UNIVERSITY OF CAPE COAST

ASSESSMENT OF VULNERABILITY TO FLOODING IN COASTAL COMMUNITIES OF KETU SOUTH MUNICIPALITY OF GHANA

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this dissertation is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's signature: .... Date..............................

Name: ……………………………………………………………….

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature………………………………… Date……………...

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Co-Supervisor's Signature………………………………. Date……………...

Name………………….……………………………………………….

ABSTRACT

Some communities along the coast of Ketu South Municipality in Ghana remain vulnerable to coastal flood events from storm surges, high tidal waves, lagoon overflow and heavy rainfall. However, the local conditions including biophysical and socioeconomic conditions that make these communities vulnerable are poorly understood and knowledge on which community is most vulnerable is lacking. This study improves the conceptual understanding of different dimensions of vulnerability that exist across the communities including Blekusu, Agavedzi, Salakope, Amutsinu and Adina and the various levels of vulnerability that each exposed community exhibits. The study also provides knowledge on determinants for relocation as an adaptation option. The study used data from eight (8) in-depth interviews, nine (9) Focus Group Discussions and 354-household survey to explore local vulnerability issues and to construct exposure, sensitivity, potential impact, adaptive capacity and composite vulnerability indices at community levels. Results from the study show that the communities have different levels of vulnerability as a result of differences in their exposure, sensitivity and adaptive capacity levels. And willingness to relocate is determined by household flood duration, number of livelihoods and sea defence preference. These results are useful for flood disaster management programs and implementation of robust adaptation options with inclusion of local knowledge.

KEY WORDS

Adaptive Capacity

Exposure

Flood

Relocation

Sensitivity

Vulnerability

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DEDICATION

To my family: my parents and siblings.

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LIST OF ACRONYMS

Acronym	**Meaning**
CANS	College of Agriculture and Natural Sciences
FGDs	Focus Group Discussions
GIS	Geographic Information System
IDI	In-depth Interview
IPCC	Intergovernmental Panel on Climate Change
IRB	Institutional Review Board
LECZ	Low elevation coastal zones
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organization
NHC	National Hurricane Centre
NSSL	National Severe Storms Laboratory
OR	Odds Ratio
UCC	University of Cape Coast
UN/ISDR	United Nations/International Strategy for Disaster Reduction
USDA	United States Department of Agriculture

CHAPTER ONE:

INTRODUCTION

Coastal flooding induced by sea level rise and flash flood, is one of the increasing coastal hazards threatening coastal communities (Osman, Nyarko & Mariwah, 2016; Owusu, 2016; Yankson, Owusu, Boakye-Danquah & Tetteh, 2017). The coast of Ghana, particularly the eastern coastline, suffers from coastal flooding and has been documented as highly at risk to impacts (Boateng, Wiafe & Jayson-Quashigah, 2017). Hence, communities along this coastline including those of Ketu South Municipality remains, vulnerable to these hazards. This study aims to investigate the underlying factors of flood vulnerability in the communities and to examine their vulnerability levels.

The scope of this study is informed by previous vulnerability studies on the consequences of climate change relating to flood events (Cutter, 1996; Balica, Douben, & Wright, 2009; Cutter, Boruff, & Shirley, 2003; Balica et al., 2012; Yankson et al., 2017). The quest to reduce disaster risk triggered the need for vulnerability assessment dating back to 1970s and has evolved over the past years from hazard risk assessment to integrated approach encompassing hazard risk and socioeconomic conditions that make a system susceptible to a hazard (Cutter, 1996; Birkmann & Wisner, 2006; Chen, Cutter, Emrich, & Shi, 2013)

Background to the Study

Coastal areas serve as a home to a significant proportion of the world population. It is estimated that coastal areas typically have population densities higher than inland areas (Small & Nicholls, 2003) and host several resources that contribute significantly to local, national and the international economy (Bijlsma et al., 1995). However, the impacts of climate change especially sea-level rise in coastal areas has become increasingly observable. And most coastal dwellers remain vulnerable to its threats manifesting as storm surges, high tidal wave flooding coupled with rising water table and erosion(Rehman et al., 2019). Global sea level rise among the other anticipated consequences of climate change, is already taking place unlike the others. According to Mcgranahan, Balk, Mcgranahan, and Bartlett (2007), in Africa, a total of 56 million people are residing in low elevation coastal zones (LECZ; zones that are 0-10 meters above sea level) and these zones are exposed to the threats of sea level rise.

For the last 100 years, global sea level has been observed to rise by 1–2.5 mm/y (Ranasinghe, 2021; Sterr, 2008) and predictions of future sea-level rise range from 20 cm to 86 cm for the year 2100 (Ranasinghe, 2021). Under low emissions, some projections show sea level rise continuing at a rate similar to today (3–8 mm per year by 2100 versus 3–4 mm per year in 2015), while others show a significant acceleration to more than five times the current rate by 2100, especially if emissions remain high and processes that accelerate Antarctic Ice Sheet retreat occur widely (Fox-Kemper et al., 2021). The rate at which Ghana's sea-level is also rising at 2.16 mm/year as reported from records from the port of Takoradi from 1925 to 1970 and some selected monthly records for 1992, 2007, 2008, and 2009, (Evadzi et al., 2017; Woodworth et al., 2009) conforms with the global rate . Current predictions of sea level rise suggest that rising sea level will reach unprecedented heights in the 21st century and beyond (Church & White, 2006) and this may have detrimental effects on coastal human settlements, especially in the coast of the Gulf of Guinea including the coast of Ghana (Mensah, Kabo-bah, & Mortey, 2017). These effects would be manifested in frequent high tide flooding, storm surges and increase rate of erosion.

Along the coast of Ghana, the effects of storm surges, high tidal wave flooding, coupled with lagoon overflow and heavy rainfall have been occurring over the past years and many communities are exposed to it (Addo, Amisigo, Ofori-Danson, 2011; Boateng, 2012a). Coastal flooding in the form of storm surges and high tidal waves in particular have become the most common threats from sea level rise aside coastal erosion (Boateng, 2012a). Some vulnerability studies on physical exposure to sea level rise in Ghana have provided evidence that communities along the coast of Ghana are at risk to flooding from sea level rise effects (Boateng et al., 2017 et al., Addo, Nicholls, Codjoe, & Abu, 2018).

While physical phenomena are required for the occurrence of a natural hazard, their transformation into risk and the potential for disaster is dependent on human exposure and a lack of capacity to deal with the negative consequences of that exposure on individuals or human systems (Vincent & Cull, 2010). According to the United Nations (2005), "*the starting point for reducing disaster risk and for promoting a culture of disaster resilience lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long term, followed by action taken* *on the basis of that knowledge"*(Birkman et al., 2011). This implies that knowledge on the physical, social and economic factors that make social systems vulnerable to disaster risks and knowledge on their adaptative capacity are inevitable in disaster risk management. Developing robust policies towards building adaptive capacity to climate change in social system depend on the knowledge of the existing social and economic characteristics, existing local adaptation strategies, existing infrastructure, and climate change impacts (Oliver-smith, 2009; Alam, Alam, K., & Mushtaq, 2017).

Vulnerability results from a variety of factors, such as social development, hazard awareness, settlement and infrastructural patterns, public policy and administration, and disaster and risk management institutional capacity (Oliver-smith, 2009). Empirical studies suggest that age, gender, income class, literacy, and employment, among other socioeconomic characteristics, impact vulnerability and adaptation process in flood-prone communities (Hadipour et al., 2020; Khan et al., 2020). The key adaptation strategies identified in flood prone communities commonly include no action, house reinforcement, home design modification, and house abandonment, and temporal shelter at safe havens among others (Addo & Danso, 2017; Lee, 2014; Munji et al., 2013; Osman et al., 2016).

Statement of the Problem

In the climate change domain, vulnerability to hazards such as sea-level rise is a multidimensional concept, encompassing biophysical, socioeconomic, and political factors (Grinsted & Christensen, 2020; IPCC, 2007). Knowledge of all these factors would help policy makers to use a holistic approach to instil climate resilience in vulnerable areas. The existing social, economic, and political characteristics in Ghana create an adaptive capacity that does not offset the magnitude of exposure and sensitivity to these hazards (Yankson et al., 2017). Yet, most of the vulnerability studies on accelerated sea-level rise in the country focus largely on the physical vulnerability assessment (Addo & Adeyemi, 2013; Addo, 2013; Boateng et al., 2017) with less effort on the socioeconomic and institutional aspects (Yankson et al., 2017; Aboagye, Attakora-Amaniampong, & Owusu-Sekyere, 2020).

Concerning the evidence of physical vulnerability in terms of coastal erosion and flooding provided by these studies, Ghana's mitigation and adaptation options are usually towards implementing policies that focus on large-scale technical and engineering adaptation actions that are mostly expensive, less sustainable and do not benefit the poor communities that are exposed (Yankson et al., 2017). The Keta Sea Defence Project as the first reactive measures to sea-level rise impacts is an example of this narrative. Geophysical surveys, geomorphic investigations and modelling of sea-level rise were the main assessments that led to the construction of these defence structures (West Africa Coastal Areas Management Program [WACA], 2007; Boateng, 2009) Similar investigations were carried out for the other sea defence projects at Ada (Bollen et al., 2011) ,Western, Central and Greater Accra regions of Ghana.

This implies that physical vulnerability assessment studies including geophysical surveys, geomorphic investigations and sea-level rise modelling only inform policies that come up with hard structure defence projects. They fail to elucidate how inherent socioeconomic and institutional factors may exacerbate or influence the vulnerability of the communities that are exposed, complicating Ghana's prospect of building integrative adaptive capacity that holistically tackles the foregoing issues of coastal flooding (Aboagye, 2012b).

According to Wu, Yarnal, and Fisher, (2002), assessing physical vulnerability alone does not capture the pattern of differentiated impacts and social factors among the populations exposed to the hazards. Thus, to provide more efficient and effective adaptation solutions, especially for marginalized and poor communities, composite vulnerability information encompassing the biophysical, political, and socioeconomic aspects of a coastal area is needed (Sendai Framework, 2015; Cutter et al., 2003; Felsenstein & Lichter, 2014). Also, investigating vulnerability at the local scale is crucial for understanding its characteristics which are necessary for developing site-specific and appropriate adaptation measures to match the level of exposure and sensitivity of the particular area under study (Yankson et al., 2017; Munji et al., 2013; IPCC, 2007). Notwithstanding, understanding the socioeconomic aspect of vulnerability of population groups at the local level also drives prioritization and efficient allocation of scarce resources in the disaster phases of mitigation, preparedness, response, and recovery.

Currently, there is no specific study on socioeconomic vulnerability of coastal communities in Ketu South Municipality to coastal flooding in the literature. This area falls within the eastern coastline of Ghana and has been experiencing periodic flooding induced by sea-level rise and heavy rainfall over the years. According to (Boateng et al., 2017a), the eastern coastline is at a high risk to sea-level rise impacts among the other coastlines of Ghana. Their findings indicated that 1m sea-level rise has a probability of permanently inundating more than half of the frontage of the entire coast, meanwhile global sea level is predicted to rise to about 1m by 2100 (Ranasinghe, 2021; IPCC, 2007). Coupled with this is lagoon overflow flooding from heavy rainfall that affects the population of the communities close to the stretch of Keta lagoon unlike the other communities in Ada and Keta Municipality that are part of the Eastern Coast.

Knowledge on the socioeconomic characteristic of these communities, adaptive capacity and their vulnerability levels would be helpful to locate vulnerable communities and to intervene with inclusion of local perspectives on flood vulnerability.

Objectives of the Study

Main Objective

The main objective of this study is to assess the vulnerability of communities along Ketu South Municipality to flooding.

Specific Objectives

The specific objectives are to:

1. map key communities in the municipality that experience extreme coastal flooding events;

2. determine community perception of factors influencing their vulnerability to coastal flooding;
3. determine vulnerability indices of communities;
4. assess predictors of relocation as an adaptation option for communities in the municipality.

Significance of the Study

The study explores and examines the factors that make communities along the coast of Ketu South Municipal vulnerable to coastal flooding and their adaptive strategies.

The study improves the knowledge and understanding of the research community on the spatial extent, depth, duration and frequency of flood events in the various communities of the study area. This knowledge is important for proper land use mapping and planning in terms of identifying areas that are free of flooding for relocation and settlement purposes. The study further provides knowledge on the types of floods that are prevalent in the communities. The types of floods include storm surge flooding, tidal wave flooding, lagoon overflow flooding and heavy rainfall flooding.

In addition, the study also explores the extent to which households are sensitive to floods through the examination of the socio-demographic and economic factors that aggravate the impact of floods in the communities. The study also documents local adaptation strategies and the adaptive capacity of the communities in the bid to provide further information for disaster risk management. This is relevant, especially in integrating disaster management policies with local knowledge so as to fulfil Priority 4 of the Sendai Framework (UNISDR, 2015).

Delimitations

This study covers only the assessment of vulnerability to coastal flooding in selected communities of Ketu South Municipality of Ghana. It explores the exposure, sensitivity and the adaptive capacities of only the selected communities that are periodically exposed to coastal floods as could be allowed by the resources available. The indicators used to construct the vulnerability indices were selected based on the qualitative study results and these were site-specific. They were local indicators that apply to the studied communities only and may not apply to other populations. These indicators were used because the study aimed to provide information on a place-based vulnerability status of the communities in order to in-form a site-and-context-specific solution. It is also important to note that the indicators were standardized using maximum and minimum values method standardization. As noted by Hahn, Riederer, & Foster, (2009) indices constructed from the mentioned standardization method cannot be compared with future studies unless these studies adopt similar method.

Limitation

A limitation to this study was the absence or refusal of certain selected household heads to participate in the study. Immediate available household heads were used to replace them. The inability of certain household heads to recollect certain events that happened in the past was faced and this was reduced by triangulating the data collected through focus group discussions and key informant interviews as well as field observations as were reported earlier (Aboagye, 2012; Osman et al., 2016; Owusu, 2016; Khan, Zubair, Amir, & Safdar, 2020).

Definition of Terms

Flood: is defined as "an overflowing of water onto land that is normally dry and it can happen during heavy rains, when ocean waves come on shore, when snow melts quickly, or when dams or levees break" (NSSL, 2021).

Hazard: is defined as: "A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage"(UN/ISDR, 2009).

Disaster Risk: **"**The potential disaster losses, in lives, health status, livelihoods, assets and services, which 10 could occur to a particular community or a society over some specified future time period" (UN/ISDR, 2009).

Sea level rise: is an increase in the level of the world's oceans due to the effects of global warming (National Geographic Society, 2019).

Climate Change: is a change in the usual weather conditions of a place such as temperature and rainfall over a long period of time (NASA, 2014).

Vulnerability: is defined as "the extent to which a natural or social system is susceptible to sustaining damage from climate change or it is a function of the sensitivity of a system to changes in climate, adaptive capacity and the degree of exposure to climatic hazards" (McCarthy et al., 2001).

Exposure: is the extent to which any socioecological group interacts with climate events or a specific climate consequence such as sea level rise, drought, among others (Marshall et al., 2009).

Sensitivity: "is the degree to which a system will respond to a given change in climate, including beneficial and harmful effects" (McCarthy et al., 2001).

Adaptive Capacity: is "the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate" (McCarthy et al., 2001).

Mitigation: is "the lessening or limitation of the adverse impacts of hazards and related disasters" (UN/ISDR, 2009).

Early warning system: is “the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss” (UN/ISDR, 2009).

Recovery: is “the restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors” (UN/ISDR, 2009).

Indicator: “An indicator, or set of indicators, can be defined as an inherent characteristic that quantitatively estimates the condition of a system; they usually focus on minor, feasible, palpable and telling piece of a system that can offer people a sense of the bigger representation” (Balica et al., 2012, p. 80).

Vulnerability Index: is a single numerical result that is a composite of multiple indicators, and it is achieved through some formula (Yankson et al., 2017).

Organisation of the Study

Chapter One covers the background information, the problem statement, the significance of the study and the objectives of the study. Chapter Two discusses, the concept of the study, flood hazards, types of floods, vulnerability concepts, flood vulnerability frameworks, the three dimensions of vulnerability (exposure, sensitivity, and adaptive capacity), vulnerability assessment approaches, socioeconomic vulnerability characteristics, adaptation options that are robust for flood management, factor analysis procedures and regression analysis procedures. Chapter Three includes the research methodology and data collection process, data organization and analysis whiles Chapter Four explains the empirical findings on flood exposure, flood sensitivity, flood adaptation measures, exposure vulnerability indices, sensitivity indices, potential impact, adaptive capacity scores, community (composite) vulnerability scores and determinants for flood prevention measures recommendation. Finally, the last chapter (Chapter Five) includes conclusions and recommendations.

CHAPTER TWO:

LITERATURE REVIEW

Introduction

This study assesses flood vulnerability determinants, flood vulnerability levels and predictors for relocation in coastal communities of Ketu South Municipal. The chapter elaborates on the concept of flood hazard and vulnerability with respect to climate change in coastal communities. In this chapter the study reviewed literature on flood hazard, types of coastal floods, characteristics of flood, causes of flood, flood impacts, vulnerability and its concepts, vulnerability conceptual framework, vulnerability factors (exposure, sensitivity and adaptive capacity), approaches to vulnerability assessment, coastal vulnerability determinants, adaptation options, relocation, developing a vulnerability index and regression analysis.

Conceptual Base of the Study

The underlying theoretical concept of this study is explained by the third perspective of vulnerability as presented in the "hazard- of-place model" (Cutter et al., 2008; Messner & Meyer, 2006; Yankson et al., 2017). The third perspective discusses the integration of exposure, sensitivity and adaptive capacity factors in determining the extent of vulnerability of societies to natural phenomena. The concept remains the standard approach used in most climate change vulnerability studies (Fussel, 2005). According to Fussel (2005), the conceptualization of vulnerability in a specific assessment setting tends to contain factors of vulnerability that are considered as targets for policy interventions. The "hazard-of-place model' captures vulnerability as a combined effect of physical (exposure), social (sensitivity), and wealth and institutional concepts (Adaptive capacity) of vulnerability. Figure 1 is a conceptual framework of this study adapted from the hazard-of-place models. It has the three IPCC vulnerability factors (exposure, sensitivity and adaptive capacity) with their respective indicators.

Exposure is a measure of the character, including, magnitude, depth, duration, and frequency of flood and the population that are exposed to the impact of floods. The sensitivity aspect on the other hand, is a measure of social characteristics of a community including gender, age, disability and household size among others. Thirdly, adaptive capacity measures wealth and institutional capacity, a collection of governance measures; both local and external measures, that influence the adaptability of societies and communities that are exposed to extreme events that are characteristic of climate change (IPCC, 2012; Balica et al., 2012).

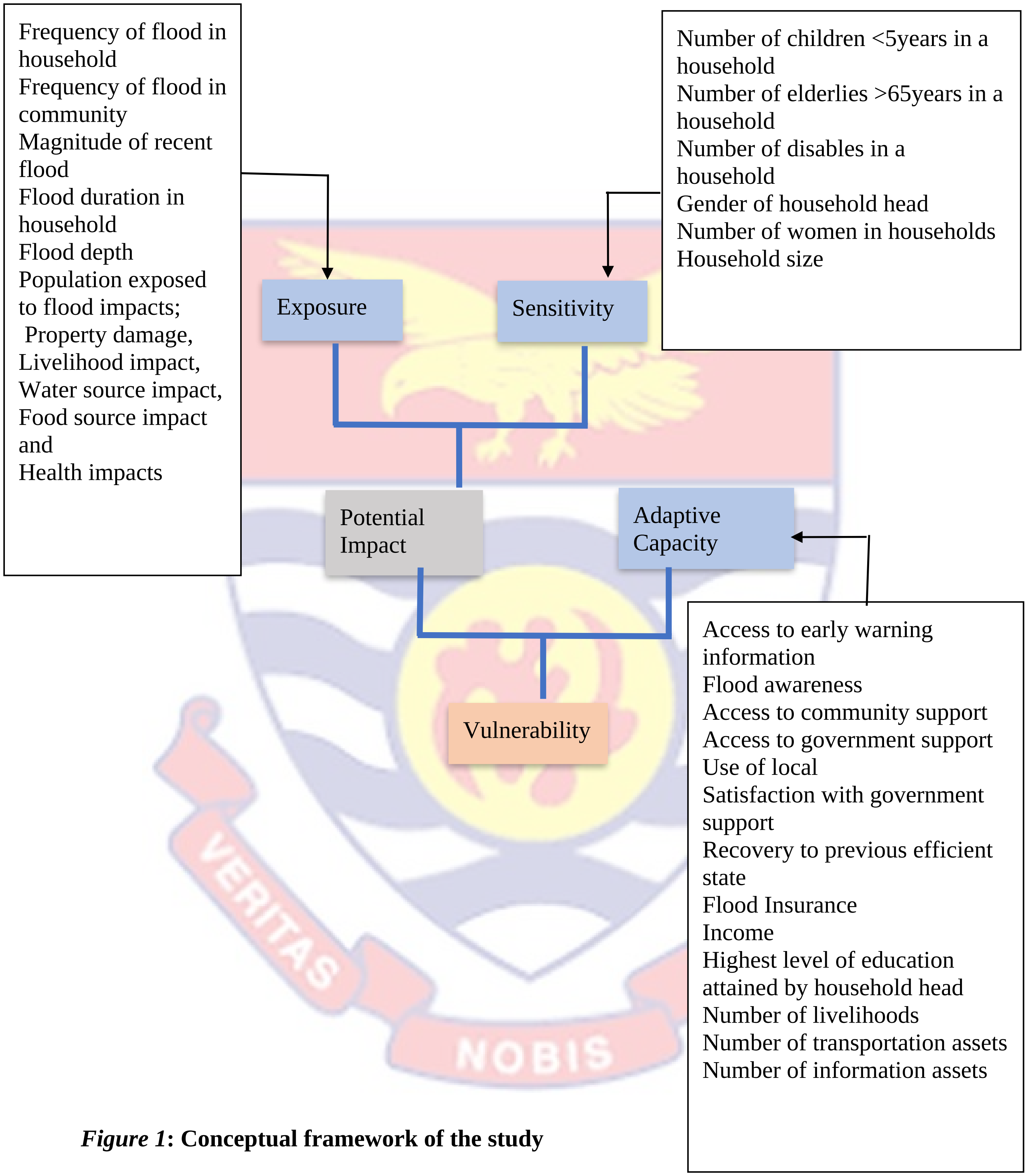


***Figure 1*: Conceptual framework of the study**

Source: Adapted from Messner & Meyer (2006); Marshall et al. (2009); Yankson et al. (2017).

Flood Hazard

Flooding is defined as a "temporary covering of land by water as a result of surface waters escaping from their normal confines or as a result of heavy precipitation" (Kron, 2009, p. 58). NSSL (2021) also defined flooding as "an overflowing of water onto land that is normally dry and it can happen during heavy rains, when ocean waves come on shore, when snow melts quickly, or when dams or levees break" (NSSL, 2021). A flood becomes a hazard when it has a tendency of causing harmful impacts such as property damages, life losses, halt socioeconomic and cultural activities, injuries, and diseases, among others (Osman et al., 2016). Flooding may be disastrous, even with only a few inches of water, or it can completely engulf a property. Floods may happen in a matter of minutes or take days, weeks, or even months to occur (NSSL, 2021). According to Kron (2009), flooding is the major cause of natural disaster losses in many parts of the world, and it leads to more catastrophic incidents than any other sort of natural hazard.

Coastal Floods

Storm surges

Storm surges occur when there is an abnormal rise in sea level due to low atmospheric pressure plus wind storms such as hurricane or cyclone causing a set-up of water levels reaching 17 feet on the sea (Jonkman, 2005 ; National Oceanic and Atmospheric Administration [NHC], 2008;Verlaan, Winsemius, Aerts, Ward, & Muis, 2016). The primary cause of a storm surge is either a tropical cyclone or a hurricane with low atmospheric pressure having minimal contribution (NHC, 2008). Storm surges coupling with astronomical high tide at the sea is called storm tide and it results in in extremely high water levels and flooding of the coastal area (NHC, 2008). Storm surges can raise the sea level as high as to house roof top levels or above roof top levels of coastal communities before beginning to surge on the communities, an evidence is a catastrophic storm surge that surged about 4.5m (i.e. 15ft) in Bangladesh (Jakobsen, Azam, Ahmed, & Mahboob-ul-Kabir, 2006). This is illustrated in figure 2 below.

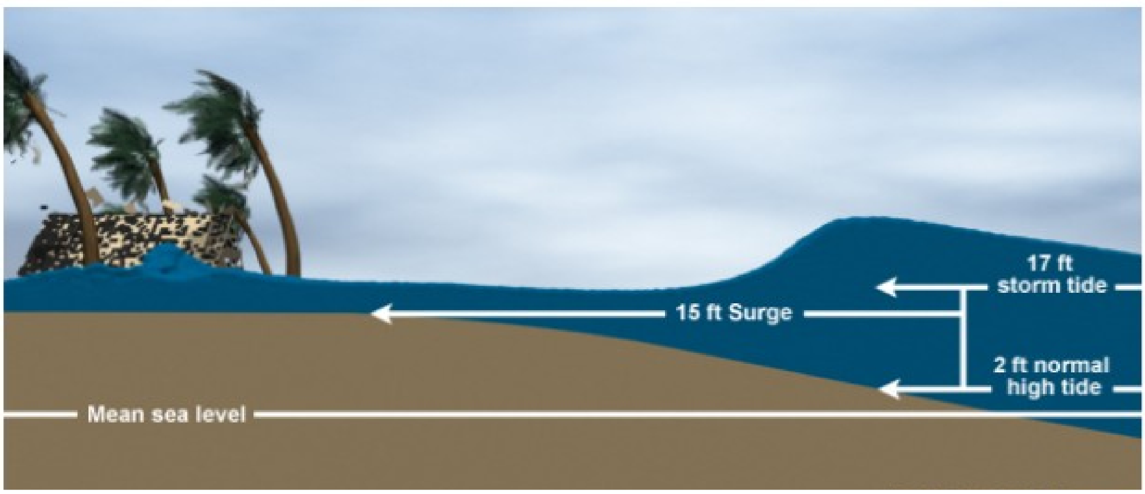


***Figure 2*: A storm surge diagram**

Source: NHC (2008)

Tsunami

Tsunami is a succession of huge sea waves produced by destructive phenomena that can be a sudden displacement of the sea floor as a result of dislocation of tectonic plates or the movement of a body slipping along the sea floor (Tinti, Maramai, & Graziani, 2004). And the main sources of these destructive processes are submarine landslides, volcanic eruption, or earthquake resulting in a sudden displacement of seawater (Tinti et al., 2004). The huge waves that are produced during a tsunami capable of propagating over long distances and large coverage areas and causing surges that can be destructive to exposed coastal areas (Jonkman, 2005).

Tidal waves flood

Tidal waves are the rise in levels of normal tides caused by atmospheric activities on the sea. These waves move rapidly from the sea and causes nuisance flood to coastal areas. With global sea level rise which is being caused by climate change, tidal wave floods are becoming more rampant, destructive, inundating and eroding coastal communities and paving ways for seas to permanently encroach on coastal lands (Jonkman, 2005).

Flash floods

Flash floods occur when heavy rain causes a rapid rise in water levels in rivers, lagoons or lakes or any surface waterbody causing overflow of water from the waterbodies onto exposed areas (Jonkman, 2005). Because flash floods combine the destructive force of a flood with extraordinary velocity, they are the most disastrous type of flood. Flash floods occur when heavy rain exceeds the ground's ability to absorb it. They can also occur when water fills typically dry creeks or streams, or when enough water accumulates to force streams to breach their banks, causing fast water levels to rise in a short period of time (NSSL, 2021). According to Jonkman (2005) there is a limited amount of time to anticipate flash floods ahead of time, but historical heavy rainfall experience in the affected regions can be utilized as an indicator of flash flood hazard.

Characteristics of Flood

Characteristics of floods are very important for disaster planning and management purposes. Knowledge on flood frequency, depth, magnitude, duration, time of onset, and spatial extent is crucial for proper flood control and planning in order to reduce flood negative impacts (Ezemonye & Emeribe, 2011; Osman et al., 2016). The spatial extent of a flood is one of the characteristics of floods that attract planners. The spatial extent illustrates the coverage area of flood events that occur in an area and helps to identify element and sites that are free of flooding and elements that have been flooded (Osman et al., 2016).

Floodwater depth is another important factor to be identified. It is a measure of the height of flood from the ground level (Messner & Meyer, 2006). Knowledge on the depth of floodwater is important because it determines the extent of damage that is incurred from a flood event. A study conducted by (Chang, Lin, & Su, 2008) identified that as flood depth increases, the magnitude of damages caused by flood increases. Also, flood time of onset which is the time gap between the flood's precursors and its actual manifestation is particularly valuable for flood emergency evacuation planning and design (Osman et al., 2016). Flood duration and frequency are the temporal variability factors of floods whereas flood frequency is the return period of flood and flood duration is the maximum time it takes for a flood to recede (Javelle et al., 2002).

Causes of Flood

Man-made and natural factors can be used to classify flood causes. Floods are caused by natural forces such as precipitation (rainfall), storms, and watershed physiographic factors such as size, form, geology, relief, hydrography, and land use (Osman et al., 2016). Global sea level rise which is causing frequent storm surges, high tidal wave flooding and projected to cause permanent inundation of coastal areas is not an exception of these natural factors (Boateng, 2012a; Rehman et al., 2019). Human-induced floods are usually human encroachment or developments that constrains the natural drainage of rivers, streams, and other surface waterbodies. An example is the construction of the Akosombo Dam which was reported to complicate flood events in the Volta Delta (Luna & Young, 2019). Construction of structures on flood routes, obstruction of drains by solid waste as a result of dumping of refuse in gutters and domestic waste in streams; deforestation of catchment basins, and land reclamation are only a few examples of human encroachments (Osman et al., 2016; Mensah & Ahadzie, 2020). In addition, poor and inadequate drainage systems have also contributed to flood events, most especially in urban areas. According to Mensah & Ahadzie, (2020), urban flooding in Ghana is caused by poor drainage systems, poor waste management, the removal of urban vegetation, and poor urban and structural planning. However, Ghana's planning system has failed to successfully control urban physical development, exacerbating the effects of urban flooding (Mensah & Ahadzie, 2020).

Impacts of Flood

The extent of damage caused by a particular flood event is a crucial factor that compels politicians to increase flood policy measures in the aftermath of flood catastrophes. Flood disasters encompasses all types of damage resulting from a flood. It covers a wide spectrum of negative consequences on individuals, people's health, and possessions, as well as public infrastructure, cultural heritage, natural systems, industries, and the economy (Messner & Meyer, 2006). The impacts of flooding can be further divided into direct and indirect damages (Messner & Meyer, 2006).

Direct flood damage refers to any type of harm caused by floodwater coming into direct contact with people, property, or the environment. Some examples of these are damage to infrastructures, commercial products, and dykes, loss of farm crops and cattle in agriculture, loss of human life, direct health consequences, and pollution of ecological systems. (Messner & Meyer, 2006; Osman et al., 2016). Some of the direct implications of coastal flood in Dansoman, Ghana, reported by Addo, Amisigo, & Ofori-Danson (2011) include injuries, diseases (such as malaria, cholera, skin and foot rashes), population displacement, loss of land, house properties and loss of livelihoods. Indirect impacts comprise damage, that occurs as a further implication of the flood that causes destructions in social and economic activities such as the loss of economic production as a result of damaged facilities, loss of energy and telecommunication sources, and health impacts among others (Messner & Meyer, 2006; Osman et al., 2016).

Vulnerability

The magnitude or amount of flood damage (impact) depends on the vulnerability of any system that is exposed to it, and it is broadly defined by their potential of experiencing harm from a hazardous event. This implies that a system that has a tendency of suffering harm is more vulnerable, and the more it is exposed to a hazard, the more it is susceptible to the forces of the hazard (Messner & Meyer, 2006).

Concepts of Vulnerability

The quest for vulnerability assessment dates back to 1970s when it became more relevant for reducing disaster risks (Birkmann & Wisner, 2006; Wisner, 2016). In the research community of natural hazard, vulnerability was first defined as “the degree of loss to a given element, or set of elements, at risk” and was often quantified in a number of indices. But the narrative started to change in the 1980s and 1990s when there was a recognition on the importance of environmental, economic, social and political factors influencing vulnerability of social systems (Cutter, 1996; Kelly & Adger, 2000). The idea was to consider different perspectives including the assessment of susceptibility to harmful impacts and the ability to adapt or moderate the impacts (Cutter, 1996) than just exposure assessment that only communicate the likelihood of risk to policy makers. Most recently, IPCC has refined the definition of vulnerability (in terms of climate change) to include exposure, susceptibility (sensitivity), and coping or adaptive capacity (Birkmann & Wisner, 2006). These factors can be measured as biophysical, and socioeconomic variables.

Aside the mentioned evolutionary concepts, vulnerability assessment can be conceptualized in terms of disciplines and that can be construed in three main perspectives (Fussel, 2005). The three perspectives are: (1) the risk-hazard concept, which assesses a system's physical exposure to hazards (Addo et al., 2018; Boateng, 2012b; Boateng et al., 2017). This perspective is common to the disaster risk management discipline. (2) The social constructivist concept, which dominates the fields of Political Economy and Human Geography and regards vulnerability as a function of socioeconomic and political factors (Noy & Yonson, 2018). (3) The third concept is the integrated assessment of biophysical, socioeconomic and institutional factors to assess the vulnerability of any system to climate change events which is interdisciplinary (Cutter et al., 2003; Balica et al., 2012; Aboagye et al., 2020).

The conception of vulnerability can also depend on the level or scale of analysis be it global, regional, country or local levels (Birkmann, 2007; Dolan & Walker, 2006). Some of the factors that are considered important for vulnerability assessment at the global scale often include indicators such as population distribution, relative mortality rate and relative GDP losses (Brouwer, Akter, Brander, & Haque, 2007; Birkmann, 2007). At the regional scale, indicators are selected based on the characteristic of exposure, socioeconomic status and resilience (Balica et al., 2009). Local scale or community level assessment of vulnerability differ largely depending upon the scope of the assessment and data availability (Cutter et al., 2003; Balica et al., 2012).

Figure 3 further expounds the widening concept of vulnerability (Birkmann & Wisner, 2006). In this figure, the spheres of vulnerability widened from a mere risk assessment to a multidimensional assessment of vulnerability. The former defines vulnerability as a likelihood to suffer loss and harm from an event whiles the latter widens as with a dualistic view of vulnerability, (susceptibility and lack of ability to cope and recover) (Jörn Birkmann & Wisner, 2006)

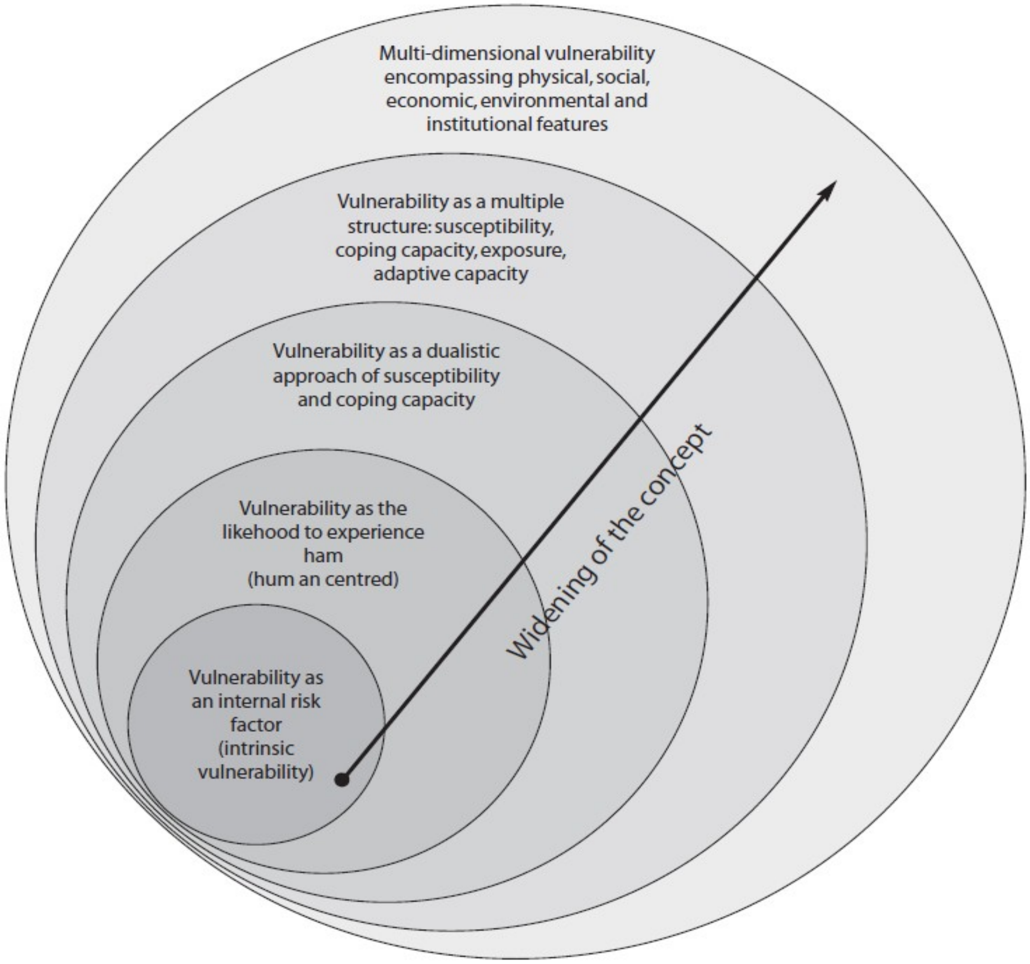


***Figure 3*: Key spheres of the vulnerability concept**
Source: Birkmann & Wisner (2006)

Vulnerability Conceptual Framework

A number of frameworks and conceptual models have been developed to provide context specific understanding of vulnerability and serve as a tool to knowing underlying factors that influence the vulnerability of localities (Twigg et al., 2001; Juan, 2006; Adger, 2006). A vulnerability framework can be a model for risk assessment of a hazard (exposure assessment) or a more complex and multi-dimensional concept for assessment of physical, social, economic, institutional and environmental assessment of vulnerability (Joern Birkmann, 2007). Figure 4 is a typical vulnerability framework.

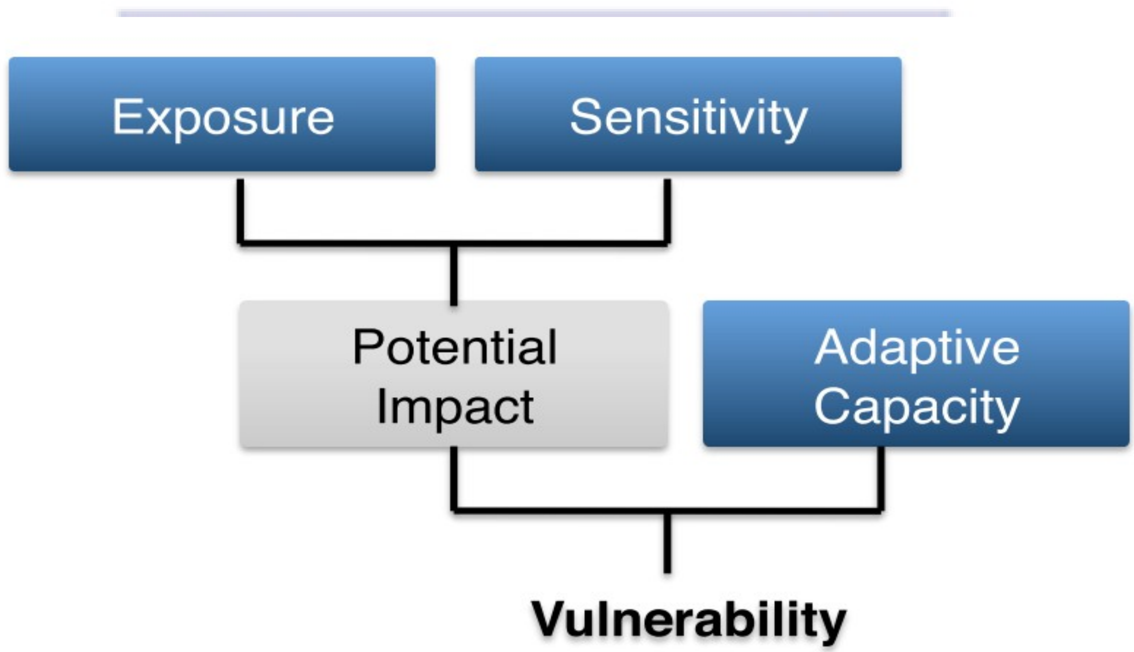


Figure 4: **A typical vulnerability framework**

Source: Marshall et al. (2009)

Exposure

The exposure factor of vulnerability is the extent to which any socioecological system interacts with climate change-related events. The socioecological systems may include human settlements, ecosystems, livelihoods, livestock and exposed resources that may be liable to suffering negative effects from any climate change-related events. For example, coastal settlements particularly those close to the high-water mark of the sea may have high exposure to sea level rise effects such as storm surges, tidal wave flooding as well as erosion (Marshall et al., 2009). Coastal aquifers exposed to sea level rise may suffer saltwater intrusion which to some extent may affect the availability of potable water in coastal areas.

Sensitivity

Sensitivity captures the characteristics or state of a system that influence its likelihood to experience harm when exposed to a climate change stressor. Sensitivity comes in different dimensions comprising of physical, economic, social, environmental and cultural aspects (Weis et al., 2016).

It is also the degree to which a system will respond to the influence of a given climate change factor including beneficial and harmful effects. In social systems, sensitivity is broadly determined by the socioeconomic characteristics such as gender, age, income, disability among others. It is also determined by the level at which individuals, households, or a community relate or depend on resources that are being impacted by climate events (McCarthy et al., 2001). An example is coconut plantations, fishing boats/gears and/or salt pans which are the main sources of livelihood, food and income for communities, households or individuals may become sensitive to climate events. Again, if coastal aquifers which are sources of portable water for consumption and usage for communities may become exposed to salt water intrusion from sea level rise the communities would become sensitivity to its services.

Adaptive Capacity

The adaptive capacity needed to moderate the impacts and cope with climate change-related events differ significantly across regions, countries, and other socioeconomic groups. Access to and distribution of wealth, technology and information, risk perception and awareness, equity, empowerment, social capital and institutional frameworks or policies to address climate change hazards are the determinants of adaptive capacity (IPCC, 2014). They can be identified at the smaller levels, that is, individual and community levels that are found within the larger regional, national and international domain (Dolan & Walker, 2006).

The ability or potential of a community to respond to impacts of climate change-related events may be complex. It may be influenced strongly by some important characteristics, or by a considerable number of social characteristics. A well-informed village with a cooperating traditional leader who can formulate appropriate plans and make decisions that benefit and involve all members of the community, for example, will most likely have high adaptive ability. The same as a household with multiple sources of income from different livelihood options may have higher adaptive capacity to climate change impacts than those that have very limited sources of income.

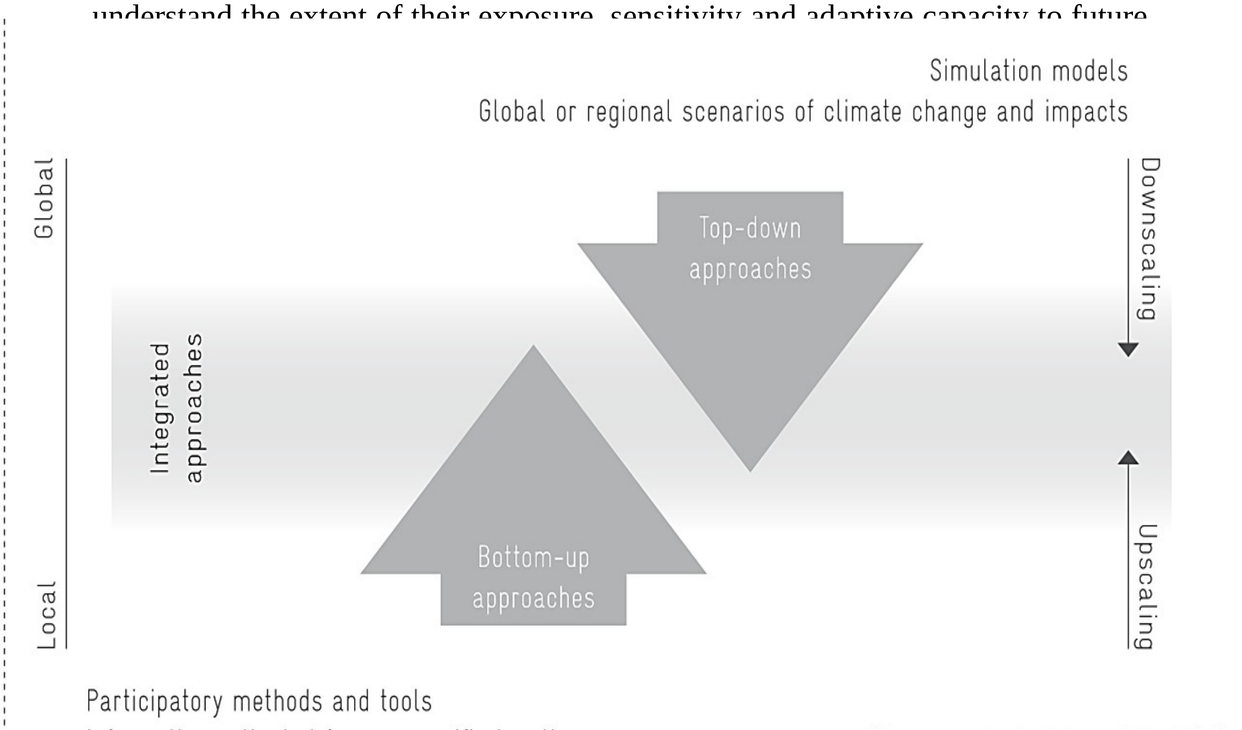
Any group or region that has an adaptive capacity that is limited in any of these dimensions is more vulnerable to climate change stresses. Improvement of adaptive capacity is crucial for moderating or offsetting vulnerability, particularly for regions, nations, and socioeconomic groups that are most vulnerable (IPCC, 2014).

Approaches to Vulnerability Assessment

Vulnerability assessments are typically classified as either top-down or bottom-up in nature (Bhave, Mishra, & Raghuwanshi, 2013). The bottom-up approaches begin with an assessment of the people affected by climate change, while top-down approaches begin with an assessment of climate change and its implications using climatic scenarios (van Aalst, Cannon, & Burton, 2008). This contrast is also referred to as "end-point" versus "start-point" in scientific literature (Kelly & Adger, 2000), “biophysical” versus “social” vulnerability (Brooks, 2017), or ‘outcome’ versus ‘context’ vulnerability (Brien et al., 2011).

Top-down approaches involves taking global factors such as greenhouse gas concentration, the rate at which the earth is warming to model climate change impacts (IPCC, 2014). IPCC has been an international body that has actively engaged in this approach and has been able to come up with scenarios to describe how the future of climate change is going to be. This approach is mainly science based and does not include local knowledge. The scenarios have been the core indicators in the top-down vulnerability assessment of potential effects of climate change consequences on the physical environment such as ecological systems, built environments, and agricultural systems (IPCC, 2001; IPCC, 2007; IPCC, 2014).

While the bottom-up approaches involve the assessment of the conditions of vulnerable people and because this deals with understanding factors affecting the vulnerability of the people, the unit of analysis is smaller and localized including households or communities (Munji et al., 2013; Liton et al., 2019). The focus is more on current status of the unit (i.e., households or communities) to understand the extent of their exposure, sensitivity and adaptive capacity to future



(Source: adapted from GIZ, 2013)

2016; Khajehei et al., 2020; Yankson et al., 2017). The institutional determinants

Source; Hinkel, Schipper, and Wolf (2014)

include resources that ensure the resilience of a coastal community to flooding hazard such as the existence of disaster management systems (e.g. early warning systems), and structural measures (e.g. sea defence structures) (Boateng, 2012a); and the biophysical determinants which include hydro-geological and geographical factors (Messner & Meyer, 2006; Balica et al., 2012).

Gender

Most societies of the developing world including Africa have discriminatory tradition towards the female gender especially regarding the ownership of resources. Having such discriminatory traditions toward female populations render them more vulnerable than the male population. Studies have demonstrated that the female populations have limited chances of getting access to resources and information during and after disasters and this had had negative impact on their physical and mental health (Cutter et al., 2003; Wood, Burton, & Cutter, 2010; Zhang, Yi, & Zhao, 2013). For example, a study on flood vulnerability in Accra revealed that majority of the victims were female household heads due to inability of women to access available resources unlike men (Aboagye, 2012b).

It is also widely documented that women have higher mortality and poverty rates in disaster occurrences (Cutter et al., 2003; Wood et al., 2010; Zhang et al., 2013). Furthermore, studies show that female populations and female-headed households have positive correlation and significant statistical effects with the severity of social vulnerability of a locality (Cutter et al., 2003; Wood et al., 2010; Zhang et al., 2013)

Considering factors such as domestic responsibilities, women are in a way are less able to respond appropriately to a crisis. Their domestic responsibilities and status may restrict their ability to respond quickly in terms of evacuation to rescue grounds or seeking relief on time in the advent of a disaster (Ajibade, McBean & Bezner-Kerr 2013; Mavhura, 2019).

Income

Low-income people are economically weak and are affected by disasters disproportionately. It is identified that they are unable to afford assets or generate income that can help them prepare for a disaster or recover after a disaster (Cutter et al., 2003; Mavhura, 2019). Their possessions most often are also likely to have low monetary value but the loss of it is comparably more expensive to replace particularly for those without homeowner's or renter's insurance (Katrina, Peacock, Morrow, Gladwin, & York, 2005).

Low-income people are usually likely to be unemployed. It is often found that elevated levels of unemployment relate with high levels of vulnerability in disaster events (Wood et al., 2010; Kelly & Adger, 2000). The unemployed population and those near the poverty line cannot provide income and this makes them to become vulnerable as they lack the income capacity to cope with or recover from a hazard. High-income earners on the other hand, may incur -more property losses in absolute terms, yet find their situation moderated with property and health insurances, secured employment and financial investments in the wake of a hazard.

Age

Children under five (5) years of age and old people, above 65 years, are most often not able to respond to disasters without assistance(Chen et al., 2013; Lee & Vink, 2015 Mavhura, 2019). They are more susceptible to significant physical and psychological impacts compared to the other age group (Lee & Vink, 2015). Children who have inadequate support from family are usually disadvantaged when they have to respond to a disaster (Morrow, 1999) and with the elderly groups, even if they are not poor or physically weak, they are more likely to lack the physical and economic resources necessary to respond to a disaster efficiently and effectively (Mavhura, 2019; Aboagye, 2012). Example, Aboagye (2012) discovered that elderlies above 55years were more vulnerable to flood disasters in Accra, Alajo, as they sustained severe injuries and lacked flood insurance. It was also reported that they lack funds to afford proper housing because they are not working. Besides the physical challenges that evacuation and relocation brings, elderly people become depressed about leaving their own homes to stay in a group quarter or in a rescue place (Mavhura, 2019; Aboagye, 2012).

With the other age groups between 14 and 60 years, that have low dependency ratio and are working-age adults with good health, they are likely to have better capabilities to respond to disasters, therefore, are less vulnerable in the face of exposure to hazards (Morrow, 1999).

Education

Households with low level of educational attainment are usually less proficient in English and reading and are therefore less likely to access emergency information without assistance. They are also more subjected to income fluctuations due to unsecured employment and less able to manage risk (World Bank, 2000). But people with higher levels of education attainment are more likely to receive hazard information and respond to it accordingly especially with regard to preparation and recovery (World Bank, 2000).

Disability

Mentally or physically disable people have lesser capability to be able to respond to disasters effectively because they require additional assistance in to prepare for and recover from disasters. Disaster managers need to target areas with more disabled people, for early evacuation and also for disaster preparation measures (Morrow, 1999).

Studies have shown that the effects of factors that increase social vulnerability increases with families having a physically or mentally challenged member, and also in homes with members suffering from a terminal or chronic diseases (Lee, 2014; Vincent & Cull, 2010).

Wealth

Wealth improves one's ability to plan for and endure losses in the event of an emergency, and vulnerability is thought to be exacerbated by a lack of wealth (Felsenstein & Lichter, 2014). The wealth of a household is characterized with the quality of the housing structure, possession of household assets and income sources (Felsenstein & Lichter, 2014).

The quality of a housing structure is a crucial factor in assessing vulnerability to a disaster and it is related to individual wealth. The poor people usually live in houses that are poorly constructed or mobile homes which are more vulnerable to storm surges, floods and other coastal hazards (Cutter et al., 2003). Mobile homes and shacks are structurally incapable of resisting the effects of extreme weather conditions or natural disasters such as flooding and typically do not have strong foundations (Donner, & Rodríguez, 2008). According to Fatemi, Okyere, Diko, & Kita, (2020), in the course of socio-economic interventions, it is relevant to pay attention to housing structures of residents in exposed to flood hazard in order to build adaptive capacities and resilience to flooding for vulnerable communities.

Ownership of household assets such as evacuation devices (e.g., automobiles or canoes), information and communication gadgets (e.g., televisions, radio and mobile phones) makes a household better off in receiving and processing information on imminent hazards and also in preparation for and evacuating from hazards (Felsenstein & Lichter, 2014). Televisions, radios and mobile phones are important in mediating socioeconomic vulnerability. They act as a medium of information access, and their usage do not necessarily require high literacy level or formal education. (Noble et al., 2014). Lack of transportation assets is an important aspect that increase the vulnerability of and individual or a social group. An empirical evidence was the lack of transportation assets resulted in unnecessary suffering for persons living in poverty or near poverty in the central region of New Orleans who did not have privately owned vehicles or other means of transportation to leave their homes to safer grounds (Kelly & Adger, 2000).

Institutional capacity

Institutional capacity such as early warning systems, disaster management organizations and sea defence structures are determinants of a community's resilience to a flood hazard. In the advent of a flood hazard brought by biophysical vulnerability, the existence of this capacity in a community is paramount in contributing to the coping ability of the entire population in the community (Collins & Kapucu, 2008; Vincent & Cull, 2010; Sufri, Dwirahmadi, Phung, & Rutherford, 2020).

Smaller units such as households or communities may be unable to protect themselves due to the degree at which they lack autonomous control over their circumstances and therefore require institutional supports to offset the impacts of hazards (Vincent & Cull, 2010). The ability to respond appropriately to hazards may be dependent on households' or communities' support from external decision makers (Allen, 2006). The ability of a community to face hazards can be directly tied to its connection to government or political power structures. Rural communities are likely to be ignored in a highly politicized environment during disasters and they may require advocacy and supports if they need to face threats from climate change-related hazards (Morrow, 1999)

Early warning systems

The availability of early warning systems in any community provides opportunity for disaster preparedness. Early warnings and emergency information are to a great extent reduce the vulnerability of the exposed population to hazards including saving lives, minimizing potential injuries and property losses (Sufri et al., 2020). Lack of these systems can result in unpreparedness towards unforeseen circumstances and thereby complicate issues for socioeconomically vulnerable populations (Collins & Kapucu, 2008).

Disaster management bodies

The role of disaster management bodies can promote the resilience of vulnerable communities by ensuring appropriate monitoring of the hazard, public information dissemination, and ensuring emergency preparedness and pre-disaster planning towards hazards (Kelly & Adger, 2000). This could be accomplished by collectively improving coping mechanisms and possibly resource redistribution, such as assuring food aid and other social insurance measures for exposed communities. This implies that, effective disaster management organization can ensure that hazards do not result into harmful impacts on exposed populations (Allen, 2006).

Sea defence structures

Sea defence structures are robust infrastructures that serve as barriers between the sea and the coastal communities and therefore protect the communities from storm surges and coastal floods. Communities with sea defence structures are less exposed to the impacts of sea-level rise hazards in absolute terms because these infrastructures are designed to withstand more intense and frequent extreme events of sea-level rise (Boateng, 2012a).

Adaptation Options

Adaptation has to do with the reduction of risk and vulnerability through taking advantage of opportunities; building or improving the capacity of nations, regions, cities, the private sector, communities, individuals, and natural systems. It is to moderate the impacts of climate change related disasters on the sectors and mobilize the capacity to implement decisions and actions (Tompkins, Vincent, Nicholls, & Suckall, 2018).

Adaptation to climate change hazards in any specific system requires adequate information in order to select robust adaptation options that can be helpful. There is therefore the need to engage people with different knowledge, experiences and backgrounds. In the case of coastal areas, there are so many adaptation strategies including protection, accommodation and retreats(Nicholls, 2007).

Protection option involves reducing the risk of a hazard event by decreasing the probability at which it occurs and this is done by protecting systems, population and their assets through hard structural (sea defences) or soft structural interventions (beach nourishment, dune restoration and creation, wetland restoration and creation, etc.

A***ccommodation option*** has to do with changing conditions to improve adaptive strategies or a society's ability to withstand or cope with the harm that a hazard may cause. This is done through hazard emergency planning (early warning and evacuation systems), hazard insurance, modification of land use and agricultural practice, modification of building styles, among others. Boateng (2012a) conducted a study on physical vulnerability and coastal adaptations and recommended accommodation policies, that can encourage settling in an exposed area for long before a subsequent retreat, could be adapted to accommodate vulnerable settlements in the eastern coast of Ghana.

Retreat option can be in the form of relocating away from the hazard through property acquisition, buyouts, or relocation programs to reduce the risk of the event and limit its potential effects (Boateng, 2012a).

The preference for any of these options is dependent on the local context such as the type of support (political and public) available, technical and financial resources, institutional capacity as well as the socioeconomic characteristics (Bukvic, Zhu, Lavoie, & Becker, 2018) It is also influenced by the complexity of the hazard risk in terms of the magnitude of impacts as a result of local characteristics like topography, hydrology, ecological systems, tourism, and the presence of other hazards (Bukvic et al., 2018).

Relocation

Some areas such as regions with low-lying coastal plains, islands and deltas are highly vulnerable (Williams, 2013). According to Bukvic et al. (2018), due to the complexity of hazards that these areas are exposed to, particularly, areas with interconnected waterbodies (deltas), the robust adaptation option may either be the combination of all the options or relocation. Relocation is an effective strategy for coastal flood hazard mitigation (Bukvic et al., 2018), yet its implementation can depend on the integration of governance or institutional frameworks (Abel et al., 2011). The willingness of communities and households to consider relocation is another important factor to consider (Bukvic, Smith, & Zhang, 2015; Seebauer & Winkler, 2020). Bukvic et al. (2015) evaluated the drivers of coastal relocation in Hurricane Sandy affected communities and found out that the extent and duration of disaster exposure, socioeconomic factors and household recovery rate were the main determinants of relocation decision at household levels. However, empirical evidences indicated that sense of place and emotional connections restrain households willingness to relocate from a disaster-prone area (Buchori et al., 2021; Xu et al., n.d.)(Buchori et al., 2021; Xu et al., 2017).

Developing a Vulnerability Index

The concept of developing a composite index was introduced in the 1990s to capture the complexity and multidimensionality of development issues (Talukder et al., 2017). Since then, some international organizations such as the World Bank, United Nations, European Commission and studies have developed composite indices (Talukder et al., 2017). Examples include; the Environmental Performance Index (EPI), the Human Development Index (HDI), Gender Empowerment Index (GEM), Livelihood Vulnerability Index (Hahn et al., 2009), Flood vulnerability index (Balica et al., 2009; Dinh et al., 2012), among others.

Developing an index involves the conceptualization of the phenomenon and operationalization of the concept with identified measurable indicators (Hinkel, 2011). The operationalization stage mainly involves (i) normalization, (ii) weighting, (iii) aggregation of the indicators scores into an index and (vi) classification of the results into either quantile, equal interval, natural breaks or standard deviation, and (iv) Uncertainty and sensitivity analysis (Moreira et al., 2021).

When all the indicators are measured with the same unit (e.g., percent or ratios), data can be aggregated without being scaled. However, in many instances, the indicators to be aggregated have various units and measurements such as nominal, ordinal, interval, and ratio scales. In this circumstance, normalization is the technique used to standardize the indicators on a common scale. The choice of a preferred normalization approach should be made with consideration when constructing composite indices, taking into account the composite index's aims as well as the data attributes (Talukder et al., 2017). This is because varied normalization procedures provide different results and can have significant implications for composite index scores (Talukder et al., 2017).

The most widely used normalization techniques in the literature are; ranking, Z-score, min-max and distance to target as presented in Table 1 below.

Table 1:Normalization Methods

Method	Equation	Description	References
Ranking	$Nias = Rank(Xias)$	Uses on ordinal variables that can be converted to quantitative variables.	Hahn et al. (2009); Marshall et al. (2009)
Z scores	$Z = \frac{x-\mu}{\sigma}$	Transforms all indicators values to a single scale with a mean of 0 and a standard deviation of 1.	Dinh et al. (2012); Hahn et al. (2009)
Min–max	$Isc = \frac{S - S_{min}}{S_{max} - S_{min}}$	Rescales indicator values between 0 (worst rank) and 1 (best rank).	Hahn et al. (2009); Yankson et al. (2017)
Distance to target	$Nias = \frac{Xias}{Target\ Xias}$	Rescales values between 0 and 1. It is the ratio of the value of the indicator to its maximum value.	Hahn et al. (2009); Marshall et al. (2009)

The final score and ranking of the composite indices depend on the weighting of the normalized values of the indicators. Weighting reflects the importance of each indicator relative to the overall. Weighting can be very important because it modifies the sub-indices values before aggregation to a composite index is done. However, Sajeva et al.(2005) found that different weighting techniques do not influence the ranking of composite indices. There is no agreed-upon mechanism for weighing individual indicators. The two main types of weighting in the literature include; equal weighting used in the Human Development Index, HDI (Qasim, 2013) and flood vulnerability indices, (Bathi & Das, 2016) or unequal weighting (Frigerio et al., 2016; Qasim, 2013; Yankson et al., 2017)

The aggregation method of a composite index can be compensatory (linear aggregation) or non-compensatory (geometric aggregation). Compensability of indicators, which is defined as compensating for any indicator's dimension with an appropriate surplus in another indicator's dimension, is the most fundamental issue in aggregation. The method of aggregation used has a significant impact on the index scores. Moreira et al. (2021) found that when geometric aggregation was opposed to linear aggregation (additive), the geometric aggregation (multiplication) approach was more sensitive as it provided less compensability for the indices, resulting in lower scores. Many vulnerability indices have been aggregated from the IPCC's three components, Exposure (E), Sensitivity (S) and Adaptive Capacity (C) using any of the two aggregation techniques expressed as;

Linear aggregation (additive function) ___ $V = \alpha_1 E + \alpha_2 S - \alpha_3 C$ (Yankson et al., 2017)

Geometric aggregation (multiplication function) ____$V=\frac{E*S}{C}$ (Balica et al., 2009; Il Choi, 2019)

According to Siagian et al. (2014) and Frigerio et al. (2016) there is no specified or general procedure to creating a vulnerability index, and different studies have used a range of procedures.

Yankson et al. (2017) used a min-max normalization method to develop vulnerability indices at community levels. The method transforms each indicator into scores that range between 0 and 1. In order to determine the vulnerability indices in line with IPCC vulnerability factors- sensitivity, exposure, potential impacts and adaptive capacities, Yankson et al. (2017) used the standardization procedure as follows:

$$Isc=\frac{S-S_{min}}{S_{max}-S_{min}}$$

Where: Isc is the standardized index for each community (c),

S is observed value for each community,

S_{max} and S_{min} are the observed maximum and minimum values, respectively.

The mean index, for each of the factor, sensitivity, exposure or adaptive capacity was determined using the following formula.

$$f\,I_{SC,mean}=\frac{1}{n}\sum I_{SC}$$

Where f either exposure (E), sensitivity (S) or adaptive capacity (A) index, and n is the total number of indicators for the factor.

Community vulnerability indices were finally determined by computing Potential Impact index as follows:

$$P_{cmean} = E_{Iscmean} + S_{Iscmean}$$

And subtracting the adaptive capacity index from the potential impact index as follows:

$$IPCC_{Isc} = P_{Iscmean} - A_{Iscmean}$$

Where:

$IPCC_{Isc}$ is the community vulnerability index,

$P_{Iscmean}$ is the potential impact index

$A_{Iscmean}$ is the adaptive capacity index.

CHAPTER THREE:

RESEARCH METHODS

This chapter presents a detailed description of the study area, study design, data and methods used for this work with justifications for using them. It also explains the processes of data collection, management and analysis employed at various phases of the study. Under the data collection processes, sampling methods, survey instrument and fieldwork procedures were also explained.

Study Area

The Ketu South Municipality lies within latitudes 6^0 03 north and 6^0 10 north, and longitude 1^0 6 east and 1^0 11^0 east. It shares borders with the Republic of Togo on the east, the Keta Municipality on the west, at its north with Ketu North District and the Gulf of Guinea to the south (Figure 6). The Municipality has a total land size of approximately 779 square kilometres representing 3.8 per cent of the regional land area (Allan et al., 2015) According to the 2021 population census the municipality has a total population of 102,905 (2020 population projection Volta Region). The coast of Ketu South Municipality falls within the eastern coastline of Ghana and constitutes an area of valuable resources such as wetlands (particularly mangroves and marsh lands), lagoons, living marine resources (fisheries), minerals (salt and sand), and groundwater, that when properly managed could have a significant impact on several sectors of the economy in the municipality (Nicholls et al., 2020). Agriculture (vegetable farming), salt production, aquaculture, lagoon and artisanal fisheries, firewood sales, petty trading, tourism, among others are some of the main occupations of the inhabitants in the area (Allan et al., 2015). Together, these occupations represent a broad spectrum of socio-economic activities, which largely rely on the natural and valuable resources provided by the coastal area.

However, the coastline has been identified as highly at risk to sea-level rise in terms of physical vulnerability and one meter rise in sea-level is projected to inundate 50 percent of the entire coast (Boateng et al., 2017). Although its proximity and studies show its physical vulnerability, socioeconomic and institutional factors are also key to consider in determining how vulnerable the communities of this municipality are to the flooding hazard (Balica, 2012; Wu et al., 2002). In addition, the coastal area of Ketu South municipal is a deltaic area sandwiched between the Keta Lagoon, wetlands and the sea, complicating its vulnerability to multiple flood hazards from the sea, river overflows and torrential rainfall. The area is already experiencing periodic flooding from storm surges affecting the settlements and the economic activities.

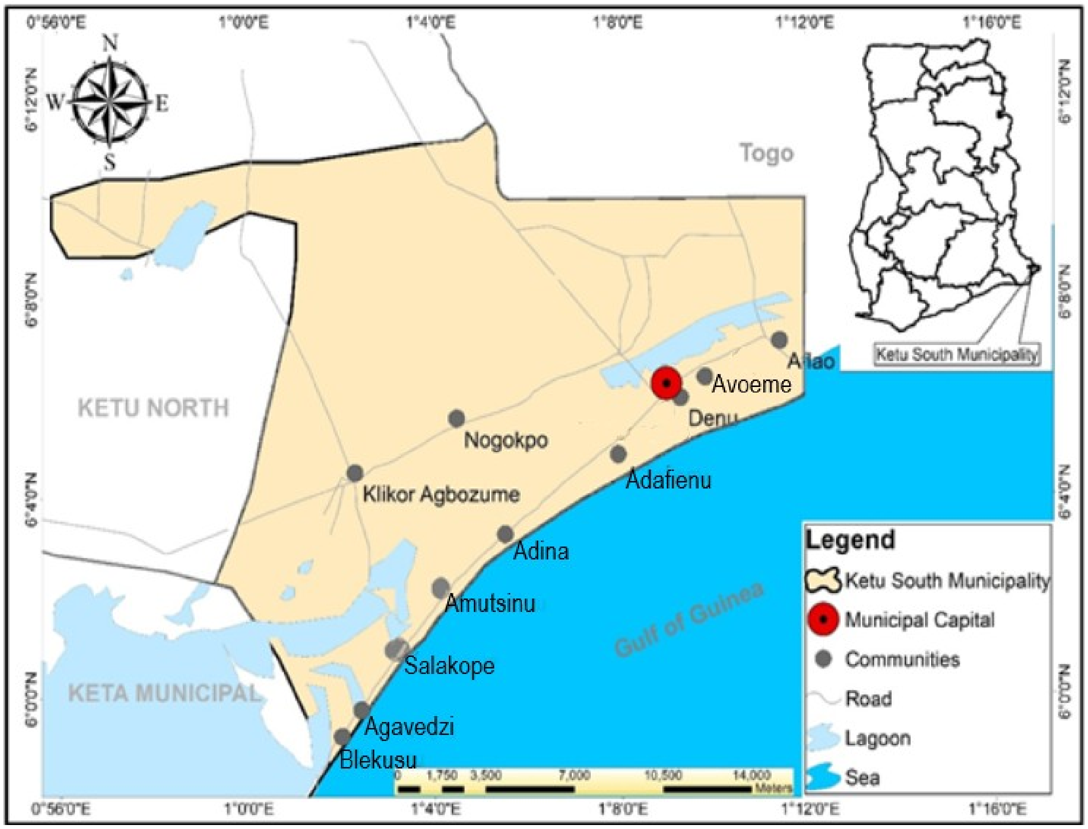


Figure 6: **Map of the study area**

Research Approach and Design

A mixed method research approach, with sequential exploratory research design (Cresswell, 2017) was adopted for the study. The research design involved the integration of both qualitative and quantitative data. In this research design, qualitative research phase was done first followed by a quantitative phase. Qualitative data involving those from in-depth interviews and focus group discussions were collected and used for the study. The qualitative study explored the views of the participants on flood exposure, institutional and socioeconomic factors that contribute to their vulnerability to flooding. Participants in the qualitative research were purposively selected to help provide relevant site-specific information needed for understanding the research problem and to select relevant variables for further examination in the quantitative research. Portion of the data collected during the qualitative study was therefore used to develop the instrument (structured interview guide) for the quantitative phase.

The in-depth interviews and focus group discussions were followed by participatory mapping of the latest flooding extent in the communities. The participatory mapping was later validated with NADMO. This exercise was done to graphically present the communities that experience flooding events and those that do not, in the study area. The purpose was to aid in selecting communities that are geographically vulnerable to coastal flooding along the coast of Ketu South Municipal for the survey phase of the study.

The flood participatory mapping solicits communities' and stakeholders' inputs in flood mapping (Oteng-Ababio, 2014; Klonner, 2021). Acquiring the spatial understanding of the historical impact of the recent floods through the engagement of flood-affected communities is one way to identify vulnerable communities and to reduce future disaster risks (Sudaryatno et al., 2017; Klonner, 2021). It also helps to identify areas that are free of flooding and could be used as rescue grounds for the communities in the phase of flooding.

In the quantitative phase, the study adopted a survey research design as the strategy of inquiry. A "survey" is a type of research design under the quantitative research approach that involves a systematic method of gathering information using instruments and providing a quantitative or numeric description of trends, attitudes, and opinions of a population (Groves et al., 2011). It generates results that can be generalized for an entire population. In other words, studying human populations requires a survey design to accurately sample target population to avoid biases and to be able to generalize the research findings to the entire population (Groves et al., 2011).

The survey method of data collection in other words, is an empirical approach to assessing flood risk or vulnerability for a study area that is rural and informal and as a result, lacks hydrological and geomorphological data for flood exposure analysis. It is also used in flood vulnerability studies that integrate resident's experiences and perceptions into understanding their flood vulnerability in the exposure, sensitivity and adaptive capacity dimensions (Fatemi, Ardalan, Aguirre, Mansouri, & Mohammadfam 2017; Gomez, Adelegan, Ntajal, & Trawally, 2020).

Population

The target population of the study was in the communities of the Ketu South Municipality that have been experiencing perennial coastal flooding. The population consist of fisherfolks, salt miners, and other artisanal skilled workers with petty traders who are all coastal dwellers.

Sampling Procedure

Participants in the qualitative study were community leaders and members who as a result of their knowledge and previous experiences on flooding issues in their communities could provide valuable information on prevalence of flooding in the study area. The sample size for this technique was determined when data saturation was attained during data collection. The data saturation point was when no new information was provided during interviews. In all, eight (8) in-depth interviews and nine (9) focus group discussions were conducted for this phase. A minimum of eight participants was in each focus group discussion.

In the quantitative study, a multi-stage sampling method was employed by using the information from the in-depth interviews and FGDs together with that from community flood participatory mapping to identify communities that were regularly exposed to coastal floods. These communities include Blekusu, Agavedzi, Salakope, Amutsinu and Adina. The information was solidly validated by NADMO, which confirmed that aside the identified communities, the other coastal communities, Adefienu, Denu, Avoeme and Aflao do not experience flood events. The household populations of the selected communities served as the sample frame from which households were selected for the administration of the structured interviews. The household population size for the various coastal communities; Blekusu, Agavedzi, Adina, Amutsinu, and Salakope were 1698, 798, 1637, 217, and 200 respectively (Ghana Statistical Service, 2020). The Sum of these population sizes gives a total of 4550 as the target population size and following the Krejcie & Morgan (1996) table for sample size calculation, the sample size was estimated to be 357. The probability proportional to size sample technique was then employed to sample for each community as specified by Antwi et al. (2015) and Yansaneh (2005).

That is, sample size for; Blekusu¿ $\frac{1698}{4550} \times 357 = 133$

Agavedzi¿ $\frac{798}{4550} \times 357 = 62$

Adina ¿ $\frac{1637}{4550} \times 357 = 128$

Amutsinu: ¿ $\frac{217}{4550} \times 357 = 17$

Salakope = ¿ $\frac{200}{4550} \times 357 = 15$

With a simple random sampling method, households were selected where each household had a chance of being selected. Household heads were interviewed as the respondents for the survey and they were selected irrespective of their occupation.

Instruments for Data Collection

In-depth interview guides were developed, reviewed and used to collect information from participants. There was pre-testing of instruments to ensure content reliability and plausibility and to improve the questions, format and scales. One of the coastal communities, Blekusu, was used for this pre-test exercise. The in-depth interview guide consisted of four sections: the first section (A) consisted of questions on demographic characteristics; Section B had questions on participants' exposure to flooding hazards; while Section C had questions on sensitivity to flooding hazards and Section D had questions on household and community adaptive capacity and resilience to flooding issues.

The FGD guide consisted of three sections: Section A explored flood events over the past five years and their impacts; Section B explored questions on sensitivity to households regarding demographics, social and economic vulnerability to the floods; and Section C explored community resilience which had questions on preparedness and local adaptation strategies the flood events.

A structured interview guide was designed with a mix of close-ended and open-ended questions for the quantitative phase of the research. The instrument was reviewed and pre-tested to ensure that respondents understand the questions. A few corrections were done to the questions. Questions delved into flood experience, types of floods, the causes of flood in the communities, the frequency of flood events, flood depth, magnitude, demographic characteristics, socioeconomic conditions of households, flood damages and their coping capacity to flood hazards.

Procedures for Data Collection

Recruitment and training of field assistants

Five field assistants were recruited for the study. The recruitment of the field assistants was based on: the ability to write, speak, and interpret Ewe and English language; the level of education considered was tertiary level and prior knowledge on issues relating to coastal flooding. The assistants were trained for three days to help them understand the nature of the study and the data collection procedures.

In both phases of the data collection, a consent form that explains the study topic, purpose of the study, the study procedures, the risk, and the benefits involved in the study and ethical issues were provided to each of the participants and respondents. The questions were read out and explained to the respondents in the local language of the respondents after which they signed or thumb printed the consent form.

Qualitative data collection procedures

Data collection initially began with a reconnaissance survey to familiarise with the study area and the target population and this was followed with community entries. The community entries were done to ask for permission and to earn the trust and confidence of the study population before the data collection. This exercise was helpful in selecting and scheduling time with the participants for the FGDs.

. Qualitative data collection was done between February, 2021 and March, 2021. For the in-depth interviews, seven (7) community leaders (example; Figure 7) and one (1) NADMO official (Figure 8) were interviewed. Nine FGDs were conducted with at least eight participants from five communities who were members of the communities. Women FGDs (Figure 9) were separately done from the men FGDs (Figure 10) in each of the communities. The Focus Group Discussion was done simultaneously with community flood extent participatory mapping.

In the community participatory mapping process, members and leaders of flood-affected communities were engaged to draw the spatial extent of the recent extreme flood they have experienced on a printed 2021 Google Earth map (Figure 11). Coordinates of the flood extent boundaries were taken using the geographical

Figure 7: An in-depth interview session with a community leader (a chief)

positioning system (GPS) for georeferencing and development of flood extent maps. The elevation of the various locations where the coordinates were taken was also recorded.

Municipal NADMO official

Figure 9: A focus group discussion session with women in Adina

Figure 10: A focus group discussion session with men in Agavedzi

Quantitative Data collection procedure

Survey data collection was done between March and May, 2021 in the five coastal communities that are exposed to frequent flood events. Survey respondents were household heads in the selected communities. A total of 351

A

B

household heads were randomly sampled and interviewed using structured

Figure 11: Flood participatory mapping sessions (A and B)

interview guides.

Data Processing and Analysis

Identification of Communities that are Regularly Exposed to Floods

Data from the in-depth interviews and FGDs together with that from community flood participatory mapping was analysed and used for identifying communities that were regularly exposed. During the interview and FGDs the following questions were asked under flood exposure component; Has there been any flooding events in your community? When did it happen? What do you think were the causes of the flooding? Why? How often has it occurred? Is it increasing or decreasing? How much area is affected during a flooding event?

Responses on these questions were audio recorded, note transcribed and analysed using deductive thematic analysis technique after Babbie (1986); Braun, Clarke, Braun, & Clarke, (2008) into codes and themes such as community flood experience, flood history, causes of flood, frequency of flood, flood depth, flood duration and spatial coverage of flood. Based on these flood exposure results, five communities, Blekusu, Agavedzi, Salakope, Amutsinu and Adina were selected for flood participatory mapping.

During the flood participatory mapping the coordinates of flood extent boundaries were obtained using GPS. These coordinates were mapped using “create polygon” tool on a base map in ArGIS 10.4.1 to develop flood extent maps for the communities.

Determination of Vulnerability Factors in the Selected Exposed Communities

To determine the factors that influence vulnerability to flooding in the selected coastal communities, in-depth interviews and Focus Group Discussions (FGDs) data that were audio recorded and noted were transcribed in Microsoft word using the intelligent verbatim transcription method. Using deductive thematic analysis technique after Babbie (1986) and Braun et al. (2008), the transcripts were analysed and coded into themes. This process involves assigning any key piece of text a specific code that can be applied consistently and repetitively to all interviews and FGDs and grouping codes under their corresponding themes (Bryman, 2016).

Survey Data Analysis

The statistical software used for analysing the survey data was the Statistical Package for Social Sciences, IBM SPSS version 21. Using central tendencies mean, mode and standard deviations etc. the data was summarized to enhance the understanding of the distribution of key variables. For further analysis, there was a triangulation of the qualitative and survey data sets collected during the study according to (Khan et al., 2020).

Determination of Indices for Vulnerability

In the determination of vulnerability indices for factors such as exposure, sensitivity, potential impact and adaptive capacity, this study selected variables from the survey data as indicators (Table 1). Similar to Chakraborty, Tobin, and

Montz (2005) and Yankson et al. (2017) the variables were summarized using percentages and averages (Table 4, 5 and 6).

Following Yankson et al. (2017) standardization method (min-max) to develop vulnerability indices at community levels was adopted. The method transforms each indicator into scores that range between 0 and 1. The procedure used by Yankson et al. (2017) was followed to standardize each indicator as follows:

$$Isc = \frac{S - S_{min}}{S_{max} - S_{min}}$$

Where:

Isc is the standardized index for each community (c),

S is observed value for each community,

S_{max} and S_{min} are the observed maximum and minimum values, respectively.

The mean index, for each of the factor, sensitivity, exposure or adaptive capacity was determined using the following formula.

$$f\, I_{SC,\,mean} = \frac{1}{n} \sum I_{SC}$$

Where f is either exposure (E), sensitivity (S) or adaptive capacity (A) index, and n is the total number of indicators for the factor.

Community vulnerability indices were finally determined by computing Potential Impact index as follows:

$$P_{cmean} = E_{Iscmean} + S_{Iscmean}$$

Following Balica et al. (2009) and Il Choi (2019) composite community vulnerability indices were finally determined using geometric aggregation method (multiplication) as follows:

$$V = \frac{E * S}{C}$$

Where:

$V =$ ¿ Composite community vulnerability index,

$E =$ ¿Exposure sub-index

$S =$ ¿ Sensitivity sub-index

$C =$ ¿ Adaptive capacity sub-index

Following Cutter et al. (2003); Balica et al. (2009) and Bathi & Das (2016) the values of the vulnerability factors were aggregated without weighting. Weighting is done to solve the problem of aggregating indicators with different dimensions (units) and magnitude. However, this problem can be addressed with standardization of the individual indicators (Lee, 2014) and this has been already done in the standardization steps above.

The min-maxim method used to develop the indices transforms the indicator scores between zero (0) and one (1), with 0 being the worst score and 1 being the best score. Following Yankson et al. (2017), Exposure and Sensitivity was ranked as High (≥0.30), Medium (0.18–0.29) and Low (<0.18); and Potential Impact was ranked as High (≥0.7) and Medium (0.5-0.69). According to Weis et al. (2016), since potential impact (exposure + sensitivity) and the composite vulnerability indices (potential impact-adaptive capacity) are aggregated from the main vulnerability factors, no absolute conclusion can be drawn on their scores, the correct conclusions are relative statements for the communities. Hence the composite vulnerability scores were ranked using relative statements after Yankson et al. (2017); a score of 0.67–1 is highly vulnerable, 0.34–0.66 vulnerable, and 0–0.33 least vulnerable.

Table 2: Indicators Used for Developing the Vulnerability Indices

Components	Indicators	Description
Exposure	*Flood frequency* Average flood frequency in community Average flood frequency in households	Flood frequency measures the return period of flood events in the communities.
	Average flood duration	Flood duration is the number of days flood takes to recede in the communities.
	Flood depth Percentage of households with flood depth at waist height	Flood depth determines the height of flood from the ground level to the water surface, the higher the depth the greater the degree of damage (Hadipour et al., 2020).
	Flood magnitude Percentage of households that reported flood magnitude as more	Flood magnitude was measured based on the perception of the respondents, and this is classified as less, medium or more.

	Flood impacts Percentage of households who have experienced house property damage Percentage of households who have experienced livelihood impacts Percentage of households who had experienced impact on water source Percentage of households who experienced impact on food source Percentage of households who experienced health impacts	Flood impacts were measured at household levels in the dimension of house property damage, livelihood loss, water source impact, food source impacts and health impacts as identified in the qualitative studies.
Sensitivity	Percentage of female headed households	Studies have demonstrated that the female populations have lower chances of getting access to resources and information during and after disaster and this had had negative impact on their physical and mental health. It is also widely documented

	that women have higher mortality and poverty rates in disaster occurrences and studies have shown how female population and female-headed households have positive and significant statistical effects or relation with the severity of social vulnerability of a locality (Cutter et al., 2003; Wood et al., 2010; Zhang et al., 2013)
Average household size	In high-density areas, there is less probability of evacuation and the higher risk of death (Hadipour et al., 2020)
Number of children <5years	The young, that is, children under five (5) years of age are most often not being able to respond to disasters without assistance (Clark & Moser, 1997; Chen et al., 2013) and they are more susceptible to significant physical and psychological impacts. Children who have inadequate support from family are usually disadvantaged when they have to respond to a disaster (Morrow, 1999)

Number of elderlies >65yrs	Elderly groups, even if they are not poor or physically weak, they are more likely to lack the physical and economic resources necessary to respond to a disaster efficiently and effectively (Mavhura, 2019). Besides the physical challenges that evacuation and relocation brings, elderly people become depressed about leaving their own homes to stay in a group quarter or in a rescue place (Mavhura, 2019; Aboagye, 2012).
Number of persons with disability	Mentally or physically disable have lesser capability to be able to respond to a disaster effectively because they require additional assistance in to prepare for and recover from disasters. Disaster managers need to target areas with more disabled people, for early evacuation and also for disaster preparation measures (Morrow, 1999; Lee, 2014; Vincent & Cull, 2010).
Number of women	Considering factors such as domestic responsibilities, women

		are in a way are less able to respond appropriately to a crisis. Their domestic responsibilities and status may restrict their ability to respond quickly in terms of evacuation to rescue grounds or seeking relief on time in the advent of a disaster (Mavhura, 2019).
Adaptive Capacity	Percentage of households that receive early warning information on flood	The availability of early warning systems in a community provides opportunity for disaster preparedness, early warnings and emergency information, which in extent substantially reduce the vulnerability of the exposed population to a hazard including saving lives, minimizing potential injuries and property loss (Sufri et al., 2020).
	Percentage of households that were aware of recent flood prior to flooding	Flood awareness reduces flood risk (Yankson et al., 2017).

Percentage of households that have community support to address flood risk	Societal groups involved in flood disasters are critical to manage the effects from the disaster in the absence of official state agencies. In comparison to communities without evidence of civil society flood mitigation/adaptation, a community having evidence of civil society flood mitigation/adaptation was judged better equipped (Yankson et al., 2017).
Percentage of households that receive government intervention	Flood victims' access to any type of support might be a crucial adaptation technique. Households that reported receiving support from their local government, friends, and family networks were considered to be more adaptable than those who did not (Yankson et al., 2017).
Recovery	
Percentage of households that are satisfied with government intervention	The need to recover after a disaster necessitates long-term rehabilitation efforts that are influenced by the underlying socioeconomic processes and structural limitations. The

Percentage of households that recovers to previous efficient state after flood Percentage of households that have flood insurance Percentage of households with multiple sources of income	recovery of an individual or a society is influenced by capital re-accumulation processes and external interventions (Blaikie et al., 2005). Jordan & Javernick-Will (2013) identified income, government interventions, number of businesses (livelihoods) among others as the determinants for recovery after a disaster.
Percentage of households with information assets	Ownership of household assets information and communication gadgets (e.g., televisions, radio and mobile phones) makes a household better off in receiving and processing information on imminent hazards and also in preparation for and evacuating from a hazard (Felsenstein & Lichter, 2014). Televisions, radios and mobile phones are important in mediating socioeconomic vulnerability. They act as a medium of information access, and their usage do not necessarily require high literacy level or formal education. (Noble et al., 2014).

Percentage of households with transportation assets	Lack of transportation assets is an important aspect that increase the vulnerability of and individual or a social group. Empirical evidence was the lack of transportation assets resulted in unnecessary suffering for persons living in poverty or near poverty in the central region of New Orleans who did not have privately owned vehicles or other means of transportation to leave their homes to safer grounds (Kelly & Adger, 2000).
Percentage of literate household heads	Households with limited education are usually less proficient in reading and are therefore less likely to access emergency information if they are not assisted. They are also more subjected to income fluctuations due to unsecured employment and less able to manage risk (World Bank, 2000).

Average income	Low-income people are economically weak and are affected by disasters disproportionately. It is identified that they are unable to afford assets or generate income that can help them prepare for a disaster or recover after a disaster (Cutter et al., 2003; Morrow, 1999)

Determination of Predictors for Relocation

Negative log-log regression was applied in STATA 16 to examine the predictors for relocation decision. This type of regression was applied because the outcome of the response variable, relocation, is dichotomous, “No” or “Yes” and more than 50% of the responses were “No”, that is not affirmative. A negative log–log regression model is suitable for a dichotomous response variable, that has 55% or more of responses that are not affirmative (Armah et al., 2019).

The independent variables used for the analyses were selected based on practical significance and theoretical relevance (Bukvic et al., 2015; Bukvic & Owen, 2017;Seebauer & Winkler, 2020). The variables included flood duration in houses, number of livelihoods of a household head, and sea defence preference. The analysis also controlled for theoretically relevant compositional factors and contextual factors (Armah et al., 2019). The compositional factors included gender of household head, age of household head, household size, education and monthly income of household head. While the contextual factors included communities such as Adina, Agavedzi and Blekusu. Amutsinu and Salakope were accounted for as Adina since their sample size is too small for the analysis. The compositional and contextual factors were controlled for in the model taking into consideration that these factors might affect the responses on the predictor variables (Armah et al., 2019).

In the analysis, 95% confidence interval was employed and the level of statistical significance was set at 0.05 (Armah et al., 2019). The results were reported as odd ratios (OR). An OR of 1 means that the predictor does not affect the odds of relocation; OR >1 means that the predictor is associated with higher odds of relocation decision; and OR <1 means that the predictor is associated with lower odds of relocation decision.

Figure 12 shows the workflow chart which illustrates the procedures used to achieve the mixed-method research approach.

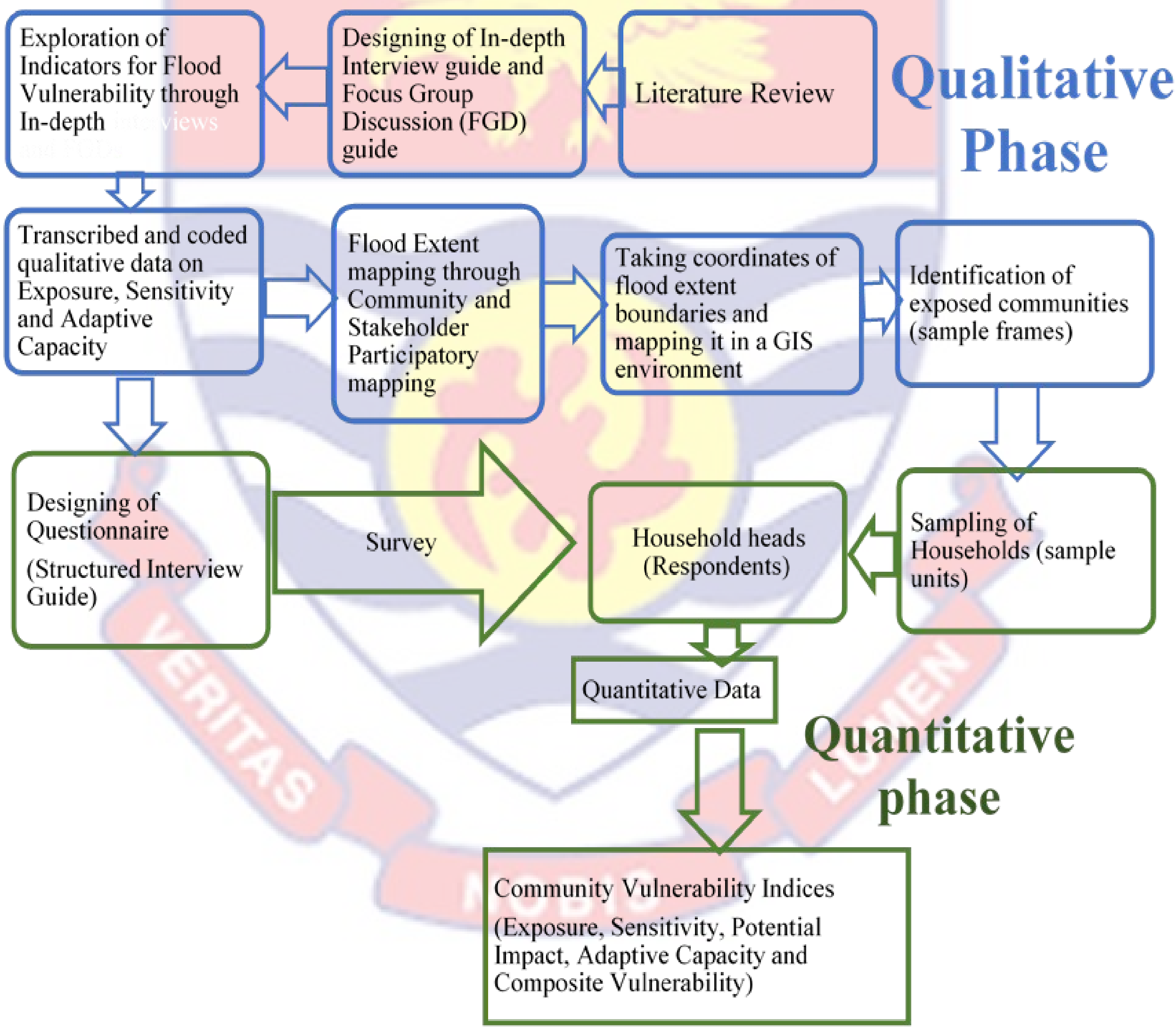


Figure 12: Workflow chart

Ethical issues

Ethical clearance was obtained from the University of Cape Coast Institutional Review Board with an ID (UCCIRB/CANS/2021/15). The University's research code of conduct regarding ethical issues was strictly adhered to. The study also ensured voluntary participation of the respondents, which requires that people are not forced into participating in the research. Moreover, the purpose of this study was made clear to the participants to establish informed consent. The participants were assured of their confidentiality and most importantly, the principle of anonymity.

Chapter Summary

The exploratory sequential mixed method research design adopted for the study was achieved through the triangulation of the qualitative and quantitative datasets. A limitation to this study was the absence or refusal of certain selected household heads to participate in the study. Immediate available household heads were used to replace them. The inability of certain household heads to recollect certain events that happened in the past was reduced by triangulating the data collected through focus group discussions and key informant interviews as well as field observations as was reported earlier (Aboagye, 2012; Osman et al., 2016; Owusu, 2016; Khan et al., 2020).

CHAPTER FOUR:

RESULTS AND DISCUSSION

Introduction

This chapter presents and discusses analysed data and results from the interviews, focus group discussion, flood participatory mapping and the household survey. The chapter is presented based on the objectives of the study. It gives results and discussion on the various aspects of vulnerability, exposure, sensitivity and adaptive capacity in the communities. The results have been presented in the form of narratives from the transcripts and statistical graphs or charts, tables, indices and maps.

Sociodemographic Characteristics of In-depth Interviewees (IDI) and Focus Group Discussions (FGDs), and Survey Respondents.

The Socio-demographic characteristics of the participants in the in-depth interviews and focus group discussions are presented in Table 2. A total of eight (8) participants were interviewed and a total of 81 participants participated in the FGDs. All the interview participants were males because all the communities studied had male leaders. Five (5) female FGDs and four (4) male FGDs were conducted. In the table, the ages of the in-depth interview participants range from 39-85. Five (5) of the participants were chiefs and two were chief regents with one (1) NADMO official. Six (6) of them had had attained basic education, one (1) attained secondary-technical and the NADMO official attained tertiary level of education. Majority of the participants were fishermen with one mason, a carpenter and a NADMO official.

In the second section of the table present the socio-demographics of the FDGs participants. In Blekusu, the age of the females ranges from 39-83 and the men ranges from 54-77. The females were fish processors, petty traders, coconut oil producers and vocational workers with 60% having basic education attainment whiles the men were fishermen and vocational workers with 90% having basic education attainment. In Agavedzi, the age of the females ranges from 45-71 and the men ranges from 29-68. The females were fish processors, petty traders, salt winners and vocational workers with 60% having basic education attainment whiles the men were fishermen, salt winners and vocational workers with 90% having basic education attainment. In Salakope, the age of the females ranges from 50-82 and the men ranges from 52-80. The females were fish processors, petty traders, salt winners and vocational workers with 60% having basic education attainment whiles the men were fishermen, salt winners and vocational workers with 60% having basic education attainment. In Amutsinu, the age of the females ranges from 42-70 They were fish processors, petty traders, salt winners and vocational workers with 60% having basic education attainment. In Adina, the age of the females ranges from 42-81 and the men ranges from 50-68. The females were fish processors, petty traders, salt winners and vocational workers with 70% having basic education attainment whiles the men were fishermen, salt winners and vocational workers with 90% having basic education attainment.

Table 3: Socio-demographic Characteristics of In-depth Interviewees (IDI) and Focus Group Discussions (FGDs).

IDI	**Community**	**Participant**	**Gender**	**Age**	**Education**	**Occupation**
n=9	Blekusu-Aninime	Chief Regent	Male	72	Basic	Mason
	Blekusu_ Anyiheg-	Chief	Male	68	Basic	Fishing
	Blekusu-Dome	Chief	Male	68	Basic	Fishing
	Blekusu-Fetriki	Chief	Male	72	Basic	Carpentry
	Agavedzi	Chief	Male	85	Secondary - Technical	Retired engineer/ fishing
	Salakope	Chief	Male	68	Basic	Fishing
	Amutsinu	Chief Regent	Male	63	Basic	Fishing
		NADMO Officer	Male	39	Tertiary	NADMO official

	Community	**Group (size)**	**Gender**	**Age**	**Education**	**Occupation**
FGD n=81	Blekusu	8	Female	39-83	60% educated to basic level	Fish processors, petty trading, coconut oil production, vocational work.
		8	Male	54-77	90% educated to basic level	Fishing, vocational work
	Agavedzi	9	Female	45-71	90% educated to basic level	Fish processors, petty trading, salt mining, vocational work.
		11	Male	29-68	60% educated to basic	Fishing, vocational work

				level	
Salakope	8	Female	50-82	60% educated to basic level	Fish processors, petty trading, salt mining, vocational work.
	8	Male		60% educated to basic level	Fishing, vocational work.
Amutsinu	8	Female	42-70	60% educated to basic level	Fish processors, petty trading, salt mining, vocational work.
Adina	9	Male	4-68	60% educated to basic level	Fishing, vocational work
	12	Female	42-81	10% educated to basic level	Fish processors, petty trading, salt mining, vocational work.

Table 2 shows demographic characteristics of the structured interview respondents (household heads). Among the 354 respondents, 38.7% were male household heads while 61.3 % were female household heads. The most predominant age group accounting for 37.6% were above 60+ years, whiles 35% were between 40 and 59 years and 27.4% were between 20 and 39 years. This suggests that large proportions of household heads exposed to flood events are in the economically inactive age cohort. This is consistent with the responses from the in-depth interviews and Focus Group Discussions which revealed that the youth have migrated to other neighbouring coastal countries and communities because of limited livelihood options and environmental problems leaving the aged and children in the communities.

The majority of the respondents (71.8%) were married with a small proportion (3.1%) divorced, 4.2% single and 20.9% widowed. The highest level of education attained for most household heads was the basic level accounting for 59%, and 29.4% had no formal education, whiles 7.9% had secondary education and very few (3.7%) attained tertiary education.

Table 4: Socio-demographic Characteristics of Survey Respondents (Household heads)

Variables	Frequency	Percentage
Community (n=354)		
Blekusu	133	37.6
Agavedzi	62	17.5
Salakope	16	4.5
Amutsinu	17	4.8
Adina	126	35.6
Gender		
Male	137	38.7
Female	217	61.3
Age groups (years)		
20-39	97	27.4
40-59	124	35
60+	133	37.6
Marital Status		
Single (never married)	15	4.2
Married	254	71.8
Widowed	74	20.9
Divorced	11	3.1
Educational level		
None	104	29.4
Basic	209	59.0
Secondary	28	7.9
Tertiary	13	3.7

Table 5: Indicators for Exposure Index

Indicators	Max	Min	Adina	Amutsinu	Salakope	Agavedzi	Blekusu
Average flood frequency in community (per annum)	5.5	3.65	3.65	5.18	5.5	4.23	4.69
Average flood frequency in households (per annum)	5.75	3.067	3.13	4.29	5.75	3.66	3.067
Average flood duration (days)	22.19	6.06	22.19	11.412	6.06	12.53	18.64
Percentage of households with flood depth at waist height	29.03	88.24	71.43	88.24	87.50	29.03	81.20
Percentage of households that reported flood magnitude as more	81.95	67.74	74.60	76.47	75.00	67.74	81.95
Percentage of households who have experienced house property damage	88.71	64.66	69.84	76.47	75.00	88.71	64.66
Percentage of households who have experienced livelihood impacts	87.50	67.67	85.71	76.47	87.50	72.58	67.67
Percentage of households who had experienced	42.86	8.06	42.86	23.53	25.00	8.06	11.28

impact on water source							
Percentage of households who experienced impact on food source	94.12	81.25	92.06	94.12	81.25	88.71	74.44
Percentage of households who experienced health impacts	68.75	34.92	34.92	52.94	68.75	58.06	44.36

Table 6: Indicators for Sensitivity Index

Indicators	**Max**	**Min**	**Adina**	**Amutsinu**	**Salakope**	**Agavedzi**	**Blekusu**
Percentage of female headed households	82.35	56.35	56.35	82.35	81.25	59.68	61.65
Average household size	12.18	9.63	10.59	12.18	14.63	9.63	9.66
Number of children <5years	241	37	214	37	46	95	241
Number of elderlies >65yrs	171	13	111	13	16	52	171

Number of disables	92	3	43	3	5	39	92
Number of women	569	79	459	79	97	240	569

Table 7: Indicators for Adaptive Capacity Index

Indicators	Min	Max	Adina	Amutsinu	Salakope	Agavedzi	Blekusu
Percentage of households that receive early warning information on flood	18.80	53.97	53.97	23.53	31.25	27.42	18.80
Percentage of households that were aware of recent flood prior to flooding	0.00	22.58	11.11	17.65	0.00	22.58	12.78
Percentage of households that have community support to address flood risk	0.00	6.35	6.35	0.00	0.00	0.00	6.02
Percentage of households that receive government	0.00	38.35	2.38	0.00	0.00	11.29	38.35

intervention							
Percentage of households that are satisfied with government intervention	0.00	18.80	2.38	0.00	0.00	9.68	18.80
Percentage of households that recovers to the previous efficient state after a flood	0.00	53.97	53.97	41.18	75.00	37.10	49.62
Percentage of households that have flood insurance	0	3.76	2.38	0	0	0	3.759398
Percentage of households with multiple sources of income	0	73.68	71.43	52.94	56.25	67.74	73.68
Percentage of households with information assets	0	92.06	92.06	88.24	100	87.10	87.22
Percentage of households with transportation assets	35.29	51.88	40.48	35.29	37.5	51.61	51.88

Exposure of Communities to Coastal Floods in Ketu South Municipality

All five (5) communities studied in this project have experienced and continue to experience various forms of floods. Table 7 summarizes the data from the qualitative studies. It shows the communities and their various suburbs that had suffered from floods. Certain portions of some communities suffered some form of devastation from floods at some points in time when other suburbs did not have floods. Respondents could recollect vividly years in which they experienced extreme floods. In Blekusu, in-depth interview respondents could remember that the first ever flood they experienced which extremely affected Aninime suburb of the community was in 1956, followed by that of 1962 and in the years of 1982, 1992, 2006 and 2017. These floods were mainly caused by storm surges and tidal waves from the sea. Other causes were attributed to the low-lying nature of the Aninime suburb of Blekusu, inadequate sea defences and climate change.

During the flood events, water on the surface could reach up to the waist height in depth ((**110.5)**. Other suburbs of Blekusu including Anyiehega, Dome and Fetriki suffered similar havocs caused mainly by storm surges in different years. FGDs revealed that while communities like Salakope began to experience flooding episodes since, 1966 till the present-day others like Adina had their first experience of flood in 2011, which is about ten years ago. Results revealed that certain communities like Blekusu and Agavedzi flooded only by the sea while others like Salakope, Adina and Amutsinu are flooded by both the sea and the lagoon. In addition, communities have generally observed the increasing intensity of the phenomena of flooding.

Table 8: Results on Flood Exposure in the Communities

Community	**Location**	**Exposure to flooding events**							
		Flood experience	***Year (s) and types of flooding***	***Sources***	***Causes***	***Rate***	***Duration***	***Depth/ cm***	***Intensity over time***
Blekusu	Aninime	Extreme flood events	1956,1962, 1982, 1992, 2006, 2017 from storm surges and tidal wave flooding	Sea	Low-lying area community, the sea level is above the land, under sea eruptions	1-10 years from June through to December	1 month	Waist height **(110.5)**	Increasing
Blekusu	Anyihega a chief palace	Extreme and minor flooding	Started in 1963 to 2018 from storm surges	Sea	Rise in sea level	1-10 years	3-weeks	Waist height **(110.5)**	Increasing

Blekusu	Dome	Extreme and minor flooding	Started in over 50yrs now, from storm surges	Sea	The sea rises to a level higher than the community and starts to surge on us.	1-4 years during the rainy seasons	Days	Increasing
Blekusu	Fetriki	Extreme and minor flooding	Started in 1963 to 2018 from storm surges	Sea	Turbulent nature of the sea, rise in sea level during heavy rainfalls, pushing of the sea Towards Africa with artificial islands and built ups.	Every year		
Agavedzi	Chief palace	Extreme and minor flooding	1987, 1995, 2017, 2018 from storm surges	Sea	Climatic changes	2-3 years		Increasing
Salakope		Extreme	1966-2021	Sea and	Climatic	Every year	Days	Increasing

	and minor flooding		lagoon	changes and Sea defences				
Adina	Extreme and minor flooding	2011, 2015	Sea and lagoon	The level of the sea during these events rose the community roofs top levels and surged on the community	Every year, in June, July and August	3 weeks	Waist level **(110.5)**	Increasing
Amutsinu	Extreme and minor flooding	1982 to date	Sea and lagoon	Not known		3 weeks	Knee level (59.2)	Increasing

Table 8 shows the proportion of households as against the type of flood they suffered from as recorded during the structured interviews. The houses of the communities were located south (coast ward) and north (lagoon ward) separated by the main Keta to Aflao road. The location of the housing structures influences to an extent the types of floods suffered by households. Hence, those located at the north (lagoon ward) may be affected more from lagoon floods as compared to those located south. Overall, 95% of the houses located at the south were affected by flooding from the sea, while only 3.7% and 1.4% of houses located there were impacted by flooding from lagoon and heavy rainfall respectively. Among all the houses located in the north (lagoon ward), 48.9% of them were affected by flooding from the lagoon while 39.3% were affected by flooding from the sea and the remaining 11.9% had problems with floods from rainfall. In specific communities like Amutsinu and Salakope, there were no houses to the north of the main road hence no record of flooding from the lagoon was recorded. However, in places like Agavedzi and Adina, as many as 65.5% and 55.8% respectively of houses located north ward were affected by lagoon floods. Summarily in Figure 13, the majority of households in the communities suffered from floods from the sea.

Table 9: Proportion of Households and the Type of Flood Experienced

Communities	Location	Proportion (%) of household by type of flood they suffered from			n
		Flooding from sea	Flooding from lagoon	Flooding from rainfall	
Adina	Coast	95.9	0	4.1	74
	Lagoon	25	55.8	19.2	52
Amutsinu	Coast	100	0	0	15
	Lagoon	100	0	0	2
Salakope	Coast	100	0	0	14
	Lagoon	100	0	0	2
Agavedzi	Coast	100	0	0	33
	Lagoon	34.5	65.5	0	29
Blekusu	Coast	90.4	9.6	0	83
	Lagoon	52	36	12	50
Total (mean)	Coast	95	3.7	1.4	219
	Lagoon	39.3	48.9	11.9	135
	Total	73.7	20.9	5.4	354

From the participatory mapping and the Google Earth platform, the total ... e 9 ... the ... and ... n a ... 9m^2 ... area ... a is ... and ... d a

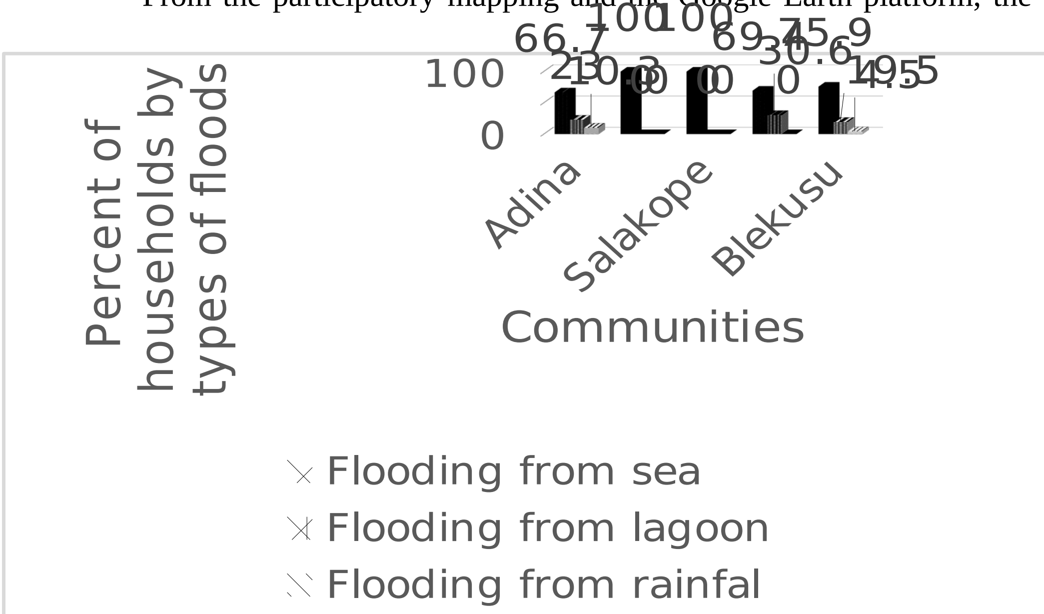


Figure 13: Percent of households by types of floods in the communities

similar compound flood event. The flood spanned over 3,535,250 m^2 of Adina's total land area of 5,694,336 m^2 representing 62 percent of the land area. Whiles in Salakope 74,224 m^2 land area was affected out of 126,042m^2 total land area. This flood coverage represents 59 percent of the total land area of Salakope.

The table also shows that the heights of the floods were at waist level (**110.5)** in Blekusu, Agavedzi as well as in Adina, and at knee level **(59.2)** in Amutsinu and Salakope. Results in the table shows the properties and infrastructure that were affected and included houses, roads, pipes that carry treated water, wells, cemetery, church, sacred forests, fish landing sites and fish smoking sites. The coordinates of the most recent extreme flood extents are mapped in Figure 14, 15, 16, 17 and Figure18 to enhance the visualization and appreciation of the flood extents in the various communities.

Table 10: Recent Extreme Flood Characteristics

Community	Type of flood	Year	Total Land Area/m²	Flood extent/ m²	%	Depth/cm	Properties/Infrastructure affected
Blekusu	Storm surge	2018	836,293.36	496,915.48	60	Waist height (**110.5**)	Houses, roads, water pipes, wells, and cemetery
Agavedzi	Storm surge	2018	368,311.38	81,651.69	22.2	Waist height **(110.5)**	Houses, roads, water pipes, wells, and cemetery
Salakope	Tidal wave and lagoon overflow	2015	126,042	74,224	59	Knee height (**59.2)**	Sacred grove, road, houses, church, wells.
Amutsinu	Tidal wave and lagoon overflow	2015	320,782	216,621	68	Knee height (**59.2)**	Houses, wells and cemetery
Adina	Tidal wave and lagoon overflow	2015	5,694,336	3,535,250	62	Waist height (**59.2)**	Houses, fish landing sites, fish smoking sites, roads, wells, church and cemetery

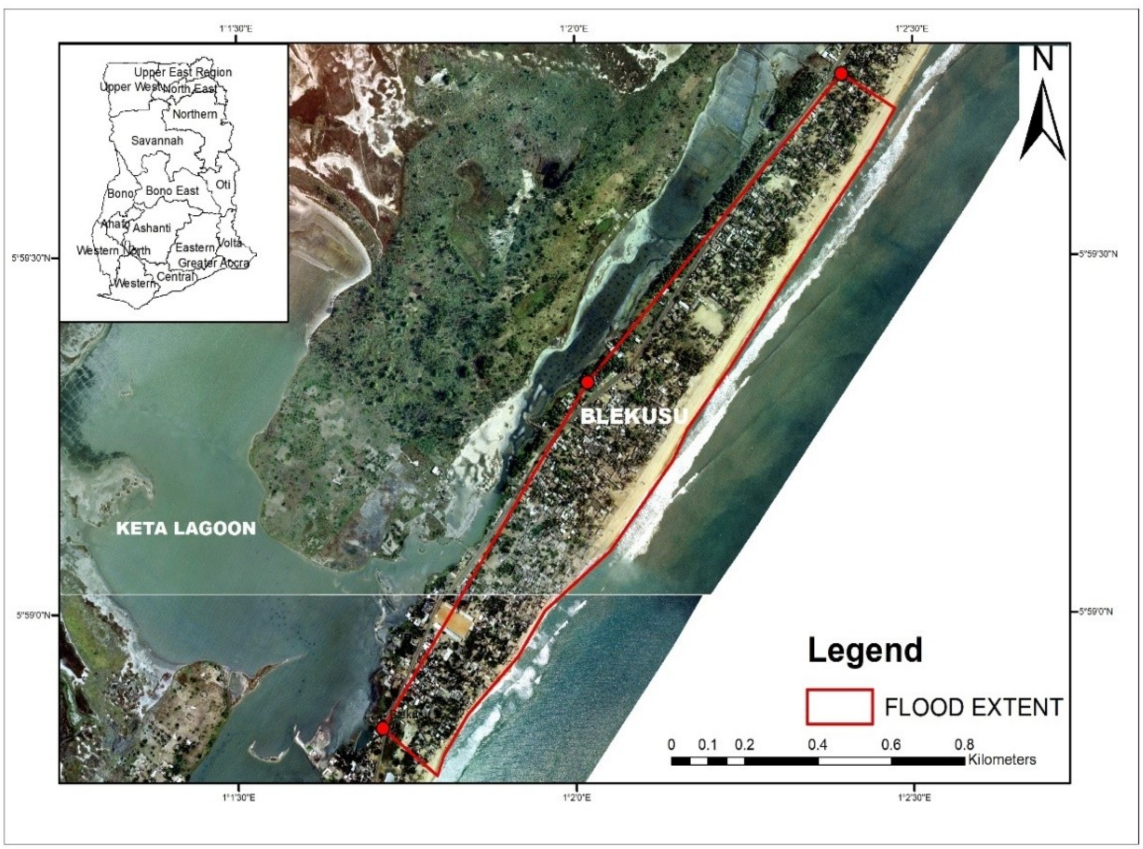


Figure 14: Recent flood extent map of Blekusu

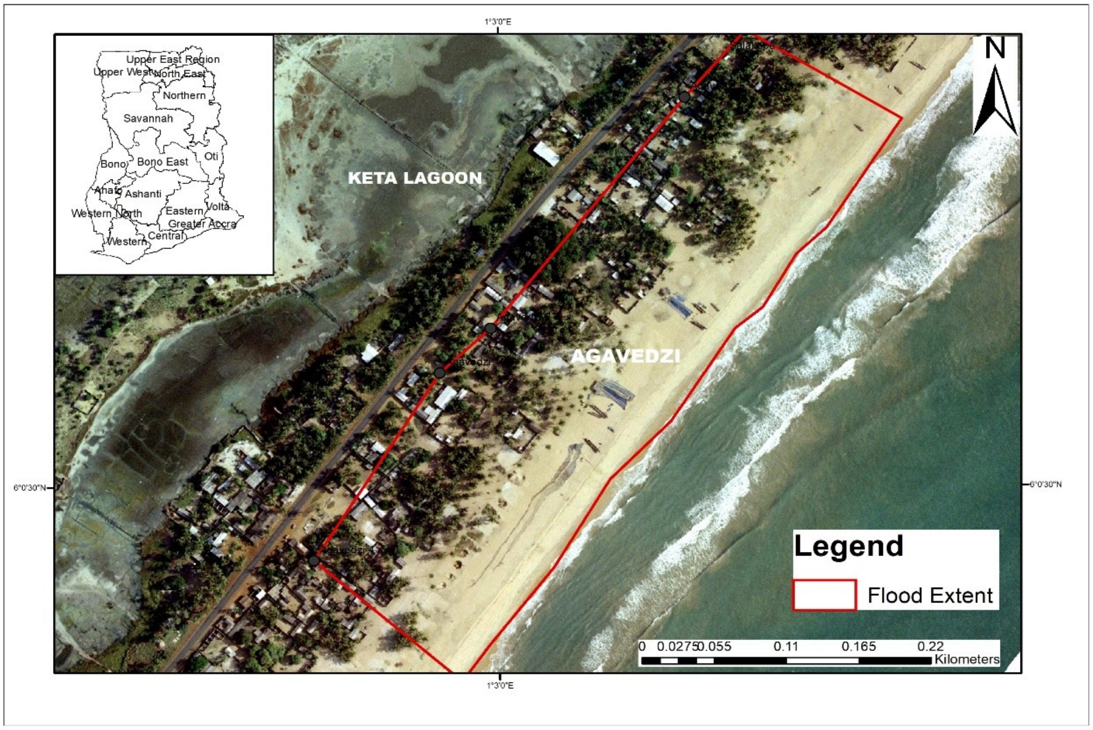


Figure 15: Recent flood extent map of Agavedzi

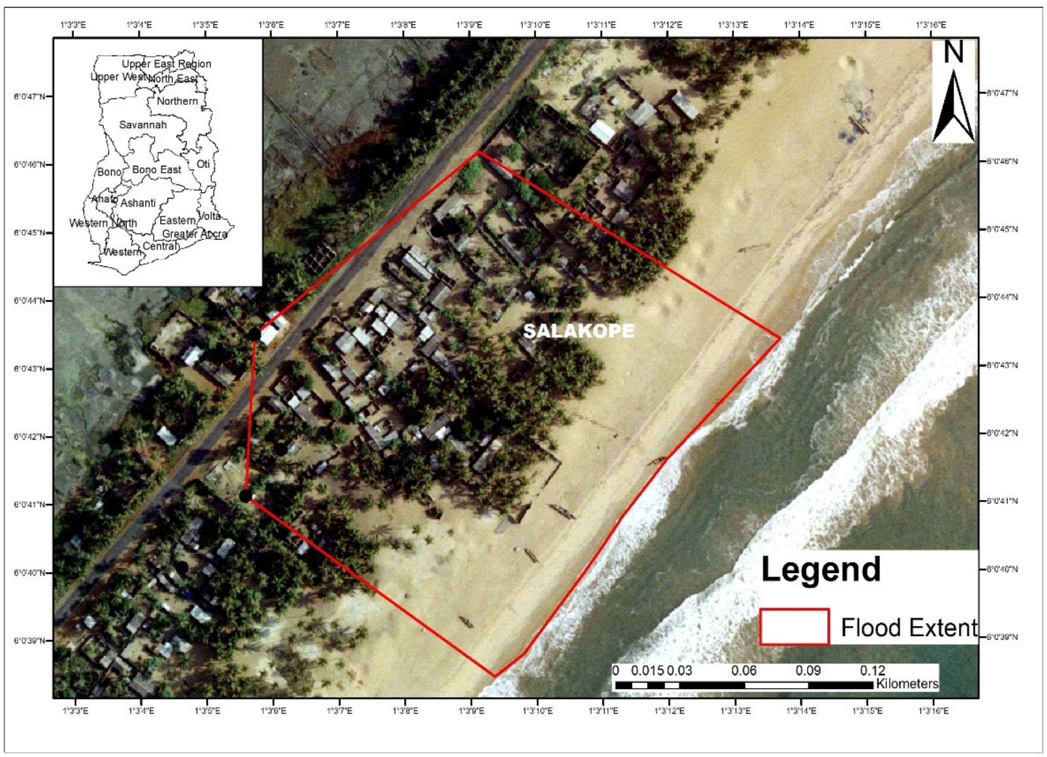


Figure 16: Recent flood extent map of Salakope

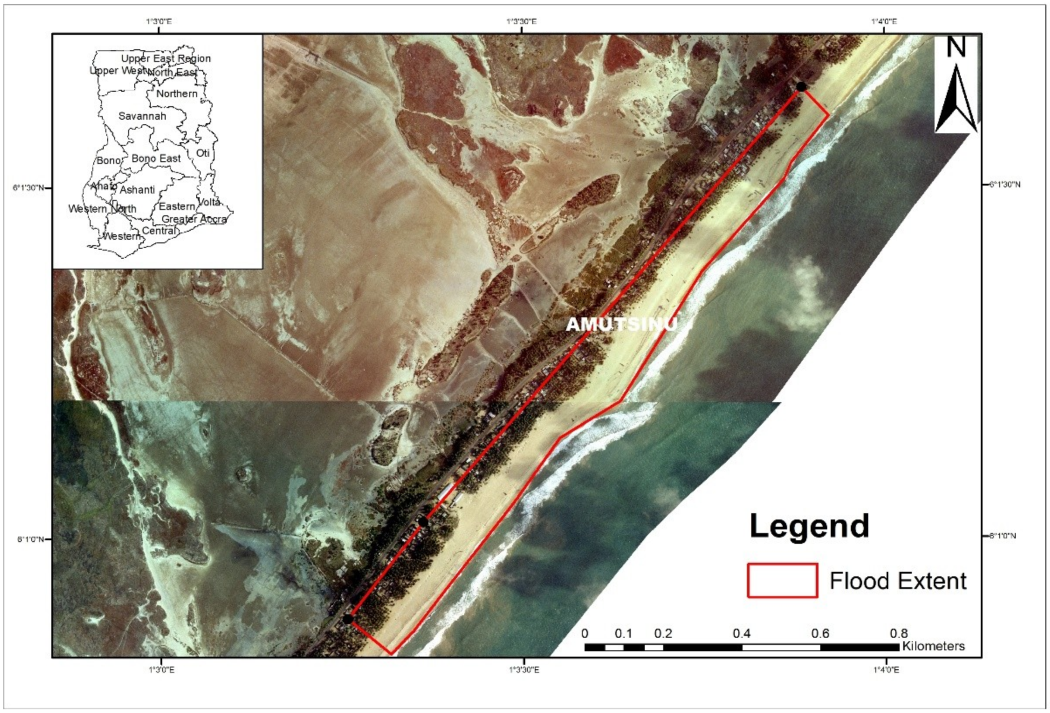


Figure 17: Recent flood extent map of Amutsinu

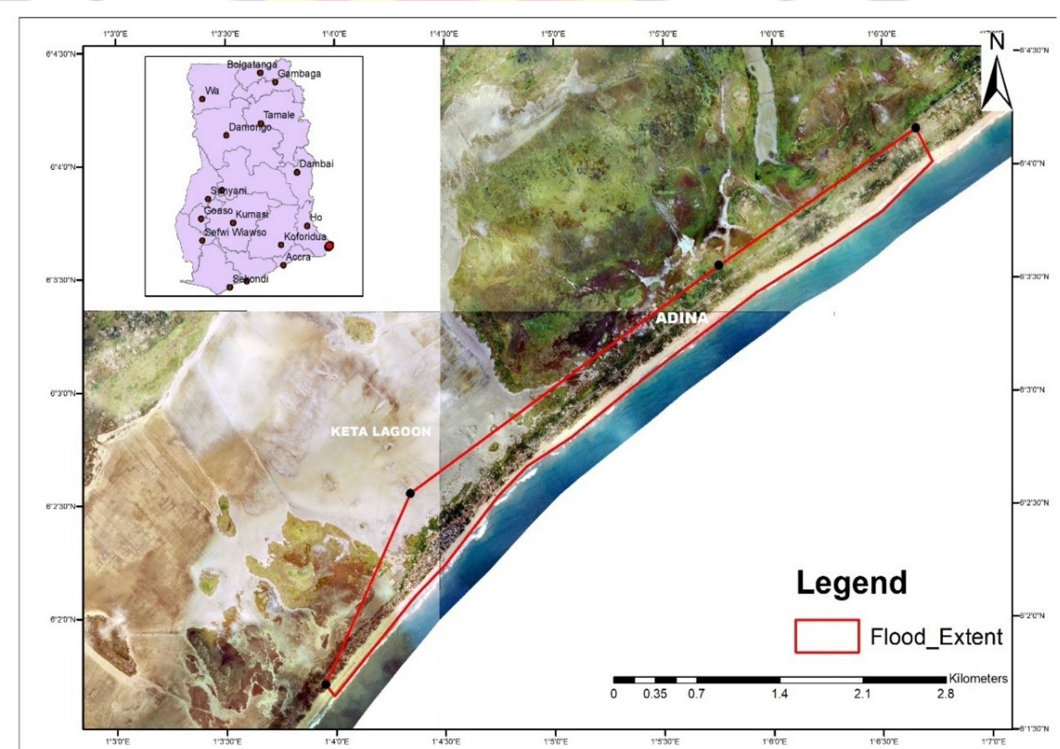


Figure 18: Recent flood extent map of Adina

Factors Influencing Vulnerability of Coastal Communities to Floods in Ketu South Municipal Area

Responses from the in-depth interviews explain that extreme flood (storm surges) occurrence in the communities dated as far back as two decades ago while minor tidal flood events or lagoon overflows coupled with heavy rainfall dated as far back as 1950s to date. Respondents also attributed the cause of these flood events to the construction of the Keta Sea Defence system. This defence system was constructed in the late 1990's and early 2000s. Respondents were of the view that until the construction of the Keta Sea Defence system, their areas were only occasionally affected by coastal floods. Some other respondents thought that the rampant floods could also be attributed to the effects of climate change, especially, sea level rise. The low elevation of the land in the areas also was mentioned as a contributory factor. The following is a response on how often flood occurs in Blekusu community:

> *"To my experience, flooding from the sea started in 1956 followed by 1962, 1982, 1992, 2006 and 2018 was the most extreme one. This means that it recurs in every 10 years"* (male, 72).

In Blekusu, a respondent opined that:

> *"Our land is a low-lying area where the normal sea level is above the land, making the sea to have way to flood us. Also, under sea eruptions causes the sea level to rise and surge on us*" (male, 72);

Another stated in Agavedzi that:

> *"We have been experiencing flooding from the sea climatic changes and it started from Horvi, Blekusu to our community, Agavedzi and is continuing to the other communities, eroding along the beaches"* (male, 85);

Another confirmed in Salakope that:

> *"The sea is raising the water table and finding a way to join with the lagoon which is likely to complicate flooding events in the community. This is because of the Keta Sea Defence and inadequate sea defences along the coast that is having a knock-on effect on the communities that are not protected with the sea defence structures. For example, the sea defences from Blekusu to Agavedzi has shifted the effects of the sea flooding and erosion to the Amutsinu and Salakope which are the neighbouring communities. The effect is such that the sea erodes the beach of Salakope and Amutsinu to build that of Agavedzi. Aside this, the sea is also raising the water table which can affect recession of floods"* (male, 68).

The in-depth interviews further confirmed that communities faced rampant flooding events. The latest of such major flood events occurred in the year 2018 and affected mostly Blekusu and Agavedzi communities. Respondents confirmed that houses in the south (coast ward) were prone to floods because they were closer to the sea. Summing it up, the NADMO official who was interviewed attributed the vulnerability of communities to coastal floods to anthropogenic activities including the rampant winning of sand and pebbles from the beach. He also mentioned that climate change could be a contributory factor because previously flood issues along the coast occurred in July and August but in recent years and especially the present year (2021), it started occurring from April. The following is a response of a NADMO official on flood exposed communities:

> *"Anthropogenic activities such as sand and pebble winnings are making the beach vulnerable to coastal flood and climate change also has a part to play because previously flood issues along the coast usually occur from July to August but this year, it has started occurring already from April"* (male, 39).

Participants in the FGDs grouped floods into four including: (i) extreme flood events which are caused by storm surges and occur every three (3) to 10 years. (ii) nuisance floods from high tidal waves that occur every year and (iii) floods from lagoon overflow and heavy rainfall and/or (iv) a compound flood which is a combination of two or more of the above-mentioned sources. Responses revealed that storm surges occur every three (3) to 10 years. They are characterized with high rises of the sea waves, mostly to the height of buildings. Most of the time storm surges occur at midnight with rampant surges into the communities. A response on flood exposure in Fetriki, a suburb of Blekusu:

> *"Flood disturbances from the sea started at Keta and Kedzi in 1963 with severe impacts but have become more intense in our community recently. It usually surges at midnight. It starts by giving signs of high sea level*

around 3:00pm and getting to 1:00am it can rise up to our roofing level before surging on the community" (male, 72).

The storm surges often lead to extreme flooding of the communities, and the flood lasts for two to three weeks maximum. The depth of the floodwaters is up to knee level and occasionally rise up to the waist level (Figure 19). Households evacuate from their homes to seek refuge in temporal shelters on their basic schools' compounds. Houses that are close to the sea during these times are completely destroyed and washed into the sea with other properties such as livestock, belongings and coconut plantations. The coastline during these times also suffers severe erosion. A response on flood duration in Amutsinu:

"Some storm surges can take three weeks and some two months to drain but with the tidal waves flooding some can take three days or some weeks because we have a lot of sand over here" (male, 63).

A response on the impacts of floods in Blekusu community:

"When there is flooding, no one works, the fishing activities stop because the sea becomes turbulent at this time and also, with the petty traders, they are not able to walk through the flood to the market to buy things and come and sell, so the flooding locks all these activities. It destroyed the houses that are closer to the sea, it breaks the houses and completely eliminate them and would deprive you of where to lay down your head. The flood extremely impacts us and does not give room for recovery. The latest one destroyed our fish smoking stoves, took our houses away and we are left with nothing to recover with" (male, 68).

Figure 19: 2018 storm surge flood event in Blekusu

Source: Fieldwork, 2021

There are also reports of displacement of households during flood events. Aside temporal relocation into available classrooms in the communities, household properties such as televisions, furniture, livestock, cooking utensils and others are lost during flood events. Again, flood events are also associated with health implications such as surge in cholera, trauma, fever, skin rashes and malaria among other diseases.

In Figure 20, respondents reported the type of damages caused by flood at household levels. In Adina, approximately 61% of respondents reported of damages to their housing structures, 20% reported loss of livestock and 19% reported loss of livelihoods. In Amutsinu, approximately 62% of respondents reported of damages to their housing structures, 19% reported loss of livestock and 19% reported loss of

livelihoods. In Salakope, 42% of respondents reported of damages to their housing structures, 32% reported loss of livestock and 26% reported loss of livelihoods. In Agavedzi, all the respondents (100%) reported of damages to their housing structures with none reporting for loss of livestock, loss of livelihoods and lives. In Blekusu, 41% of respondents reported of damages to their housing structures, 27% reported loss of livestock and 32% reported loss of livelihoods.

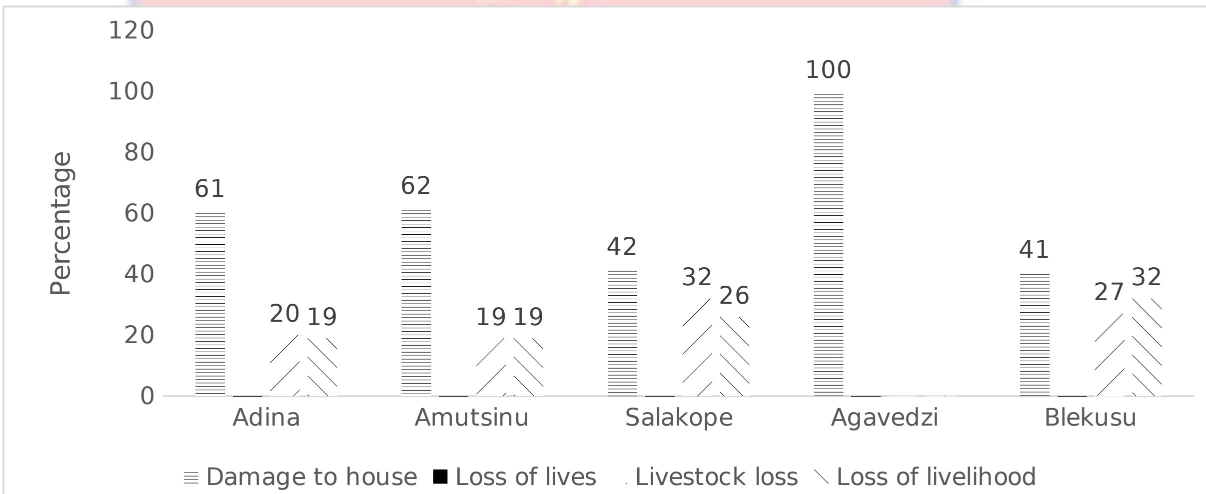


Figure 7: Responses on flood damages at household levels

In Figure 21, respondents reported the surge in episodes of malaria, cholera, trauma and skin rashes as common effects of the flood events. In Blekusu, while 56% of respondents reportedly experience none of the health impacts, trauma, 10% reported cholera, 30% reported trauma, and 4% reported malaria. In Agavedzi, while 37% of respondents experience none of the health impacts, 6% reported cholera, 30% reported trauma, 32% reported skin rashes and

14% reported malaria. In Salakope, 23% of respondents experience none of the health impacts, 13% reported cholera, 50% reported trauma, and 14% reported malaria. In Amutsinu, 42% of respondents experience none of the health impacts, 5% reported cholera, 48% reported trauma, and 5% reported malaria. In Adina,

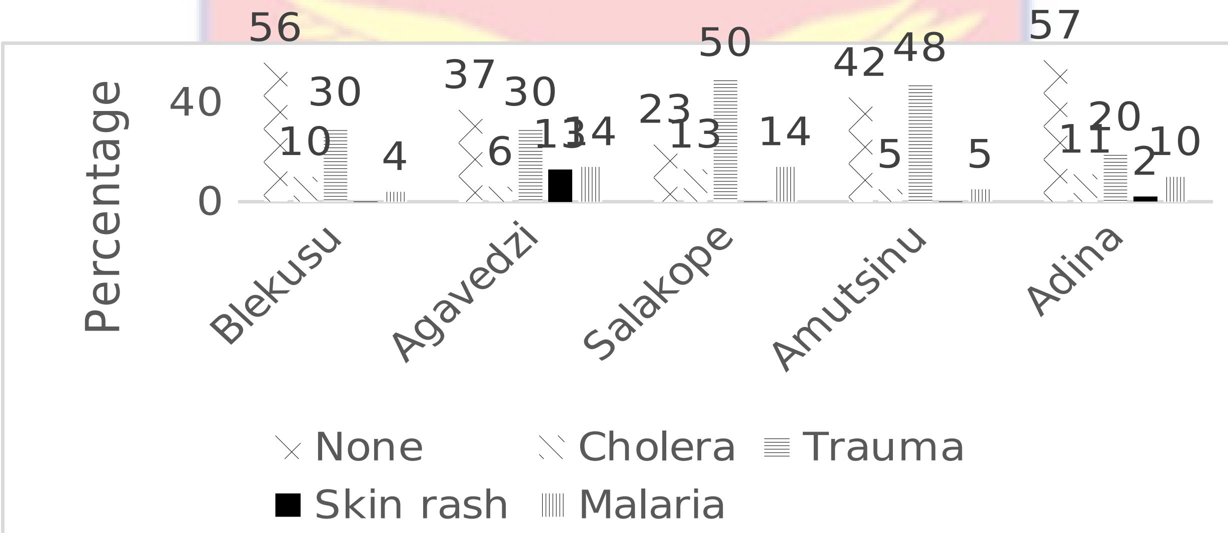


Figure 21: Responses on health impacts from flood

while 57% of respondents experience none of the health impacts, 11% reported cholera, 20% reported trauma, 2% reported skin rashes and 10% reported malaria.

On whether the respondents had ever experienced floods in their communities, all the respondents attested to the fact that they have had experiences of flood events in the communities. In Figure 22, majority of the respondents, attributed the most disastrous flood events in the communities to sea flooding which occurred in 2018. That flood event was characterized with storm surges and tidal waves floods. In Adina 67% of the respondents attributed the most disastrous flood to sea flooding, 23% attributed it to lagoon flooding in 2015 and 2018 caused by lagoon overflow and 10% attributed it to rainfall in 2015. In Amutsinu and Salakope all the respondent (100%) with none attributing it to neither lagoon flooding nor rainfall. In Agavedzi 69% of the respondents attributed the most disastrous flood to sea flooding and 31% attributed it to lagoon

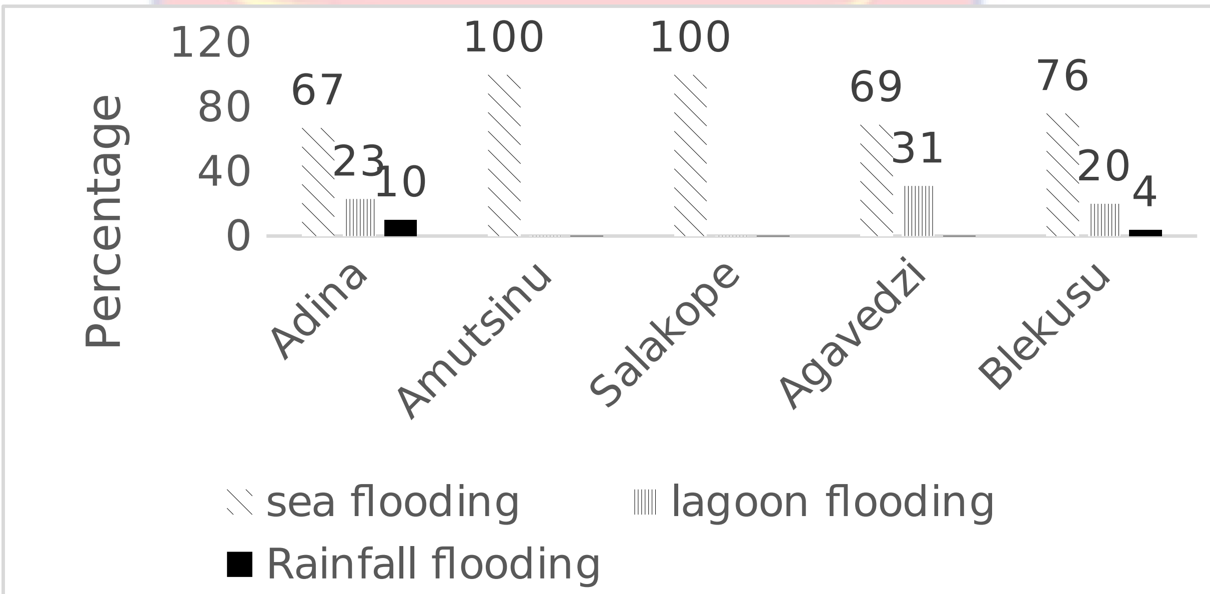


Figure 22: Responses on most disastrous flood events

flooding in 2015 and 2018 caused by lagoon overflow. In Blekusu, 76% of the respondents attributed the most disastrous flood to sea flooding, 20% attributed it to lagoon flooding in 2015 and 2018 caused by lagoon overflow and 4% attributed it to rainfall in 2015.

Figure 23 shows the responses on the latest flood causes. Majority of the respondent attributed it to high tidal wave. In Adina, 44% of respondents attributed flood causes to high tidal waves, 11% attributed it to storm surges, 12% attributed it to lagoon overflow and 33% attributed it to heavy rainfall. In Amutsinu, 94% of respondents attributed flood causes to high tidal waves, 6%

and attributed it to storm surges. In Salakope, all the respondents (100%) reported only high tidal wave as the cause of floods. But in Agavedzi, 63% of respondents

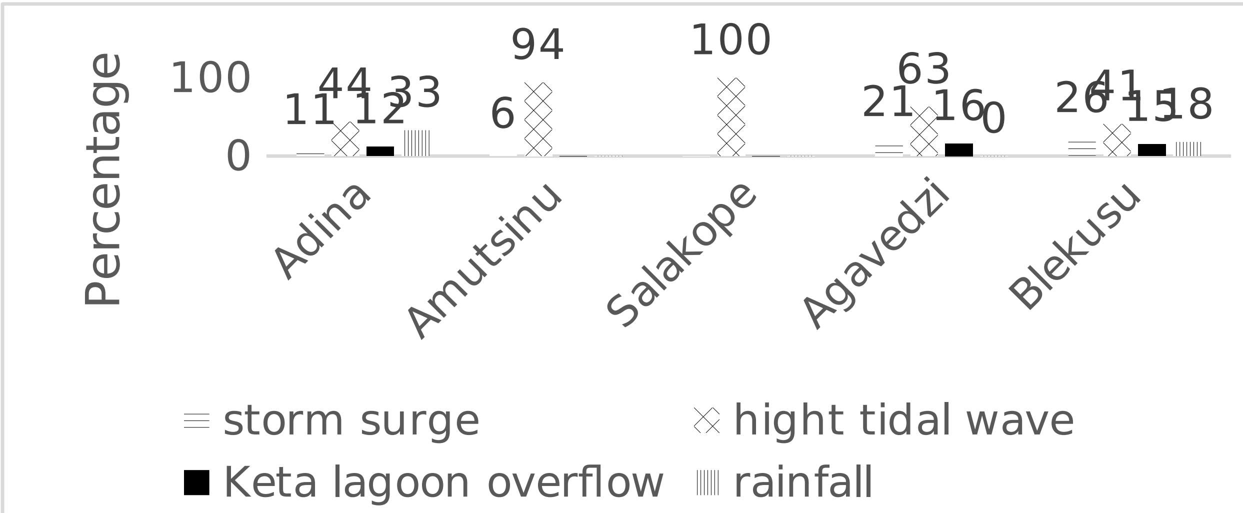


Figure 23: Responses on causes of flood events in the communities

attributed flood causes to high tidal waves, 21% attributed it to storm surges and 16% attributed it to lagoon overflow whiles in Blekusu, 41% of respondents attributed flood causes to high tidal waves, 26% attributed it to storm surges, 15% attributed it to lagoon overflow and 18% attributed it to heavy rainfall.

Results further revealed that anthropogenic and natural factors are responsible for the communities' vulnerability to flood hazards. The anthropogenic causes include dugout channels for salt production activities (Figure 24), inadequate and improper construction of sea defence and relocation of displaced households to flood prone areas (Figure 26), as well as the rampant winning of sand and pebbles from the beach as indicated by the NADMO official. The natural factors on the other hand include rise in coastal water table, and rapid shoreline recession (Figure 25). A respondent in Salakope commented on inadequate sea defence structures and rising water table as follows:

"The encroaching sea is raising the water table and finding a way to reach the lagoon which is likely to complicate flooding events in the community. This is because of the Keta Sea defence and inadequate sea defences along the coast that is having a knock-on effect on the communities that are not protected with the sea defence structures. For example, the sea defences from Blekusu to Agavedzi has shifted the effects of the sea flooding and erosion to the Amutsinu and Salakope which are the neighbouring communities. The effect is such that the sea erodes the beach of Salakope and Amutsinu to build that of Agavedzi. Aside this the sea is also raising the water table Aside this the sea is also raising the water table which can affect recession of floods" (male, 68).

Another respondent in Blekusu also commented as follows:

"No one can predict when the sea would cause flooding. But before it floods the community, the sea level can rise to the level of our roof tops giving a clear sign that it would flood us. The sea itself was discovered to be raising the water table close to the top soil. This means the sea is now under the community which makes it easy for the sea to flood us extremely because it reduces the recession period of the flood" (male, 68).

From both the qualitative and quantitative studies, results revealed that factors such as age dependent groups, disables, high population of female headed households (Table 5), high population of females (women), low level of education

(Table 5), low diversification of livelihood, low income, and large household sizes (decrease social capital) are the socioeconomic factors affecting the vulnerability of the communities. A respondent in Salakope responded on livelihood sources and the current social system conditions in the communities as follows:

"The only livelihood in this community is fishing and because of the erosion and encroachment of the sea on our fish landing sites the effectiveness of fishing activities in the community has reduced. Aside fishing, there is no other livelihood, it is only God that is taking care of us now"; and

"The population in houses has now increased because a lot of households have been displaced and they are seeking shelter in houses that are not displaced" (male, 68).

Some FGD respondents in Blekusu and Amutsinu explained that decreasing livelihood options and persistent flood events in the communities have compelled the youth (the working group) to migrate to other places leaving elderlies and children in the communities.

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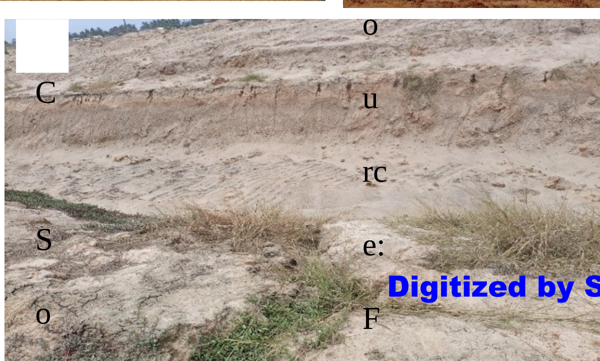

Figure 24: Dugout reservoirs to collect sea water for salt (A, B and C)

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Source: Fieldwork, 2021

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Figure 26: Houses that have been relocated into the dry areas of the Keta Lagoon.

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Source: Fieldwork, 2021

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Figure 25: A recessed shoreline in Salakope

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Source: Fieldwork, 2021

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Source: Fieldwork, 2021

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Adaptation Strategies

Despite the exposure and sensitivity to flood in the communities the study identified response strategies of community members used to minimize flood vulnerability in the communities. Community solidarity or social capital as one of the adaptive strategies during flood events. This solidarity inures to community efforts at rescuing and transferring people (aged, children) and properties during flood events to safe havens. Basic school compounds were mainly the safe havens for households that have been ravaged by floods. Households relocate and reside on the school compounds until the flood recedes from their homes after which they return. Households who lost their houses as a result of the flood, move to seek shelter with relatives and neighbours. Another support that is received by those who suffer from floods come from the Government of Ghana through NADMO. This support includes plastic cups, plates, five (5) Kg bag of rice for each household and a few roofing sheets to the communities. A respondent in Blekusu commented on flood disaster reduction measures as follows:

"As I have said, when there is flooding, with the last or current one that happened, the community had to lodge at the school's mission with their belongings. We don't use any vehicle to convey our belongings to the mission, we only try to manage to get them to the school mission. And with our canoes, we only try to find a place to tie them with ropes to a coconut tree, or do anything possible to avoid the sea flood from taking them away into the sea. Petty traders with grocery stores raise platforms for their items during the floods" (male, 68).

flood.

nerability to coastal flood.

flood.

Adding to the flood response measures, some displaced households have been relocated to the dry lands of the stretch of the Keta lagoon at the back of the communities. This is a case for Adina and its suburb minor community, Salakope. Other responses from the FGDs in Agavedzi revealed that Agavedzi community have local institutional policies in terms of salt resource mobilization in place where community leaders allocate their members to salt mining activities in order that every member get a share, The income generated is saved as insurance to prepare against flood events. Whiles at the individual household levels, sand heaping around the houses to prevent flood water from entering the house is the most common adaptive strategy used in the various communities. The communities also create channels during flood events to drain the water into the lagoon or dugout holes (Figure 27). Aside all these measures, it has been reported that some youths have also migrated to neighbouring coastal communities in response to the flood events.

Figure 27: A dug out hole for collecting flood water

Source: Fieldwork, 2021

Source: Fieldwork, 2021

production that were said to threat the vulnerability to coastal flood.

Figure 28 presents the responses on local flood adaptation strategies in the communities. In Adina, 45% of the respondents rely only on sand heaping around their house to prevent the flood from entering their house, 17% rely only on creating house to house channels to drain water from their flooded houses and 4% rely only on community channels that are created to drain water from the community into the lagoon whiles 27% rely on the combination of any of these strategies and 27% have no local adaptation strategies. In Amutsinu, 29% of the respondents rely only on sand heaping around their house to prevent the flood from entering their house whiles 71% have no local adaptation strategies. In Salakope, 31% of the respondents rely only on sand heaping around their house to prevent the flood from entering their house, 31% rely only on creating house to house channels to drain water from their flooded houses whiles 69% have no local adaptation strategies. In Agavedzi, 44% of the respondents rely only on sand heaping around their house to prevent the flood from entering their house, 6% rely only on creating house to house channels to drain water from their flooded houses whiles 18% rely on the combination of any of these strategies and 32% have no

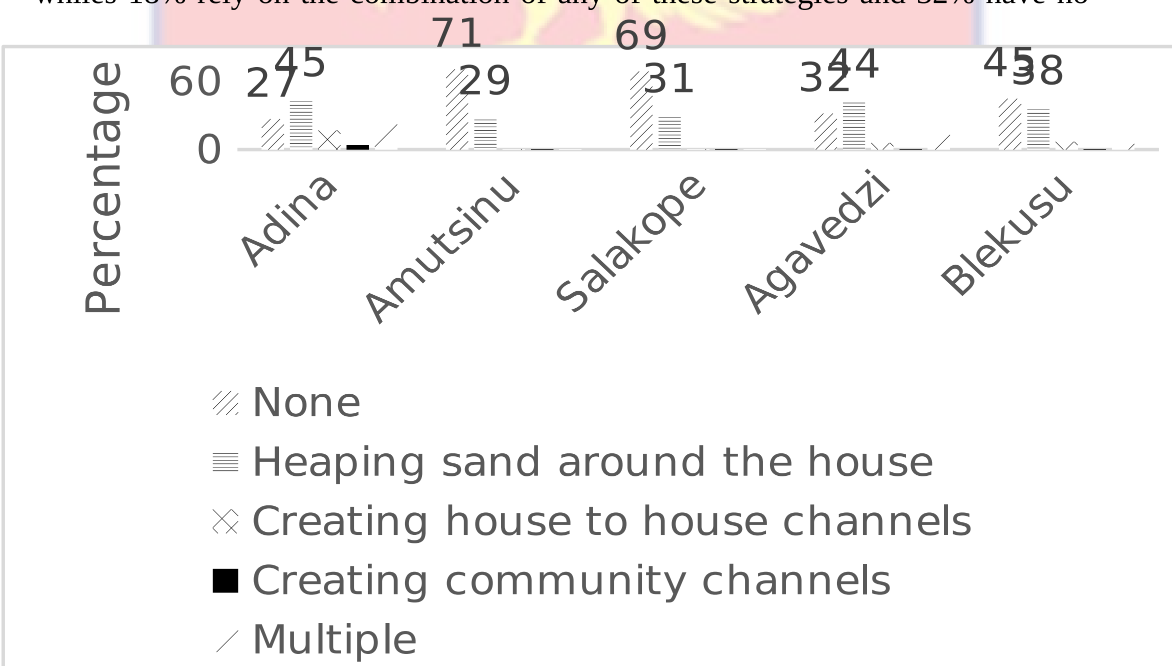


Figure 28: Responses on local flood adaptation strategies

local adaptation strategies. In Blekusu, 38% of the respondents rely only on sand heaping around their house to prevent the flood from entering their house, 7% rely only on creating house to house channels to drain water from their flooded houses whiles 10% rely on the combination of any of these strategies and 45% have no local adaptation strategies.

The officer from NADMO indicated that his office has structures through which it responds to disasters such as the flood events. These structures include the Zonal Coordinator and the Disaster Group Volunteers (DVGs). While the DVGs are community volunteers who are residents of the various communities and therefore reside there, and the Zonal Coordinator is a staff of NADMO. In the event that flood occurs in any of the communities, the DVG communicates with the Zonal Coordinator, who visits the communities and conducts rapid assessment and liaise with the municipal NADMO office for remedial actions. He commented as follows:

"When we receive flood disaster information from the zonal coordinator, we send SOS to the regional office, then the regional office also forwards it to the national office but if we have a stock of relief items, we do our assessment to know the number of households that are affected and we go and give our relief to them but currently we do not have any relief items. Relief items are in the form of food, mattresses, blankets, and sometimes Wellington boots" (male, 39).

He also added that the organization carries out sensitization activities to stop sand winning and stone mining from the shores as this could be the cause of floods in the communities. However, NADMO has a retreatment adaptation measure in place for the communities. According to the respondent, sea defence construction is capital intensive and a long-term project and therefore the easiest adaptation option is to relocate the communities to a site behind the stretch of the Keta Lagoon in the Ketu South Municipal.

Vulnerability Indices for the Exposed Communities

Table 10 presents flood exposure, and sensitivity, indices for the communities as well as the potential impact, adaptive capacity and composite vulnerability indices. Adina, Amutsinu. Salakope, and Agavedzi have scored high, 0.48, 0.51, 0.54 and 0.44 respectively while Blekusu had medium score, 0.23 of flood exposure. The table shows that, Adina, Salakope, Amutsinu and Blekusu have high scores for sensitivity, 0.51, 0.51, 0.33 and 0.7 respectively, while Agavedzi recorded medium sensitivity that is, 0.23. In Appendix 2, results revealed that Blekusu had higher number of children (241), aged (171) and women (569). Adina followed suit with 214 children, 111aged and 459 women. These two communities therefore recorded higher sensitivity index as stated above.

Table 10 also presents the potential impact indices of the communities. Potential Impact is a combination of flood exposure index and sensitivity to understand the level of impact a community would face from a flood hazard. From the table, Salakope has the highest potential impact 1.05 with the rest Adina, Amutsinu, Agavedzi and Blekusu recording high potential impact at 0.99, 0.85, 0.63 and 0.93 respectively.

The adaptive capacity index ranges from 0.37 to 0.95. Blekusu, Adina and Agavedzi had higher adaptive capacity 0.95, 0.68 and 0.65, respectively, while the other communities, Amutsinu and Salakope had least scores, 0.37 and 0.43 adaptive capacity, respectively. Higher percentage of responses on having institutional (government and community institutional) supports, access to early warning information, formal education, information assets, transportation assets, recovery to previous efficient state and higher average income levels for Blekusu, Agavedzi and Adina (Appendix 3) are the main contributory factors to their high score on adaptive capacity as compared to the other communities.

The table also presents the composite vulnerability scores for the communities. Salakope and Amutsinu scored, 0.64 and 0.45 respectively indicating that they are more vulnerable, while Adina, Agavedzi and Blekusu relatively lower vulnerability scores of 0.36, 0.16 and 0.17 respectively.

To enhance the visualization and appreciation of the vulnerability levels across the communities, the vulnerability indices were presented on maps (Figure 29, 30, 31, 32, and 33). Figure 29-33, show the exposure, sensitivity, potential impact, adaptive capacity, and composite vulnerability levels, respectively, for the communities.

Table 11: Indices of Sensitivity, Exposure, Potential Impact, Adaptive Capacity and Composite Vulnerability

Community	Sensitivity	Exposure	Potential Impact	Adaptive Capacity	Community Vulnerability
Adina	0.51	0.48	0.99	0.68	0.31
Amutsinu	0.33	0.51	0.85	0.37	0.48
Salakope	0.51	0.54	1.05	0.43	0.62
Agavedzi	0.23	0.44	0.68	0.63	0.04
Blekusu	0.70	0.23	0.93	0.95	-0.01

Exposure and Sensitivity is ranked as High (≥0.30), Medium (0.18–0.29) and Low (<0.18); Potential Impact is ranked as High (≥0.7) and Medium (0.5-0.69); and composite vulnerability classifications, a score of 0.67–1 is highly vulnerable, 0.34–0.66 vulnerable, and 0–0.33 least vulnerable after Yankson et al. (2017) and Schmidt-Thome and Greiving (2013).

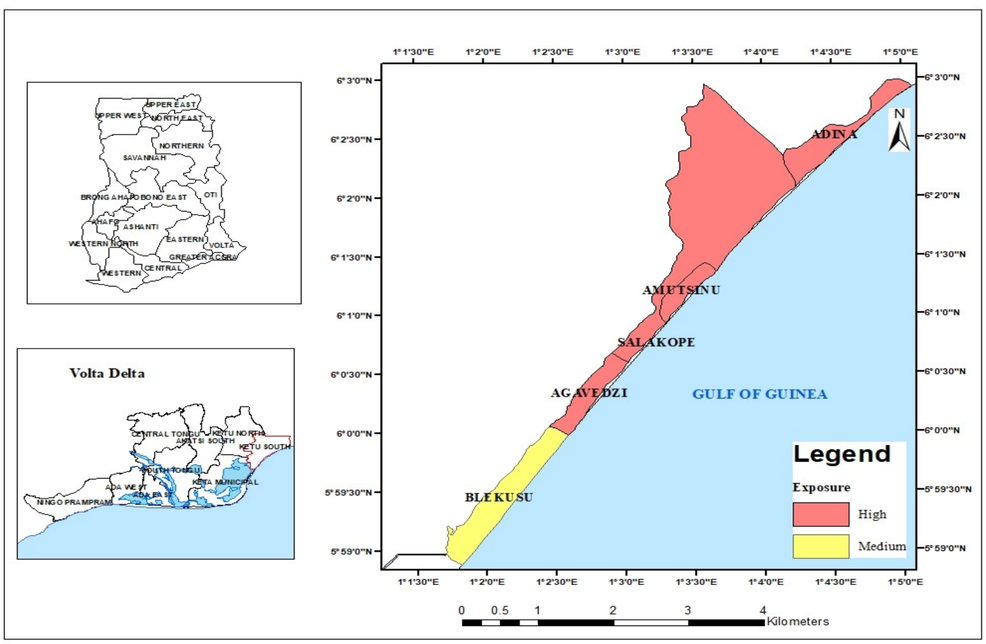
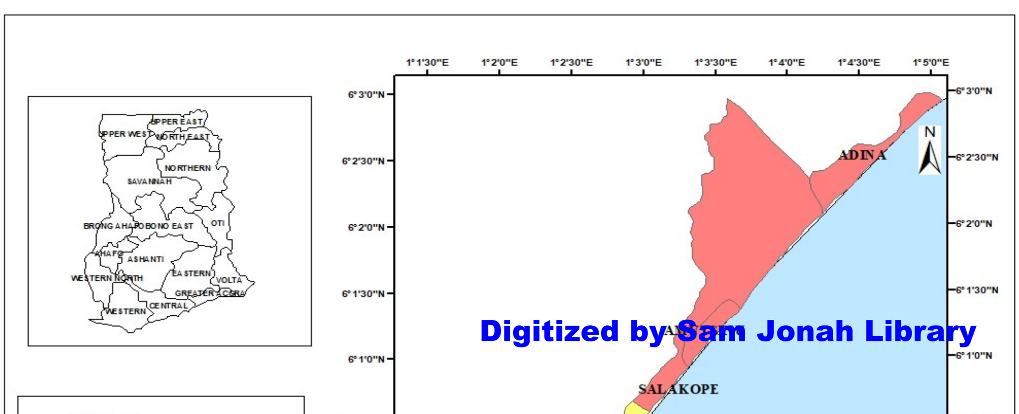


Figure 29: Flood exposure levels for the study communities



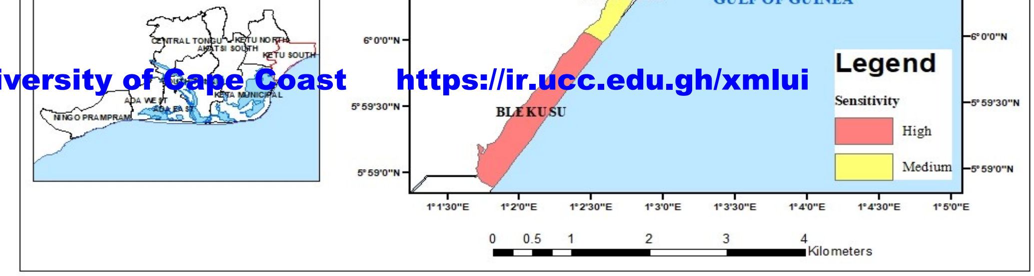


Figure 30: Flood sensitivity levels for the study communities

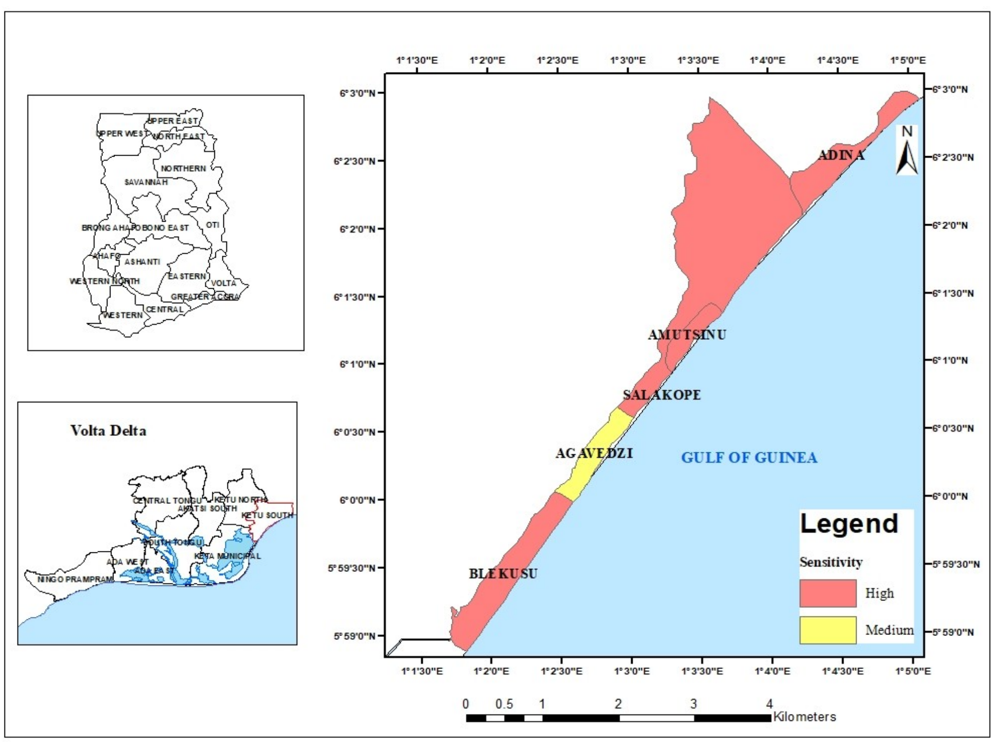


Figure 30: **Flood sensitivity levels for the study communities**

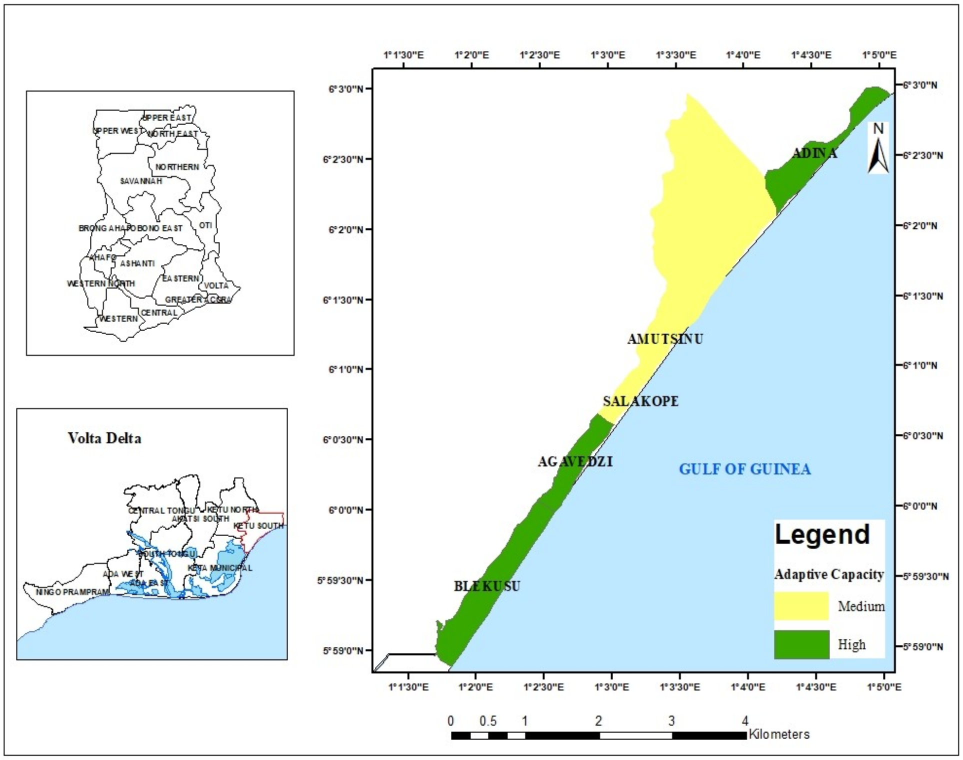


Figure 32: Adaptive capacity levels for the study communities

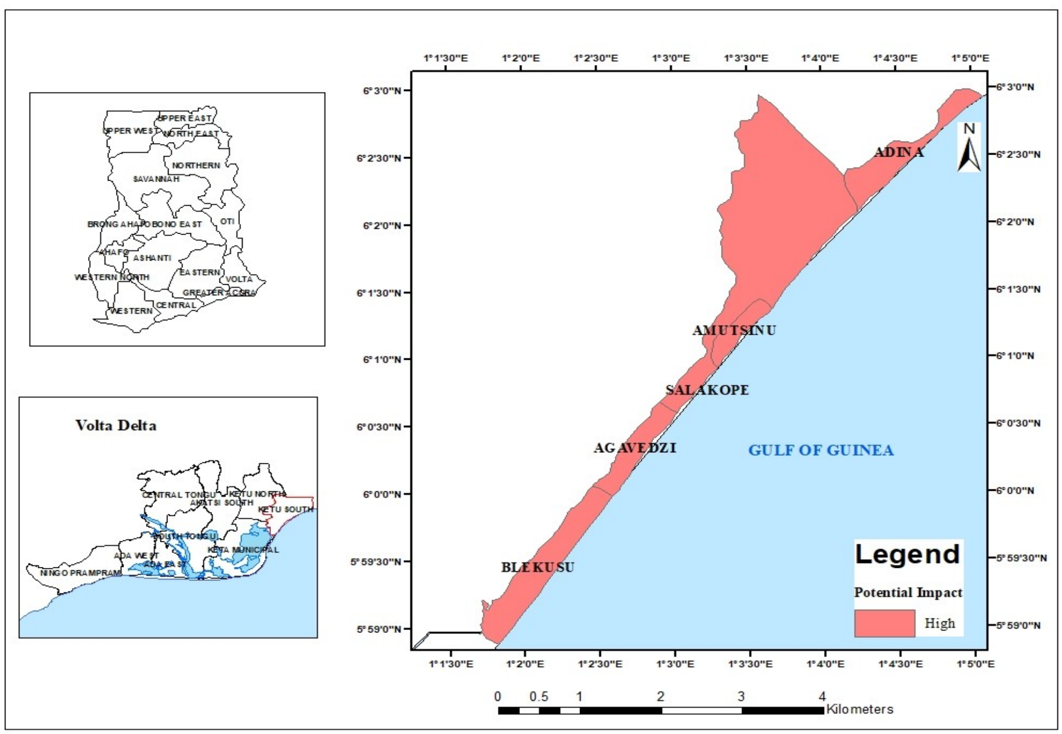


Figure 31: Potential impact for the communities

decision. Livelihood (OR = 0.5704749, P< 0.0001), a categorical variable, where two (2) livelihoods are being compared with one (1) livelihood, a reference variable, indicates that respondents with two (2) livelihoods are 43% less likely to relocate as compared to respondents with one (1) livelihood. The third predictor, sea defence preference (OR = 0.18, P< 0.0001), is a binary variable (Yes or No) where "No" responses were treated as reference variable indicates that respondents who prefer sea defence for protection are 82% less likely to take relocation decision as compared to respondents that do not prefer sea defence.

The compositional factors, including gender of household head, age of household head, household size, education and monthly income of household head as well as the contextual factors including communities such as Adina, Agavedzi and Blekusu that were controlled for in the model had probability values that were not significant (P>0.0001).

Table 12: Negative Log-Log Regression Model Showing the Relationship Between Explanatory Variables and Dependent Variable (Relocation Adaptation Option)

Variable	Predictors + compositional and contextual factors				
	OR	SE	P value	Confidence Interval	
Flood duration	1.009646	.0033071	0.003	1.003185	1.016148
Livelihoods (ref: 1 livelihood)					
2 livelihoods	0.5704749	.1086301	0.003	0.3927809	0.8285577
Sea defence (ref: No)					
Yes	0.1879353	0.0349485	0.000	0.1305325	0.2705814
Age of household head (ref: 20-30)					
40-59	1.067389	0.2157025	0.32	0.718304	1.586124
60+	0.8981923	0.1996318	-0.48	0.5810074	1.388535
Gender of household head (ref: male)					
Female	1.377811	0.2834103	1.56	0.9206629	2.061951
House size (ref: 1-4)					
5-7	1.282795	0.3962804	0.81	0.7001713	2.350228
Above 8	1.104163	0.307661	0.36	0.6395235	1.906381
Education (ref: No education)	1.119896	0.2231549	0.57	0.7578159	1.654975
Basic school	1.544611	0.453259	0.138	0.8690359	2.745366
Secondary school and above					
Monthly Income (ref: < 100)					
100-400	1.024614	0.199909	0.12	0.6990134	1.501881
500-900	1.691449	0.5515699	1.61	0.892664	3.205014
1000 and above	0.9576796	0.3090339	-0.13	0.5087984	1.802581
Community (ref: Adina)					
Agavedzi	1.089387	0.1560924	0.32	0.6476522	1.832408
Blekusu	0.8819346	0.1560924	-0.71	0.6234237	1.24764

Note: In the analysis, 95% confidence interval was employed and the level of statistical significance was set at 0.05. The results were reported as odd ratios (OR). An OR of 1 means that the predictor does not affect the odds of relocation; OR >1 means that the predictor is associated with higher odds of relocation decision; and OR <1 means that the predictor is associated with lower odds of relocation decision.

Discussion

Flood Prone Coastal Communities in Ketu South Municipality

The first objective of this study aimed to identify flood prone coastal communities in Ketu South Municipality. All five (5) communities studied were flood prone. Characteristics of floods are very important for disaster planning and management purposes (Osman et al., 2016). Flood frequency, depth, magnitude, duration, , and spatial extent is crucial for proper flood control and planning in order to reduce the negative impacts (Ezemonye & Emeribe, 2011; Osman et al., 2016).

Flood frequency in the communities was influenced by the type of flood, extreme floods such as storm surges and compound floods recur in every three (3) to ten years while tidal floods occur yearly. According to USDA (2016), flood frequency is classified as none (flooding is unlikely with zero (0) percent chance in a year), rare (flooding is unlikely but possible), occasional (flooding occurs on an average of five (5) to 50 percent in a year), frequently (flooding is likely to occur often under normal weather conditions with 50 percent chance in a year but less than 50 percent in all months), and very frequent (flooding is likely to occur very often under normal weather conditions with 50 percent chance in all months of any year). With regards to this classification, coastal flood in the study communities can be referred to as frequently occurring. This is because the floods in the communities are likely to occur in every year during the rainy seasons (June, July, August) as indicated in Table 2.

The depth of floodwater is also an important flood characteristics because it determines the extent of damage that is incurred from a flood event (Gissing & Blong, 2004). The flood depth in the communities was either at waist level or knee level. It was found that the depth of the flood was influenced by the type of flood as well. For example, communities that were exposed to storm surges had waist height flood depth whiles communities that were exposed to tidal waves and lagoon overflow had knee height flood depth. The flood depths can be related to the flood impacts the exposed communities have suffered including, loss of livelihood, damage to household properties, impact on drinking water and food sources as well as health implications. A study conducted by Chang et al. (2008) identified that as flood depth increases the magnitude of damages caused by flood increases. Rahman & Al (2014) also found in their study that the vulnerability of an area increases as flood depth increases and areas with low land elevation happened to have higher flood depth making them more vulnerable to flooding hazards.

In the case of flood duration, flood waters in the communities can persist for weeks to a month before receding. The study found that the long flood duration is as a result of the rise in water table by the encroaching sea in the communities as explained in the qualitative studies. This aligns with the findings of Henson & Harun (2008) where rise in water table was found to impede flood drainage and negatively impact crop production.

Another important flood characteristic considered in the study was flood spatial extent. The spatial extent of a flood is a characteristic that attracts planners as it illustrates the coverage area of flood events in an area and helps to identify element and sites that are free of flooding and elements that have been flooded (Osman et al., 2016). The spatial extent of recent extreme floods that were developed using community flood participatory mapping and GIS mapping varied across the exposed communities. The percentage of the lands flooded in the various communities were; 60 percent for Blekusu, 22.2 percent for Agavedzi, 68 percent for Amutsinu, 59 percent for Salakope and 62 percent for Adina. These flood extents are likely to increase in the communities' vulnerability because they are low lying areas. Sea level rise as a result of climate change would also raise the base for severe storm surges and high tidal waves to occur more frequently. According to Osman et al. (2016) flood extent is likely to increase in flood prone areas in this era of climate change.

The land uses affected by the floods were fish landing sites, fish smoking sites, cemeteries, religious sites (churches and sacred forests), residential, and transportation infrastructures (roads). Similar findings were reported in Osman et al. (2016) for two flood prone communities within Ankobra Estuary, Ghana. The infrastructures that were not affected were the communities' basic school campuses where the flood victims always sought temporal shelter. This is also similar to the findings of Addo & Danso (2017), Where school buildings serve as evacuation centres that accommodate flood victims in flood prone areas in Sekondi-Takoradi Metropolis, Ghana.

Determinants of Flood Vulnerability in Exposed Communities

The Hyogo Framework for Action (HFA) 2005-2015 emphasizes the need of developing systems of disaster risk and vulnerability indicators at the national and subnational levels that would allow decision-makers to assess disaster effects (UN/ISDR, 2005). The second objective of this study was to explore local indicators that influence vulnerability to flood in the coastal communities. The indicators found can be grouped with respect to IPCC vulnerability factors; exposure, sensitivity and adaptive capacity. Some can also be grouped as anthropogenic and natural factors.

The study found out that the exposure of the communities to flood events was largely attributed to climate change effects, sea level rise in particular, low elevation levels of the land and sea defence structures. The most disastrous flood events were rainfall, lagoon flood and sea flooding and these were directly caused by heavy rainfall, lagoon overflow, and storm surge with high tidal waves respectively. In line with a previous study, past human interventions, low land elevation, climate change and the resultant rise in sea-levels, increased storm intensity and torrential rainfall have been blamed for flood events along the coast of the Eastern Coast of Ghana (Boateng, 2012a). Moreover, the exposure to these flood events resulted in health impacts, drinking water impacts and household damages. Health impacts that were associated with the flood events were malaria, cholera and trauma while impact on drinking water was pollution of wells and inaccessibility of pipe water. Household damages include loss of livelihoods, belongings, houses, and fish smoking stoves. A similar pattern of result was obtained in the findings of Addo & Danso (2017) where more than half of their respondents reported similar health impacts, water source impacts and property damages from flood exposure in Sekondi-Takoradi Metropolis in Ghana.

Sensitivity determinants of vulnerability were found to be dependent on age groups, disability, higher population of female headed households, large household sizes, high number of women, low diversity of income sources (fishing, fish processing and petty trading), low income, and low level of education. The study found that these are the key factors affecting the socioeconomic conditions of the communities, therefore making the communities vulnerable to flood events. In accordance with previous studies these factors contribute to increase socioeconomic vulnerability significantly (Cutter et al., 2003; Wood et al., 2010; Frigerio et al., 2016;Osman et al., 2016). The findings of Adger, (2006) revealed that social characteristics are major contributors of differential vulnerability levels among communities in Xuan Thuy, Red River Delta, and rural Vietnam.

The Adaptive capacity factors that were determined were local adaptation strategies and institutional supports. The local adaptation strategies include; sand heaping around the houses to prevent flood from entering the house; creating channels during flood events to drain the water into the lagoon or dugout holes, community salt resource mobilization to generate income for flood insurance, migration and social capital. Likewise, Predo (2010) found that house enforcement, creating canals to channel flood water and executing social capital to evacuate flood victim to temporal rescue grounds were the community adaptation strategies used in Ormoc and Cabalian Bay, Philipines to minimize flood disasters. Considering migration, Munji et al. (2013) noted that periodic migration from flood prone areas to safer regions is an effective flood management strategy to reduce property loss in poor settlements. This strategy has been effective for coastal settlements that were exposed to inundation in Cameroon (Munji et al., 2013). Community solidarity as a social capital was another important adaptation strategy identified in the exposed communities. It inures to community efforts at rescuing and transferring people (aged, children) and properties to safe havens during flood events. This is consistent with a previous study (Lee, 2014) which indicated that social capital in the form of mutual aid, community cohesiveness, and trust among community members can successfully aid in decreasing the effects of disasters in flood prone areas of Chiayi in Taiwan.

The institutional factors include the relief support from NADMO during flood events to the communities and a few sea defence structures from the government. The results from the qualitative studies suggest that these institutional supports are not adequate. These supports were said to be inadequate because NADMO flood relief items are accessed by only a few victims and some of the exposed communities are also left unprotected. Munji et al.(2013) emphasized that the probability of negative implications from flood events will likely increase if there is less effort to intensify management actions. Hence the need to improve government support measures in these communities.

Some of the identified indicators were also grouped as anthropogenic factors including; dug out reservoirs for sea water collection in salt production, inadequate sea defence structures and relocation of displaced households to flood prone areas. The natural factors include; rising water table, and shoreline recession that are likely to increase their vulnerability.

Issues on the dugout reservoirs surfaced during the qualitative studies and the respondents complained that they feel insecure about the reservoirs because the can cause the channelled sea water to flood the community from the back of the lagoon where they are located, in instances of storm surges and flash flood. The dugouts serve as reservoirs for collecting sea water for salt production and it belongs to the Seven Seas Salt Company in Adina community. In addition to this is the relocation of displaced households into the dry areas of the lagoon. The dry areas of the lagoon are flood plains that get flooded during heavy rainfalls according to the findings. Thus, displaced households retreating to these areas are at risk to flooding as the ongoing threats of climate change in terms of extreme weather conditions and sea level rise continue to persist. According to Löschner et al. (2017) developments in floodplain areas are the key determinants of future levels of flood risk in the face of climate change.

It was also found that the coastline of the vulnerable communities was excessively receding and this can enhance the inland encroachment of the sea and permanent inundation of the communities. According to the findings of Pollard, Spencer, and Brooks, (2019), a coastal zone altered by erosional processes, has implications for susceptibility to rising sea levels and subsequent flooding, as well as future flood hazards, thus, the excessive recession of the shoreline in the vulnerable communities poses a risk for future flood hazards and in extent making the communities more vulnerable. Also, rise in coastal water table impedes flood drainage and negatively impacts crop production according Henson & Harun (2008). This implies that the rise in coastal water table as found in this study is likely to contribute to the vulnerability of the exposed communities to coastal flooding.

Community Vulnerability Levels

Downscaling is a useful tool for decision-makers who want to improve their investment plans in order to reduce flood damage (Balica et al., 2009). Recognizing which spatial scales are more vulnerable to flooding and where this vulnerability may be reduced more easily might help decision makers prioritize flood protection measures in local and regional areas (Balica et al., 2009). In this study community vulnerability indices were developed at community levels to identify the communities that are vulnerable and the ones that are less vulnerable based on the IPCC vulnerability factors.

Although these particular communities have been previously identified as vulnerable (Boateng, 2012a), the specific type of actions to implement remained unclear. Using the IPCC vulnerability factors including; exposure, sensitivity, potential impacts and adaptive capacity to develop vulnerability indices at community levels resulted in differential vulnerability scores across the studied communities. The variation in the vulnerability levels can be attributed to inequality of socioeconomic characteristics of the studied communities and the differences in their flood exposure levels. According to Wongbusarakum & Loper (2011), there is no one threshold that defines whether a community is vulnerable to climate change, as a result, social indicators can assist in determining where limited resources should be invested.

This study found that vulnerability levels in the dimension of sensitivity, exposure and adaptive capacity varied across the studied communities. This finding is directly in line with the findings of Yankson et al. (2017) that demonstrated that flood prone communities in the Greater Accra Metropolitan Area, Ghana exhibited different levels of vulnerability with respect to their exposure, sensitivity and adaptive capacity. Similar findings were also reported in another previous study in flood prone rural municipalities of Bosnia and Herzegovina (Sitaula, 2017).

It was found in this study that in communities such as Adina, Salakope, Amutsinu and Blekusu, sensitivity to coastal flood was high but Agavedzi had medium sensitivity. Higher number of people with disability, female-headed households, dependent age groups, women and larger household sizes were the contributory factors to the high sensitivity recorded in these four communities. It is worth discussing that the communities with high sensitivity are demographically vulnerable than Agavedzi which recorded medium sensitivity. Demographically vulnerable groups are individuals who are more vulnerable than others in a locality due to their specific demographic or socioeconomic traits. (Wongbusarakum & Loper, 2011). For example, it is reported in Owusu (2016) that in many countries, women's societal roles restrict their ability to adapt to climate change, and their obligations for childcare, water collection, and cooking fuel collection often increase their sensitivity to climate change.

In the case of exposure, Agavedzi, Adina, Salakope and Amutsinu had high scores with Blekusu recording a medium score. Higher frequency of flood, with higher responses on high flood depth, flood magnitude and flood impacts (such as household property damage, livelihood impact, food source impact, water source impact, and health impacts) are the contributory factors to the high scores for exposure in the communities. In a previous study by Chattopadhyay, Basu and Das (2017), similar local indicators were found as the contributory factors to high exposure of flood prone areas in West Bengal, India.

It is noted by Scheuer & Haase (2011) that the quantity and value of elements at risk, as well as their susceptibility, and the exposure of those elements at risk to the hazard, expressed by flood severity and likelihood, determine flood vulnerability. This implies that communities found with higher exposure scores have higher population and elements exposed to higher flood magnitude and more negative impacts from the flood events than the community recording medium exposure. Empirically, this finding can be explained with the finding from the qualitative studies in this study which suggest that Blekusu is protected with sea defence structures, minimizing its exposure to flood impacts whiles the rest of the communities are left unprotected.

When the two vulnerability components (sensitivity and exposure) were combined, all the communities had high potential impact with Salakope recording the highest. Contrary to the findings of (Sitaula, 2017) that showed that sensitivity indices was the major determinant to the high scores of potential impact in in Rural Municipalities of Bosnia and Herzegovina, this study demonstrated that the determinant of high potential scores alternate between sensitivity and exposure depending on the community. For example, Salakope had (0.51) sensitivity score and (0.54) exposure score which indicates that exposure contributed slightly higher in the high potential impact than sensitivity. Also, Blekusu had (0.70) sensitivity score and (0.23) exposure score indicating that sensitivity is the major determinant of the high potential impact.

Despite the high scores of potential impacts recorded for all the communities, Adina, Agavedzi, and Blekusu had their overall vulnerability positions remediated with high adaptive capacity unlike Salakope and Amutsinu that had medium adaptive capacity. The differences in their potential impact and adaptive capacity resulted in varied composite vulnerability scores across the communities which is consistent with the findings of Yankson et al. (2017) where all the communities they studied exhibited different levels of vulnerability in the Greater Accra Metropolis, Ghana.

Contributing to literature, these findings illustrate how complex vulnerability is, and that there are various levels of exposure, sensitivity and adaptive capacity that need to be explored in various locations to understand the overall vulnerability levels. This understanding is crucial to design effective adaptation strategies that are robust and suitable to affected communities.

Predictors for Relocation

Evacuation and relocation are the most effective measures for vulnerable communities to avoid disasters, and can ensure the safety of life and properties Thus, it is necessary to identify the factors influence residents' willingness to evacuate and relocate from hazard zones (Zhou, Ma, Guo, Deng, & Xu, 2021). The last objective of this study was to identify the predictors for relocation in flood prone communities in Ketu South Municipal, Ghana.

The findings indicate that the residents' relocation decisions were not simple. The predictors that influence their decision interplay between physical and economic factors whiles compositional and contextual factors (control variables) were not significant predictors. The key determinants for relocation as an adaptation option are flood duration in households, number of livelihoods and sea defence preference are the significant predictors for relocation in the study area.

In line with the findings of Buchori, Pramitasari, Pangi, Sugiri, and Maryono (2021), the residents were willing to relocate due to flood duration in the households. The odd ratio for flood duration recorded was 1.009646, which implies that the longer the duration of flood in a household, the more likely it is for the respondent to take relocation decision. This also agrees with the findings of Xu, Peng, Liu, Su, and Wang (2017) that demonstrated that every one-unit increase in severity of earthquake disaster in China corresponds to increases in the odds of willingness to evacuate.

In the case of livelihood, the respondents with two (2) livelihoods were 43% less likely to relocate as compared to respondents with one (1) livelihood. This suggests that livelihood can be considered as an essential asset that influence relocation adaptation measures in hazard zones. This is consistent with the findings of Addo et al. (2018) which show that voluntary and permanent relocation was overlooked by most flood victims due to fear of losing income-generating ventures that serve as sources of livelihoods in Sekondi-Takoradi Metropolis in Ghana. In addition, it can be argued that respondents with multiple livelihoods possess wealth that can help them accommodate flood disasters as compared to respondents with one (1) source of livelihood. Wealth improves one's ability to plan for and endure losses in the event of an emergency, and vulnerability is thought to be exacerbated by lack of wealth (Felsenstein & Lichter, 2014). The wealth of a household is characterized with income sources, the quality of the housing structure, and possession of household assets (Felsenstein & Lichter, 2014).

It was also found that Sea defence preference plays a strong role in predicting willingness to relocate. The odd ratio recorded for this variable, 0.18 implies that respondents that prefer sea defence for protection are 81% less likely to take relocation decision as compared to respondents that do not prefer sea defence.

The compositional factors, including gender of household head, age of household head, household size, education and monthly income of household head as well as the contextual factors, including communities such as Adina, Agavedzi and Blekusu that were controlled for in the model had probability values that were not significant. This implies that the likelihood of a respondent to agree to relocation decision in the study area is neither based on gender, age, household size, education, monthly income nor the community in which the respondent resides. This finding is consistent with findings in other studies (Bukvic & Owen, 2017; Seebauer & Winkler, 2020) where contextual factors such as communities and social dimensions did not influence relocation decisions. Similarly, Seebauer & Winkler (2020) found that relocation decision is made exclusively within households regardless of their neighbours actions or influence. There have also been a similar outcome on the compositional factors (household characteristics) especially gender and its association with willingness to relocate, Xu et al. (2017) found that gender and other household characteristics that were used as control variables in their study was not significantly related to willingness to relocate from a hazard zone in Sichuan Province , China.

However, other previous studies (Buchori et al., 2021; Correll, Lam, Mihunov, Zou, & Cai, 2021; Xu et al., 2017) have demonstrated contradictory outcomes to these findings. In these studies, compositional factors such as average income, and contextual factors such as place dependence (community bond) were significant influential factors for relocation aside hazard severity and types of livelihoods or occupations.

CHAPTER FIVE:

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This study aimed to assess the vulnerability of coastal communities along the coast of Ketu South Municipal to flooding through exploring and examining their local vulnerability factors and to investigate the predictors that determine recommending relocation as an adaptation option. The specific objectives of the study were to; map key communities in the municipality that experience extreme coastal flooding events; determine community perception of factors influencing their vulnerability to coastal flooding; determine vulnerability indices of communities; to assess predictors of relocation as an adaptation option for communities in the municipality..

The objectives were achieved through adopting exploratory sequential mixed method research design and flood participatory mapping procedures. With the exploratory sequential mixed method design, qualitative data was collected through in-depth interviews, and Focus Group Discussions. The data was analysed with deductive thematic analysis and was reported as narratives. Some of the data was also analysed with descriptive statistics and presented as percentage of responses. Flood participatory mapping was also analysed in GIS and presented as maps whiles quantitative data was analysed with descriptive statistics, mathematical operations and negative log-log regression.

Summary

The following are the key findings from the research on the study specific objectives:

Agavedzi, Amutsinu, Salakope, Adina and Blekusu were the communities identified to be exposed to coastal floods. The extent of flood covers large areas of the communities and sometimes breaching with the stretch of the Keta lagoon behind the communities. The most disastrous flood events in the communities were reported as sea flooding, rainfall flooding and lagoon overflow. The direct causes of the flood events were attributed to storm surges, high tidal waves, heavy rainfall and lagoon overflow. The land uses affected by the floods were fish landing sites, fish smoking sites, cemeteries, religious sites (churches and sacred forests), residential, and transportation infrastructures (roads).

Flood magnitude, frequency, depth, low land elevation, inadequate sea defence structures, were the identified flood exposure factors in the communities whiles age dependent groups, female headed households, people with disability, low level of education, low diversification of livelihood, livelihood loss, livestock loss, loss of personal properties and land losses to sea encroachment were the socioeconomic factors identified that complicate vulnerability to coastal flood events in the communities. Also, inaccessibility to flood warning information, lack of or inadequate institutional supports from government were identified as factors contributing to low adaptive capacity of the communities.

To achieve the third objective of this study. community vulnerability indices were constructed using the IPCC vulnerability factors, exposure, sensitivity, potential impacts and adaptive capacity. The communities had different scores with recording high and some medium for all the aspects of vulnerability. The study has found that sensitivity with respect to dependent age groups, disability, female headed households, women population and household size was high for three communities, Adina, Salakope, Amutsinu and Blekusu whiles Agavedzi had a medium score. Higher number of female-headed households, elderlies above 65 years, children below five years, women and lager household sizes are the contributing factors to the high scores for the four communities.

With the exposure component of vulnerability, Agavedzi, Adina, Salakope and Amutsinu had high scores with Blekusu recording a medium score. Higher frequency of flood exposure, with higher responses on high flood depth, flood magnitude and flood impacts in the dimension of household property damage, livelihood impact, food source impact, water source impact, and health impacts are the contributing factors to high scores for exposure in the communities recording high exposure indices.

The combination of the sensitivity and exposure scores resulted in high potential impact scores across the communities with Salakope recording the highest. But with adaptive capacity, Salakope and Amutsinu recorded medium scores whiles Adina, Agavedzi and Blekusu recorded high scores with Blekusu recording the highest. Despite the high scores of potential impacts recorded for the communities some of the communities, Adina, Agavedzi, and Blekusu had their overall vulnerability positions remediated with high adaptive capacity unlike

Salakope and Amutsinu that had medium adaptive capacity. The findings on the overall community vulnerability scores are as follows; Salakope had the highest composite vulnerability score, 0.62, followed by Amutsinu, 0.50, with the rest of the communities (Adina, Agavedzi and Blekusu) recording least composite vulnerability scores;0.31, 0.04 and -0.01 respectively.

Lastly, the study examined the predictors for relocation decision at household level and it was found that flood duration, number of livelihoods and sea defence preference were the main predictors whiles compositional factors (control variables) such as gender of household head, age of household head, household size, education and monthly income of household head were not significant predictors for relocation decision in the communities. Contextual factors (control variables) such as the communities were also not significant.

Conclusions

Along the coast of Ketu South Municipality, flood remains a constant threat to people and livelihoods. Five communities, Blekusu, Agavedzi, Amutsinu, Salakope and Adina are, annually or every three to ten years, exposed to three main types of flooding including sea flood, lagoon flood and compound flood (a combination of sea food and lagoon flood). These floods are caused by either storm surges, heavy rainfall, lagoon overflow, or high tidal waves. The flooding results in negative impacts on livelihoods, house damage, loss of properties, health impacts and sometimes loss of lives. Climate change can be attributed to this ongoing threat in addition to inherent physical, socioeconomic and institutional factors in the communities. For example, sea level rise as one of the consequences of climate change that is already happening can raise the base for storm surges and tidal waves to build and flood extremely and more frequently than usual in these communities.

The local factors that were found to be influencing vulnerability in the communities include; climate change, low elevation of land, inadequate sea defence structures, high flood frequency, depth, and magnitude as well as negative flood impacts (on health, water, food and properties). The local factors also include dependent age groups (high population of aged above 65 years and children below five years), female headed households, people with disability, low level of education, low diversification of livelihood which were found to complicate socioeconomic vulnerability of the communities. Moreover, inaccessibility to flood warning information, lack of or inadequate institutional supports from government were identified as factors contributing to low adaptive capacity of the communities.

Using the identified factors to develop vulnerability indices, it was found that vulnerability in the dimension of exposure, sensitivity, and adaptive capacity is manifested differentially across the studied communities. Communities such as Salakope, Amutsinu and Agavedzi are likely to suffer disproportionately from flood events due to their higher exposure conditions and lower adaptive capacity as compared to Blekusu and Adina that have higher adaptive capacity.

In addition, the determinants for relocation decision at household levels were flood duration, number of livelihoods of household heads and sea defence preference. Households with longer flood duration are more likely to agree to relocation decisions than households that experience shorter duration of flood. Households with multiple sources of livelihoods as well as households that prefer sea defence structures are less likely to relocate. However, the likelihood of a respondent to agree to relocation is neither based on gender, age, household size, education, monthly income nor the community in which the respondent resides since these factors were not significant predictors for relocation.

Recommendations

In order to reduce flood exposure from storm surges and tidal waves flooding, sea defences should be built to protect the communities. Since sea level rise would continue to raise the base for storm surges and high tidal waves to occur more frequently in this era of climate change. Stakeholders such as the government of Ghana, particularly the Ministry of Works and Housing should do this with the inclusion of the community inhabitants' perspectives on how the sea defence should be constructed.

As communities that are exposed to coastal flooding would suffer impacts disproportionately based on the varied vulnerability levels they exhibit, it is recommended that stakeholders such as NADMO and concerned Non-Governmental Organizations (NGOs) strengthen the adaptive capacity of the communities by providing early warning systems, increasing the scope of interventions to the vulnerable communities that receive less interventions and increasing flood risk awareness about sea level rise effects on coastal communities.

To address the sensitivity of the communities to coastal flooding, flood disaster risk reduction programs organized by governmental institutions (NADMO) and NGOs should focus on locating and giving priority to households with age dependent groups, female household heads, low level of education, disability, and low wealth levels. The study found that these factors influence the sensitivity of households and communities to coastal flooding.

Nonetheless, if relocation policies are being implemented, NADMO and other stakeholders should first target households that experience longer flood duration, and have only one livelihood since they are more willing to relocate than the others that experience shorter flood duration, have multiple livelihoods and prefer sea defence structures for protection.

It is also recommended that assessments are carried out on severity of post event impacts of coastal flood on the communities and the economic value of facilities and elements that are exposed to flood hazards. This will help in adopting robust adaptation options for the communities.

Nevertheless, sand winning which was a contributory factor to rapid shoreline recession as found in the study should be monitored by the community leaders.

Suggestions for Further Research

The study area is exposed to complex climate change impacts including coastal flooding and coastal erosion. This study has assessed the coastal flood aspect of vulnerability and therefore suggests that further research is carried on monitoring and evaluation of coastal erosion as well in order to contribute to addressing the complex climate change situation in the study area holistically.

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