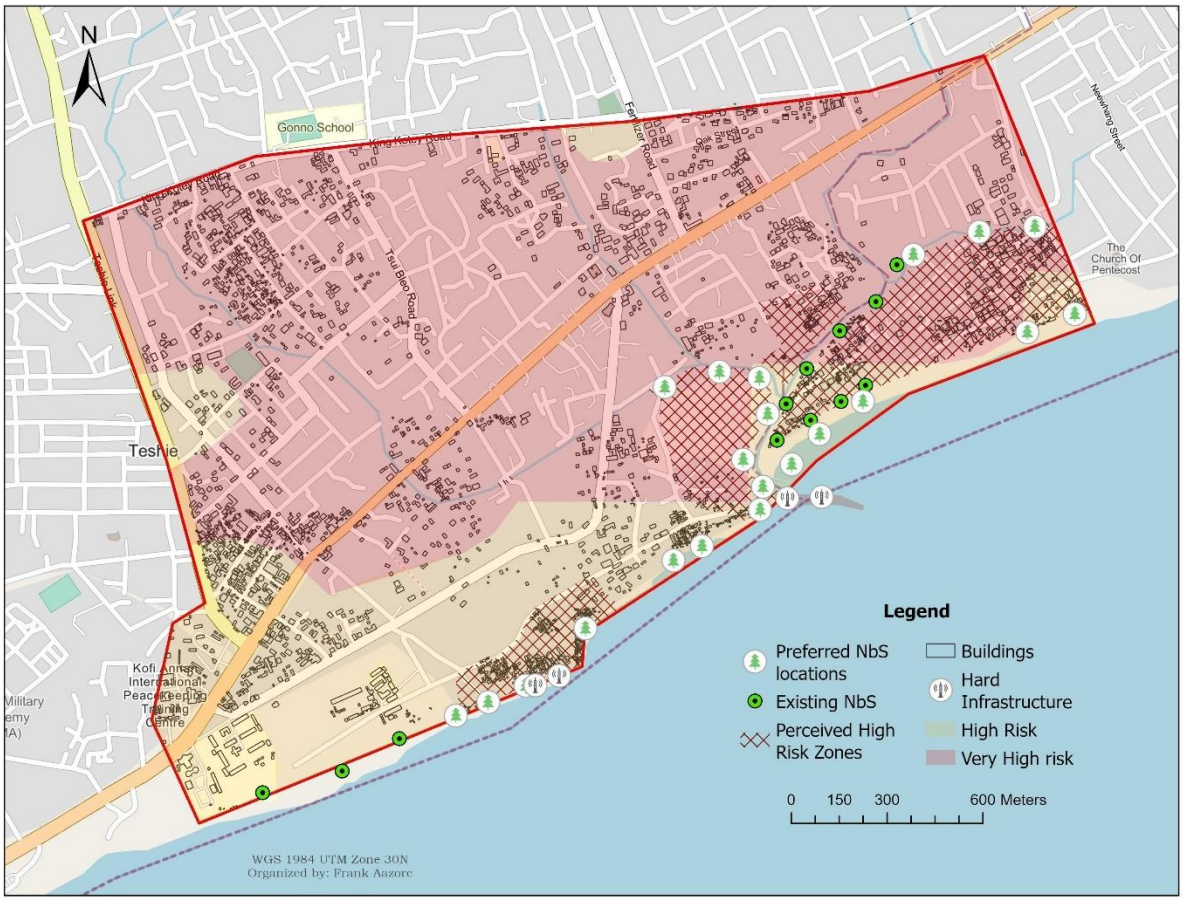

Figure 4.16 Overlay of GIS-modeled flood risk areas and community-perceived high-risk zones in Teshie

Figure 4.16 shows the GIS flood risk model overlayed with the participatory map of community-perceived high-risk zones for Teshie. Similar to the previous community, the flood risk model classified nearly the whole community boundary as either ***high risk*** (transparent yellow) or ***very high risk*** *(transparent red)*. This reflects a consistently high level of vulnerability across the community's landscape. Community-perceived high-risk zones, identified through participatory mapping, were concentrated along the eastern and central coastal corridors, including areas close to the existing hard infrastructure (see figure 4.16). These mapped zones reveal strong spatial alignment with the ***very high risk areas*** identified by the GIS model, particularly along the densely settled southeastern area. This overlap confirms the validity of both community perception and the GIS model in identifying flood-risk zones and coastal erosion.

However, a small number of **perceived high-risk zones**, particularly along the midwestern area of the coast, fell within areas classified by the GIS model as ***high risk*** but not ***very high risk***. Residents reported these zones experience frequent water accumulation and drainage overflow after rainfall events. This disparity may also be due to limitations in the GIS model inputs, which primarily focused on fluvial factors (e.g., drainage density, proximity to rivers, slope) and did not explicitly account for coastal drivers such as sea level rise or storm surge.

Although these areas were not identified as particularly high risk in the GIS model, their inclusion by community members reflects specific knowledge of urban infrastructure failures, such clogged culverts and uncontrolled runoff, which the technical analysis may not have fully captured. Additionally, the bathtub model (see Figure 4.14), which simulates static inundation based on elevation and possible sea level rise scenarios, highlights low-lying areas susceptible to tidal inundation and coastal ponding, supporting local observations of water retention and overflow, which also helps to explain why some community-perceived high-risk areas were not classified as 'very high risk' in the original GIS model.

Chapter 5 – Discussion

This chapter provides an interpretation and discussion of the study findings presented in the previous chapter of this thesis. The major important themes and implications, such as perceived vulnerability to coastal hazards, awareness and willingness to support NbCA, and the relationship between GIS models and local perceptions, were thoroughly examined. The goal of the study was to explore community-level perceptions of risk to coastal hazards, assess spatial patterns of risk through GIS assessments, and identify opportunities for Nature-based Coastal Adaptation (NbCA) using three selected coastal communities in the Greater Accra region of Ghana.

5.1 Overview of key findings

The findings from this study demonstrated significant differences in risk perceptions across demographic groups, strong associations between community-identified risk zones and the GIS flood risk model, as well as general widespread support for NbCA interventions, albeit with varying levels of community awareness. Overall, the findings support the importance of integrating local knowledge with technical and scientific risk evaluations to inform coastal adaptation planning, which is consistent with previous studies that have emphasized the need for participatory approaches in environmental planning (Anderson & Renaud, 2021; Audefroy & Sánchez, 2017; Broto et al., 2015; McKinley et al., 2021; Pasquier et al., 2020). These studies have highlighted that integrating community knowledge into climate adaptation planning improves both local relevance and the effectiveness of implemented strategies.

The consistency between geospatial modeling and community knowledge indicates that most communities possess accurate knowledge of the coastal hazard dynamics. This implies that community-based adaptation measures could be reinforced through collaboration with local stakeholders. From a policy perspective, especially in rapidly urbanizing coastal areas such as in the global south, these findings highlight the need for developing inclusive adaptation strategies that validate and operationalize on community knowledge and perceptions.

5.2 Risk Perceptions and Perceived Vulnerability to Existing Coastal Hazards

One main research objective was to assess the variations in risk perceptions and understand vulnerabilities among several demographic and socioeconomic groups within the study communities. The findings revealed a significant level of perceived risk to coastal erosion and flooding/storm surge across the three study communities. Specifically, more than half of respondents from Jamestown and Teshie perceived a very high level of risk to coastal erosion, whereas respondents in Bortianor, who claimed to be regularly impacted by the opening of the Weija Dam, expressed high perceptions of risk to flooding and storm surge. Furthermore, perceived community vulnerability was explored, with most respondents rating their community as either *moderately* or *highly vulnerable*. Ordinal regression analysis further demonstrated that demographic variables, including age (18-29), residency tenure (5-10 years) and people who reported existing adaptation measures, had a significant influence on these perceptions. Older individuals and those who have lived in the community for a longer period are more aware of long-term coastal changes and regard themselves as more vulnerable.

These results are consistent with findings from other coastal vulnerability studies conducted globally and especially in sub-Saharan Africa. Previous studies (see Lechowska, 2022; Satterthwaite et al., 2020; Talanow et al., 2021) have reported that both lived experience and social status greatly influence risk perception. Communities with limited adaptive capacity and regularly exposed to hazards tend to report higher levels of perceived risk. For instance, according to Schneiderbauer et al. (2021), education and how long a person has lived in a place may influence how environmental change is viewed and interpreted, therefore impacting how risks are perceived and addressed. The observed variations between the three communities in this study support similar findings Boateng, (2012), which underlined place-specific perceptions along Ghana's coast.

The findings suggest that historical knowledge and socioeconomic background play equally important roles in vulnerability perception as hazard exposure. The long history of coastal erosion in Jamestown, as well as the supposed ineffectiveness of existing sea defence (sea walls), most certainly influenced

participants' high-risk perception. In contrast, Teshie's vulnerability to inland riverine floods and drainage challenges may account for the community's concern about storm surge and flood hazards. Bortianor's exposure to recurring dam-induced flooding (G. Asare & Tuffour, 2023) further demonstrates how structural measures (such as managing the Weija Dam) shape community risk awareness.

Demographically, the findings showed that demographic characteristics had varying influences on perceived vulnerability to coastal hazards across the study communities. Location was a significant determinant, with respondents from Bortianor reporting higher perceived vulnerability than those from Teshie, and those from Jamestown expressed the lowest overall perceived vulnerability. Age also proved as a factor, with younger respondents (18–29 years) perceiving themselves as less vulnerable compared to older adults. Regarding tenure of residence, individuals who had resided in the community for a shorter period (5 to 10 years) reported higher perceived vulnerability compared to those who had lived in the area for over ten years. This finding contrasts with previous research suggesting that longer-term residents are more likely to perceive higher vulnerability due to their cumulative exposure to environmental changes such as shoreline erosion or seasonal flooding (Wachinger et al., 2013). In the present study, however, the high perception of risk among short-term residents may reflect a heightened awareness during a critical period of recent exposure.

Furthermore, education did not appear to be a significant factor in the statistical models for this study; however, some studies have emphasized that low levels of education may also limit access to official information sources, hence increasing reliance on knowledge through lived experiences (Bronfman et al., 2020). The awareness perception of existing adaptation measures also influenced vulnerability perceptions; respondents who reported no adaptation measures in place were more likely to perceive higher vulnerability than those who acknowledged some form of adaptation. These factors support arguments from several studies on environmental justice, which contend that marginalized

communities often experience disproportionate environmental risks without sufficient resources to address them (Chu & Michael, 2019; Fiack et al., 2021).

5.3 Awareness and Willingness to Support Nature-based Solutions

The overall responses from the household survey revealed varying levels of awareness and support for nature-based coastal adaptation (NbCA) across the three study communities. Approximately 40% of respondents in Bortianor reported familiarity with NbCA measures such as mangrove restoration and beach replenishment. In contrast, none of the respondents in Teshie or Jamestown indicated any awareness of such measures. This discrepancy could represent both past intervention experiences and ecological differences between the study communities. For example, it was discovered in Bortianor that organizations such as WACCA are currently conducting mangrove restoration initiatives, providing the residents with practical examples of NbCA and generally enhancing community awareness on such measures. On the other hand, Teshie and Jamestown lack visible ecosystems suited for mangrove restoration and have few sandy beaches suitable for beach nourishment, which may explain some of the community's lack of awareness.

In terms of perceptions of existing adaptation strategies, the existence of mangroves and ongoing restoration projects in Bortianor has most certainly increased community familiarity and trust in NbCA in general. However, most respondents in Teshie and Jamestown expressed dissatisfaction with the existing hard infrastructure. In Teshie, groins built to trap sand and lower erosion through sediment accumulation were perceived as ineffective. Consistent with previous studies (see Guimarães et al., 2016 and Lim et al., 2022) that highlighted unexpected effects of groin construction in dynamic coastal systems, community members indicated that the structures have affected natural sediment transport, potentially increasing erosion in surrounding areas. Despite varying levels of awareness, there was considerable willingness to support NbCA when respondents were informed of its benefits. Specifically, most respondents expressed willingness to participate in activities such as community cleanups, mangrove planting, and maintenance of green infrastructures.

These findings are consistent with studies (e.g Arkema et al., 2017; Narayan et al., 2016) which indicated that awareness and direct exposure to NbCA are substantially associated with community acceptance and support for ecological restoration. Lack of awareness in Jamestown and Teshie matches patterns reported in similar contexts where urbanization, degraded shorelines, or a lack of natural features have limited people's exposure to ecological solutions (Jones et al., 2020; Temmerman et al., 2013). Similarly, dissatisfaction with the groin infrastructure in Teshie is consistent with recent global criticism of hard engineering approaches (e.g Charuka et al., 2023; Rahman et al., 2023; van der Meulen et al., 2023) that disrupt coastal sediment dynamics and exacerbate erosion downstream, among other negative effects. The perceived ineffectiveness of such structures supports calls in the literature for more sustainable and adaptive systems based on ecosystem characteristics.

Additionally, the community response regarding the hard infrastructure (groins) in Teshie demonstrates an important lesson in adaptation planning; thus, poorly constructed and maintained engineering solutions can lead to negative environmental feedback loops. The alteration of sediment transport patterns, which results in unexpected erosion in surrounding areas, is well highlighted in coastal engineering literature (see Dugan et al., 2012; Guimarães et al., 2016; Lim et al., 2022), and serves as a cautionary tale for future interventions in similar urban contexts.

5.4 Participatory Mapping of Risk Zones and Proposed Solutions

Participatory mapping conducted in Bortianor and Teshie provided valuable spatial insights on perceived risks from coastal hazards and potential locations for NbCA application. Participants in Bortianor identified flood-prone areas, mostly around the Densu River and close to the shore, where it was observed that overflow from the Weija Dam often inundates low-lying settlements. Proposed NbCA solutions were wetland conservation, mangrove restoration, and coconut plantation. The presence of mangrove plantations in Bortianor has informed community support for their protection and expansion. On the other hand, participants in Teshie highlighted flood risks caused by river overflow and poor drainage systems. Participants also identified flood-prone inland locations near

small water channels and suggested the planting of vegetation buffers and desilting of blocked drains. While mangrove restoration was not suggested, likely due to the unsuitable ecological conditions, vegetative buffers were proposed as feasible solutions.

These findings support literature that advocates for participatory mapping as a way to incorporate localized knowledge into environmental planning (Klonner et al., 2021; Robinson et al., 2016; Saija et al., 2017). The ability of local participants to identify risk zones and propose practical NbCA measures also supports studies (e.g Bąkowska-Waldmann & Kaczmarek, 2021; Korpilo et al., 2022) that advocate for the use of participatory spatial methods to promote more context-sensitive and acceptable environmental solutions. Furthermore, the spatial specificity of the mapping results is consistent with the literature highlighting place-based adaptation. For example, Raymond et al. (2017) argue that understanding the cultural and ecological dynamics of target communities is critical for designing effective NbCA approaches.

The participatory mapping helps one to realize the depth of local environmental knowledge and its importance for adaptation planning. In Bortianor, the combination of lived experiences and ecological awareness, such as understanding of mangrove functions, demonstrates a readiness to accept NbCA based on biophysical reality. On the other hand, in Teshie, where ecosystem options such as mangroves are not feasible, proposed interventions were based on a realistic evaluation of existing infrastructure gaps and flood pathways. This variation reflects a larger concept in ecological design, which is that solutions must be contextually relevant and socially rooted. The participatory process also empowered communities to describe problems and propose bottom-up solutions, therefore fostering a sense of ownership and responsibility in adaptation decisions.

The results of the participatory mapping highlight the need to incorporate community feedback into spatial planning frameworks. To improve the equity and effectiveness of coastal adaptation approaches, planning authorities and practitioners should institutionalize participatory mapping methodologies, particularly in regions where geospatial data is limited. The maps produced can be

used as decision-support tools to guide the placement and location of future NbCA interventions. Through visual representation of community-endorsed priorities, these maps bridge the gap between local knowledge and formal planning institutions, therefore allowing for more democratic and resilient adaptation planning (see Cadag & Gaillard, 2012; Chambers, 2006b; Gaillard & Pangilinan, 2010).

5.5 The Relationship Between GIS Models and Local Perceptions

A comparison of GIS-modeled flood risk zones and community-identified risk areas from participatory mapping revealed a spatial consistency. In both Bortianor and Teshie, areas identified in the GIS risk model as '*very high-risk zones*' closely matched those highlighted by participants during the participatory mapping. In Bortianor, for example, flood-prone areas around the Densu River and southern coast were highlighted both in the flood risk model and by participants in the participatory mapping. Similarly, in Teshie, inland flood areas caused by blocked waterways and poor drainage were consistent across both outputs.

Generally, these findings support a growing body of literature advocating for the integration of local knowledge with scientific evaluations to improve the accuracy and relevance of hazard mapping (Gaillard & Mercer, 2013). The observed spatial consistency supports the argument that communities possess complex understandings of hazard exposure, even in the absence of formal technical training (Motsumi & Nemakonde, 2024). The hybrid approach has been used in other regions (see Bullen & Miles, 2024; and Konner et al., 2021) to co-produce risk assessments that are both technically sound and socially relevant. The consistency between GIS models and local perceptions validates both the rigor of technical hazard modeling and the reliability of community insights. This is especially crucial in situations where scientific data may be insufficient or outdated. Participatory mapping validates the predicted outcomes and provides localized context, such as informal infrastructure conditions, sociopolitical histories, or even micro-ecological elements that remote sensing does not capture (Bullen & Miles, 2024). Furthermore, this also suggests that stakeholder engagement can be employed as a form of ground-truthing, particularly when used to validate or update risk models.

5.6 Limitations

This study encountered some limitations. One key limitation of the study was the inability to conduct the participatory mapping exercise for the Jamestown community (study area 2). This challenge was as a result of the timing of fieldwork, which fell within Ghana's post-election transition period. During this time, several local assembly members and community leaders who were target participants were either being replaced or left in uncertainty due to administrative restructuring. As a result, some of the community leaders in Jamestown were mostly unavailable, while others were also unwilling to take part in formal engagements, citing political stress and distrust based on previous experiences with government-led initiatives. Despite several follow-up attempts, efforts to gain their participation in the mapping exercise were ultimately unsuccessful.

Furthermore, while the participatory mapping was successfully conducted in Bortianor and Teshie, the original plan to host a centralized, structured session on the University of Ghana campus was declined by participants from all communities. Rather, participants asked for a more casual, community-based approach, with the researcher and field assistants traveling to their communities. While this approach improved participation and enhanced local engagement, it also presented logistical challenges for the research team, which required unplanned travel, extended coordination, and on-ground facilitation within each community.

Chapter 6 – Conclusion

Coastal communities in Accra, Ghana face increasing risks from flooding, erosion, and sea level rise, but local knowledge and perspectives are often underrepresented in adaptation planning and vaguely highlighted in the research efforts. Additionally, coastal communities' vulnerability to coastal hazards, as well as the unexpected negative effects of hard-engineered approaches, highlight the importance of considering more alternative adaptation measures such as NbCA. This study focused on exploring stakeholder perceptions of coastal hazards, assessing spatial vulnerability using GIS-based modeling, and identifying priority areas for NbCA interventions in three selected coastal communities in Accra, Ghana. This study also sought to understand the role of these perceptions in adaptive behaviour and decision-making when responding to coastal hazards in the Greater Accra region.

6.1 Implications of key findings

In terms of risk perceptions and perceived vulnerability, the findings revealed significant differences in perceived vulnerability to coastal hazards across communities and demographic groups. Older individuals and those with longer residential tenure reported a high level of risk awareness, especially in communities like Jamestown, which is known to have a long history with erosion. The community perceptions were not merely subjective; they were consistent with the GIS analysis and known historical hazard patterns. The findings have critical implications for coastal climate adaptation planning in Ghana. First of all, it highlights the necessity for community-oriented risk communication strategies. Given the diverse perceptions and lived realities among communities, standardized interventions are unlikely to be effective. Secondly, when examining adaptation strategies, methodologies must clearly consider the social components of vulnerability, including age, education, and tenure of residency, as these are important factors influencing both risk awareness and adaptive behaviours.

The study findings also revealed an uneven awareness of NbCA, with Bortianor showing better familiarity due to ongoing restoration efforts, whereas communities like Teshie and Jamestown, which

lack relevant ecological features like mangroves or beaches, showed lower awareness. Nonetheless, the study found a strong willingness to promote NbCA across all communities, especially when residents were informed of the key benefits. The findings present several implications. Firstly, education and community outreach to raise awareness should be prioritized in communities with no or degrading ecological infrastructure. Such awareness-raising activities must be tailored to each community's ecological context and cultural values. Secondly, the dissatisfaction with current hard structures should inform future decision-making, encouraging a shift towards hybrid solutions that incorporate green and grey infrastructure where appropriate, as well as long-term planning using ecological measures rather than relying on reactive, short-term, unsustainable measures like grey infrastructure solutions. Moreover, planners and policymakers must consider the long-term environmental effects of engineering structures such as groins and incorporate community perspectives, co-design techniques, and adaptive monitoring frameworks to mitigate negative outcomes. Finally, community willingness to participate in NbCA implementation efforts presents an opportunity to enhance community ownership and support the sustainability of interventions, particularly if those efforts are co-designed with local stakeholders and backed by visible benefits.

Lastly, for GIS models and local perceptions, participatory mapping activities validated the GIS-based risk models while also providing spatially detailed insights into high-risk areas and potential solutions from the community. These participatory findings identified contextually suitable NbCA interventions such as mangrove expansion, drain desilting, and development of vegetative buffers. From a policy and planning perspective, these findings present several implications. First of all, participatory spatial planning should become a standard step in coastal hazard management procedures in Ghana, especially in communities with complex socio-environmental dynamics such as the three selected study communities. Secondly, the confirmed coastal hazards risk hotspots identified through both GIS and participatory mapping methods offer a logical basis for prioritizing NbCA interventions. By overlaying data on risk models with community input, planners may more accurately identify where interventions are most needed and where community support is more likely. This integrated approach

improves transparency, local ownership, and the precision of adaptation measures in urban coastal areas.

6.2 Recommendations and future research

Building on the findings and implications from this research, several areas for future research and practice are recommended. The recommendations include the following:

- Expand the Participatory Approach to Underrepresented Areas. Future studies should include more extensive stakeholder engagement in communities such as Jamestown, where participatory mapping was not completed. Research objectives should include key barriers to participation, such as political transitions or distrust in government initiatives, which could enhance inclusion in the methodology.
- Strengthen Integration of Participatory Methods with Policy and Planning Institutions. Future research should explore practical approaches to incorporate participatory GIS and community-derived risk insights into municipal and national planning frameworks, such as spatial development strategies and disaster preparedness policies.
- Conduct Livelihood Vulnerability Assessments. Future research could examine how coastal hazards and adaptation strategies interact with livelihoods, particularly in fishing and informal economies, to ensure that NbCA solutions are both environmentally and economically sustainable.
- Examine the potential alignment or divergence between scientific projections of future climate change risks and local perceptions of those same risks. While this study found that community members area generally well-aware of existing coastal hazards such as flooding and erosion, it remains unclear how well these perceptions apply to predicted future changes. Investigating the degree of overlap or mismatch between scientific assessments and local perceptions could inform more effective risk awareness strategies and improved adaptive capacity within coastal communities.

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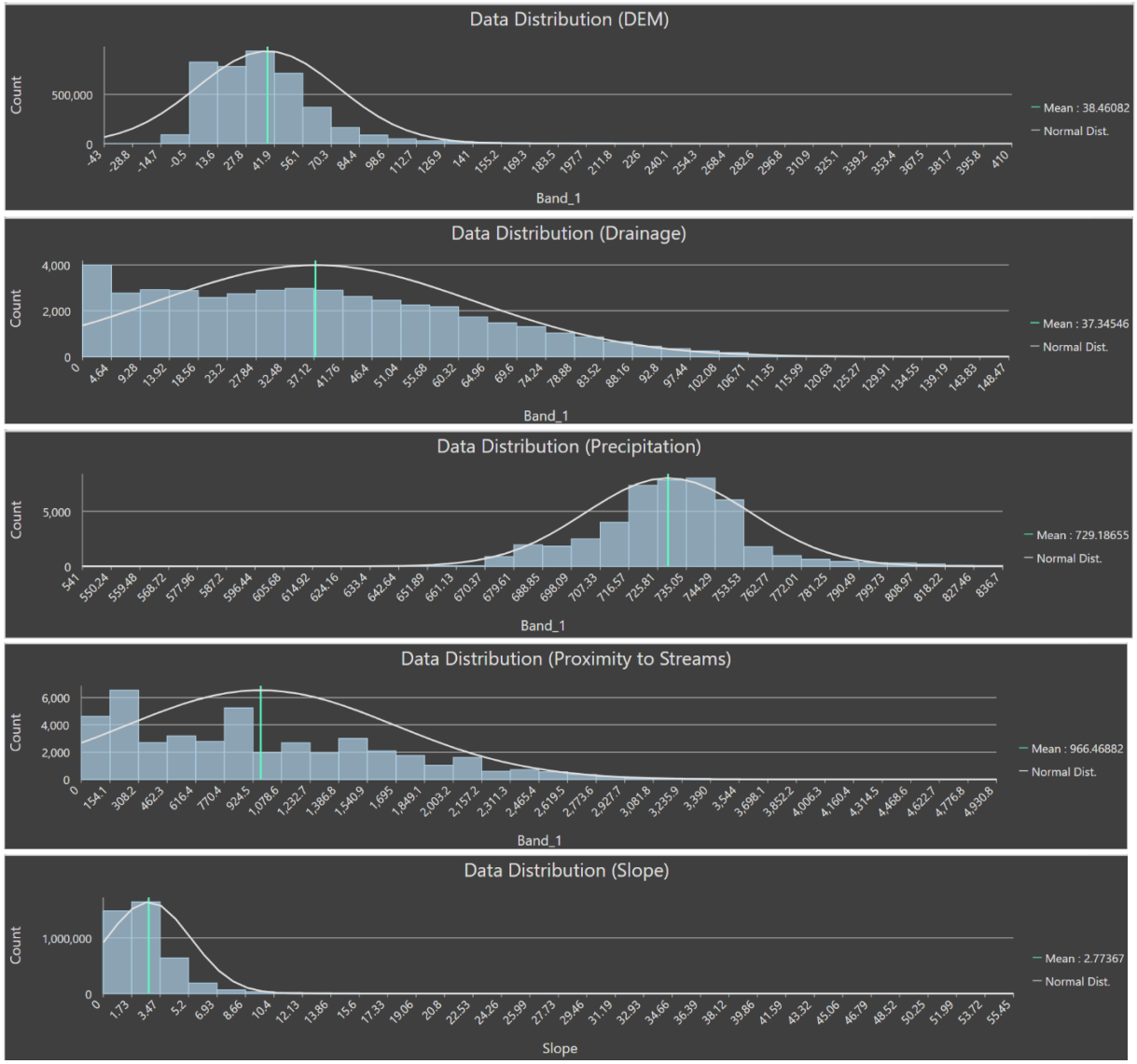
Appendix A – Supplementary Material

Histogram of Data Distributions for flood risk



Appendix B – Informed Consent & Questionnaire for Field Survey

Informed Consent Script

Nature-based Coastal Adaptation Approaches: Assessing Stakeholder Perception of the Barriers and Opportunities in Ghana

Department of Geography and Environmental Studies

Saint Mary's University, 923 Robie Street, Halifax, NS B3H 3C3

I am Frank Kwaku Aazore, a Master's candidate at Saint Mary's University in Nova Scotia, Canada. I am conducting a research project in Accra to understand the local communities' perceptions of risk to coastal hazards (such as flooding and coastal erosion) and assess the level of awareness of the potential for using natural ecosystems such as planting mangroves and restoring wetlands to protect coastal areas from erosion and flooding. Please note that your participation is important but completely voluntary, therefore, you may withdraw from this survey without penalty, and your identity will remain anonymous throughout this survey.

PURPOSE OF THE RESEARCH: This research aims to explore stakeholder perceptions of risk to coastal hazards and understand potential barriers and opportunities to implementing NbCA on the coast of Accra, Ghana.

ELIGIBILITY: This part of the study specifically targets key informants, otherwise known as community elders or leaders of the selected communities.

WHAT YOU WILL BE ASKED: You will be asked to participate in a face-to-face group discussion about the impacts of coastal hazards in your area, your perception of risks, and your thoughts on nature-based solutions as potential adaptations. The discussion will include both open-ended and closed-ended questions, meaning I may ask follow-up questions based on your responses. Additionally, you will be guided to represent your thoughts spatially on printed maps. Photos may be taken during the discussion to document key moments and insights, but these will focus on the activity rather than individuals unless you provide explicit consent. The discussion is expected to take approximately 40 minutes.

POTENTIAL BENEFITS: Your participation is important, and it is hoped that it will provide an in-depth understanding of the perceived risks to coastal hazards in Accra, Ghana. The research findings will help generate more knowledge and improve the understanding of stakeholders, researchers, and planners working to protect coastal communities from coastal hazards.

POSSIBLE RISKS: While this research is considered minimal risk, there is a chance you may experience negative reactions from questions about yourself or your history with impacts of coastal hazards in your area. However, I have tailored interview questions to avoid intimidation. You may also withdraw from the project at any time. Additionally, because confidentiality cannot be guaranteed, there is a minimal risk that your participation will be known to others. However, your name and information will be kept anonymous throughout the research, and I will not share your involvement with anyone at any time.

WHAT WILL BE DONE WITH MY INFORMATION? The responses you provide in this survey will remain anonymous as Qualtrics software protects the identity of participants. The researcher is the only person with access to your information, and it will be stored on a drive with an encrypted access code. The data will be stored until two years after completion of this Master's degree, after which the data will be deleted, and the external hard drive will be destroyed and discarded. Your responses will not be revealed in any publications or presentations, the results will only include similar or recurring responses from the survey. Once the data collection and analysis are completed, the research findings for this Masters project will be submitted to the Department of Geography and Environmental Studies and published on the Saint Mary's University academic website.

HOW CAN I WITHDRAW FROM THIS RESEARCH PROJECT? Your participation in this research is completely voluntary and you may choose to stop participating at any time. If you wish to do so, simply notify me that you would like to withdraw from the study. If you decide to withdraw, all information collected from you will be destroyed. It would be helpful for me if you plan on withdrawing to notify me before I begin the writing process around February 2025. If you have any questions about the project or the risks involved with participating, contact me at frank.aazore@smu.ca or my supervisor Dr. Danika van Proosdij at dvanproo@smu.ca.

RESEARCH PARTICIPANT RIGHTS AND PROTECTION: *(when approved)* The Saint Mary's University Research Ethics Board has reviewed this research with the guidance of the TCPS 2 based on three core principles: Respect for Persons, Concern for Welfare and Justice. If you have any questions or concerns at any time about ethical matters or would like to discuss your rights as a research participant, please contact ethics@smu.ca or 902-420-5728.

Part 1 – Demographic Characteristics of Respondents

- Choose a study area in: i) JamesTown
  ii) Teshie-Nungua
  iii) Botianor

- Gender of respondent: i) Man
  ii) Woman

- What is your age i) 18 – 29
  ii) 30 – 45
  iii) 46 – 59
  iv) 60 or older

- What is your religious affiliation? i) Christianity
  ii) Islam
  iii) Traditional Faith
  iv) None

- How long have you lived in the study area?

- Does your family have historical ties to this area?
  i) No
  ii) Yes, for one generation (my parents lived here)
  iii) Yes, for two generations (my grandparents lived here)
  iv) Yes, for more than two generations (great-grandparents)

- What is the ownership status of your house? i) Owner, ii) Renter, iii) Family-owned
  iv) Government-owned

- What is your educational background? i) No formal education
  ii) Basic/Primary
  iii) Secondary (SHS)/Vocational
  iv) Tertiary

- What is your job/employment status: i) Employed
  ii) Self-employed (e.g I own a business venture)
  iii) Unemployed

- What is your type of occupation: i) Formal Sector (Banker, Doctor)
  ii) Informal Sector (e.g caregiver, trader)
  iii) No occupation

- What is your annual household income (Based on the Daily minimum wage = ₵18.2) (₵365/month):
  i) High income – Above minimum wage
  ii) Medium income – Minimum wage
  iii) Low income – Below Minimum wage
  iv) None

Part 2 – Risk Perception of Coastal Hazards

Closed ended	Open ended
1. Are you aware of any coastal hazards affecting lives and properties in your community? (e.g., coastal erosion, coastal flooding, storm sea-level rise): • YES • NO	
2. Which of the following coastal hazards do you believe you, your family or your community are at risk to? (select all that applies) • Erosion (Worn away buildings, walls, beaches etc.) • Flooding (Water covering areas of land that are usually dry) • Sea-level rise (increase in the sea level) • Storm surge (High powerful sea rise due to a storm) • Salient intrusion (Salty water affecting agriculture, domestic use) • Other (specify) • None/Not sure	✓ Can you tell me more about your experience with these hazards? Which areas in your community do you see and experience these hazards? ✓ If Other specify……..
3. In your experience, how frequent do you experience flooding in your community? • Rarely or never (once every 10 years) • Occasionally (once every 2 to 9 years) • Frequently (once every year) • Always (multiple times in a year)	✓ Is there a particular time of the year this occurs? Which time/period/season (month) did you experience flooding this year?
4. In your experience, how frequent do you experience erosion in your community? • Rarely or never (Less than once every 10 years) • Occasionally (Once every 3-10 years) • Frequently (Once every year to every 3 years) • Always (Multiple times a year)	

5. What do you think is the level of risk of coastal erosion on your lives and properties? • Low (Minimal impact over the past year) • Moderate (Noticeable impact over the past year) • High (significant impact over the past year) • Very high (severe and continuous impact	✓ Can you tell me about your experience on whether you have suffered any physical or property damages as a result of coastal erosion? ✓ Have you moved to a different location because of coastal erosion? Do you think you will have to move again?
6. What do you think is the level of risk to flooding and/or storm surge in your community? • Low (Minimal impact over the past year) • Moderate (Noticeable impact over the past year) • High (significant impact over the past year) • Very high (severe and continuous impact	✓ Can you tell me about your experience on whether you have suffered any physical or property damages as a result of coastal erosion? ✓ Have you moved to a different location because of coastal erosion? Do you think you will have to move again?
7. How much does saline intrusion (salinization) affect your general well-being? • Low (Minimal impact over the past year) • Moderate (Noticeable impact over the past year) • High (significant impact over the past year) • Very high (severe and continuous impact)	✓ Can you tell me a little more about your experience? which aspect of your life is most impacted by salinization? (Domestic, professional/work, general living condition)
8. In your opinion, which main factor do you think is contributing to coastal hazards in your community? • Human activities (e.g. waste pollution, shoreline armouring, coastal developments construction, sand mining, mangrove deforestation) • Natural factors (e.g seasonal rainfall, tidal waves, sea level rise) • Both	✓ Can you tell me more about why you think these human activities continue to happen?
9. How vulnerable do you see yourself to these coastal hazards in the next 10 years? • Low Vulnerability (I think I might experience minor/minimal or no impacts from coastal hazards, but	✓ Are you worried about this? How often do you think about the impact of these hazards?

they will not significantly affect my life) • Moderately vulnerable (I expect to experience moderate impacts from coastal hazards, which might require some adjustments or protective measures) • Highly vulnerable (I anticipate significant impacts from coastal hazards that will likely require substantial changes to my living condition/safety) • Extremely vulnerable (I believe I will face severe and frequent impacts from coastal hazards, greatly affecting my life and potentially necessitating relocation in the next 10 years)	
Part 3 – Awareness/perception of adaptation measures	
10. Are there any adaptation measures in place that protect your community from flooding, storm surge or erosion? • YES • NO • Not Sure	
11. Which of the following adaptation measures are you familiar with/currently being used for your area? (select all that applies) • Rock armouring • Seawall • Natural vegetation (mangroves/swamps, seagrass, coral reefs) • Sand dunes • Beach nourishment (adding sand/sediment to beaches) • Land reclamation (creation/addition of new land) • Retreat (Moving communities further inland) • Other • None/not sure	✓ If Other, specify……. ✓ Do you think the current adaptation measure(s) in your community is/are sustainable? If No, why do you think they are not? -This might end up giving away answers to the next question

12. What are your concerns about the current coastal adaptation measures in Accra? • Not effective in protecting the coast against hazards • Financial loss/strain on the country • Causing more damage to the environment/community (e.g more erosion) • Other • No concerns • Unsure	✓ If Other, specify……
13. How satisfied are you with the current level of government support in addressing coastal hazards? • Very satisfied • Satisfied • Neutral • Dissatisfied • Very dissatisfied	✓ How satisfied are you with the level of government support in addressing flooding; ✓ and addressing coastal erosion?
"Nature-based Coastal Adaptation (NbCA)" approaches are adaptation measures that focus on restoring and protecting the natural environment and are cost effective approaches to minimise the impact of coastal hazards." ~ This will be explained in simple terms to participants ~	
14. Are you aware that natural measures (such as mangrove restoration), known as "Nature-based Adaptation (NbCA) approaches" can be used to help protect the coastlines from hazards like coastal erosion and sea level rise which may lead to flooding? • YES, I am aware • NO, I am not aware	
15. Are you aware of any local or national policies/regulations for coastal protection or coastal hazard adaptation in Ghana? • YES • NO • Not sure	

16. Do you believe the local government should prioritize NbCA in their coastal management policies? • YES • NO • Not sure	

17. What do you think are the main obstacles to implementing NbCA in your area?

For each statement below, please indicate your level of agreement or disagreement.

Likert Scale: Strongly Agree, Agree, Neutral, Disagree, Strongly disagree

a. There is a lack of awareness and understanding of NbCA benefits among the community.
b. There is insufficient funding and financial resources for NbCA projects.
c. There is limited technical expertise and knowledge in NbCA implementation.
d. There is resistance to change or skepticism about NbCA effectiveness.
e. There is a lack of political will and support from local government.
f. There are competing land use priorities and development pressures.
g. There is insufficient community engagement and participation.
h. The regulatory and policy frameworks supporting NbCA are inadequate.
i. There are challenges with land ownership and tenure issues.
j. Environmental factors and natural hazards (e.g., erosion, flooding) are obstacles.
k. There is limited access to relevant data and information.
l. There is a lack of coordination and collaboration among stakeholders.
m. Economic instability and lack of investment in NbCA projects are obstacles.
n. Cultural or traditional practices conflict with NbCA initiatives.
o. There are a lack of clear benefits or incentives for community members.

18. Would you be willing to support the application of NbS to protect the coast in your community? • YES • NO	✓ Why would you be willing to support (or not)?

In this section, kindly indicate your level of agreement or disagreement for each statement

19. In what way would you be willing to support the application of NbCA in your community?

For each statement below, please indicate your level of agreement or disagreement.

Likert Scale: Strongly Agree, Agree, Neutral, Disagree, Strongly disagree

a) I am willing to participate in community activities (such as planting mangroves or maintaining green spaces).
b) I am willing to organize or lead community events related to NbS.
c) I am willing to attend educational workshops or seminars about NbS.
d) I am willing to advocate for NbS initiatives in local government or community meetings.
e) I am willing to contribute financially to NbS projects.
f) I am willing to encourage others in the community to support NbS initiatives.
g) I am willing to promote NbS projects on social media or other platforms.
h) I am willing to volunteer for NbS project planning and implementation.
i) I am willing to provide technical expertise or skills for NbS projects.
j) I am willing to support NbS through in-kind donations (e.g., materials, equipment).
k) I am willing to engage in public awareness campaigns about the benefits of NbS.
l) I am willing to participate in research or data collection related to NbS projects.
m) I am willing to support policy changes that favor NbS initiatives.

20. Do you have any suggestions for successfully implementing NbS to protect the coast in your community?

Phase 2 – Participatory Mapping Discussion Guide

Guide questions for mapping:

The following questions will help guide participants during the mapping process:

i. Where are the areas in your community that have flooded most frequently in the past few years?
ii. Which locations are at higher risk due to coastal erosion?
iii. Which structures (homes, schools, markets) have been most affected by rising sea levels or storms?
iv. Can you identify areas where infrastructure (like sea defenses) has been built to mitigate coastal hazards?
v. Are there areas where the community has taken any local action to adapt to coastal hazards?

Focus Group Discussion Guide

1. What do you think are the main reasons your community is vulnerable to coastal hazards?
2. Have you noticed any changes in flooding patterns over time? If yes; what do you think is causing these changes?
3. What actions have been taken by the community or authorities to reduce the impact of flooding or erosion?
4. Are there nature-based measures (like mangrove restoration or other green spaces) being used to reduce these risks? If yes; how effective have they been?
5. Do you think the use of natural solutions (e.g., restoring mangroves, creating wetlands) could help reduce flooding or erosion? Why or why not?
6. What barriers do you think exist to implementing these nature-based solutions in your community?
7. How have coastal hazards affected the livelihoods of people in this community?
8. Which groups in the community (e.g., fishermen, traders, families) are most affected by these hazards?