UNIVERSITY OF CAPE COAST

FLOOD RISK ASSESSMENT AND REDUCTION IN THE ANKOBRA ESTUARY OF THE WESTERN REGION OF GHANA

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DECLARATION

Candidate’s Declaration

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for any other degree in this university or elsewhere.

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Supervisors’ Declaration

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

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ABSTRACT

Floods are common phenomena within the Ankobra estuary. However, the unavailability of records on the nature of floods, exposure of communities to floods and a flood risk map tend to limit effective flood risk control and management within the estuary. This study therefore sought to assess flood risk within the Ankobra estuary and examine how geodesign can be used as a flood risk reduction strategy within the plan.

The research techniques employed in the study include interviews, community mapping, observation, measurements (tape) and geographic information systems techniques (onscreen digitising, global positioning system mapping, spatial multi-criteria evaluation and geodesign). Results from the study indicate that the estuary experiences three types of flood (riverine, coastal and urban). Risk levels derived ranged from extreme, 0.75 – 1; high, 0.5 – 0.74; medium 0.25 – 0.49 to low, 0 – 0.24. The extreme risk zone covered an area of 46,725m^2; high risk zone covered 701,525m^2; moderate risk zone, 248,150m^2 and low risk zone, 9,167,758m^2.

Geodesign simulations (change of height foundation of buildings and remodelled landscape including drainage system) were undertaken. They produced more desirable result than the original risk levels. It was recommended that persons within high risk zones after the geodesign simulations should be relocated to low risk zones.

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DEDICATION

I dedicate this work to my family and the inhabitants of the Ankobra estuary.

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CHAPTER ONE

INTRODUCTION

Background to the study

Flooding is one of the oldest natural hazards experienced by man since the dawn of time. A translation of cuneiform symbols of the Weld-Blundell Prism shows that flood occurrences go way back in antiquity during the Sumerian civilisation (Ashmolea Museum, 2011). The Australian Geosciences (2011) define flood as a general and temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters. According to the International Strategy for Disaster Reduction (ISDR, 2011), there has been an increase in flood hazards with over 3,455 reported cases between 1980 and 2011. Increase in flood events have put over 24 million people and an estimated $2,203.97 billion worth of assets at risk in the world (Nicholls & Wong, 2007).

Floods events have not always been negative, sometimes they play a positive role in the maintenance of biodiversity and ecosystems of riverine systems (Poff, Allan, Bain & Stromberg, 1997). Floods can create plains, which have been attractive places for human settlement because of their economic potentials, that’s they are often fertile agricultural areas which has supported food production of countries like Egypt, India, Bangladesh and China (Food and Agriculture Organisation of the United Nations, 2008). Bach, Clausen, Jensen and Taylor (2012), estimated that the average annual value of flood benefits resulting from the overflow of the Mekong River in Asia is approximately $10 billion. On the other hand, negative flood impacts have been recorded in almost every part of the world. In Asia, floods tend to occur almost every year with the most badly hit countries being Pakistan, India, Australia, China and Cambodia. In May 2010, floods affected about 28 provinces in China with about 4,000 people reported dead or missing; this was one of the worst floods China had suffered in more than a decade. Similarly, floods heavily hit Australia in December 2010 through to January 2011 over 35 people were confirmed dead with 200,000 people affected and the economic damage estimated at $2.38 billion (Carbone & Hanson, 2012). In the United States of America, states through which the Mississippi River flows tend to be most vulnerable to flood hazards. In 2011 when the Mississippi River overflowed its banks, it destroyed various farmlands and household properties to the tune of over $2 billion. Barredo (2009) identified over 122 flood events throughout countries in Europe from 1970-2006. A total of 27 of the flood events from the 122 produced a loss of $140 billion, with an average annual flood loss of $3.8 billion.

In Africa, floods rank the second highest natural hazard; it recorded 586 events from 1980 to 2008 (Centre for Research on Epidemiology of Disasters, CRED 2010). In 2011, floods affected most Southern African countries such as Mozambique, Zimbabwe, Namibia, Botswana, Zambia and South Africa. In South Africa alone, a total of 91 people were killed, 6,000 displaced and over $100 million worth of properties damaged. Vulnerability to floods in Africa is very high due to poor spatial planning, low quality of building materials, low income and structural developments along marginal lands or flood prone areas resulting from rapid urbanisation and population growth (Wisner, Blaikie, Cannon & Davis, 2003).

In Ghana flooding is largely attributed to improper land use practices, development on areas liable to floods and inadequate drainage systems (Atuguba & Amuzu, 2006). When a catastrophic flood event affected Northern Ghana in 2007, over three hundred thousand (300,000) people were affected with 31 deaths recorded in Upper East and 10 deaths in Upper West (National Disaster Management Organization, 2007). Urbanized coastal towns in Ghana are areas most hit by flood hazards, largely because the grounds are covered with buildings, roads and pavements which obstruct sections of natural channels and drains that ensure that water moves to rivers faster than it should under natural conditions (Action Aid, 2006). The National Disaster Management Organization (2011) reported that over 14 people died while 43,087 people were displaced by floods in the Greater Accra Region in 2011.

Floods could be catastrophic; hence, the need for carrying out flood risk assessments in areas usually affected by floods. These may include identifying flood risks and deciding on the appropriate interventions to employ in controlling or managing them. Flood risk assessments help in understanding the source of floods, how and where they flow (pathways) as well as the people and assets they affect. They also help in evaluating if such risk levels are tolerable (Office of Public Works Ireland, 2009). As stipulated by Westen & Kingma (2009), knowledge acquired through flood risk assessment is useful in developing control measures to reduce flood occurrence. However both structural (building dykes, floodwalls and widening river channels) and non structural (land use planning and flood warning systems) flood control measures can fail (Musiake, 2003). A case in 2005 showed that 80% of New Orleans got flooded when most dykes and flood walls could not sustain flood waters during the hurricane Katrina disaster (Reid, 2007). Also, in the Hague-Netherlands which has a comprehensive land use plan and dykes to control floods was inundated in 2012 (Corder, 2012). As a result, new and better measures are always sought for effective flood risk reduction.

Geodesign is a new intervention which geospatial technicians believe has the potential to control and manage floods by ensuring that designs maximise flow of flood waters (Yu, 2014). Geodesign combines the age-old practice of planning, designing, implementing and evaluating changes to our built and physical environment with modern tools including digital databases and representational and analysis software tools (Dangermond, 2010). This measure could ensure a win-win situation for both man and the natural environment by taking into consideration the full spectrum of the earth's life support including everything that lies below, on, and above the surface system (Miller, 2012). Due to the advantage of geodesign, planners in Asheville and Cap Cod (United States of America), Sabah Al-Salem (Kuwait) and Bodegraven (Netherlands) have been able to design the landscape to ensure a friendly coexistence of man and nature (flood) (McElvaney, 2012).

Statement of the problem

Ankobra estuary is exposed to different types of hazards; those caused by the sea result in storm surges, floods, sea level rise and erosion. Communities in this estuary are situated on marginal lands between the sea, wetlands and Ankobra river which makes them highly prone to flood occurrences. In recent times, the frequency and magnitude of floods experienced have increased due to high tides and heavy rains which pile large quantities of water into communities instead of flowing directly into the sea and adjourning wetlands, thereby destroying goods and properties of inhabitants (Coastal Resource Centre-Ghana, 2012).

A flood risk assessment of the estuary, that is the nature of the flood hazard and the degree of exposure of the communities in the Ankobra estuary to the hazard, is unavailable. Hence the need for flood risk assessment within the Ankobra estuary. Also most floods risk assessments have been technical experts centred due to paradigm shift from conventional methods of flood risk assessment which use watermarks on buildings and report cases in the news media to using flood models advocated by Nyarko (2000). These technical experts usually focus largely on automatic delineating and mapping of floodplains using digital elevation models (Radaideh, Fehlman, Ruark, & Murray, 2004). This puts the ability of flood risk assessment in the hands of these experts without the involvement of members of the affected community Zein (2010). Therefore, there is a need for a community participatory approach in assessing flood risks in the Ankobra estuary. This is because indigenous knowledge can provide useful information while serving as supplementary knowledge for cross-validation of automatic flood delineation as well (McCall, 2008).

Moreover, once flood risk assessment is done, attention is shifted to flood risk control measures and management. A major challenge from most flood measures is that they have been inadequate in reducing risk to flood due to the changing nature of river flow characteristics and sea action resulting from climate and rapid land-use changes (McMillan & Brasington, 2008). This was the case in the study area when the Assembly man through the help of the

District Assembly and Chinese engineers dredged channels within the estuary to help solve flood situations. According to Foley (2013), the inadequacy of old techniques calls for new flood control measures to solve our greatest environmental problems, hence, the need for geodesign. Geodesign does not only give a measure but also the impact of the measure to ascertain whether its implementation will help solve the problem (McElvaney, 2013).

Research questions

i. What is the nature of the flood hazards within the Ankobra estuary?
ii. Which elements are at risk to the floods?
iii. What is the level of vulnerability of elements at risk?
iv. What are the coping strategies of the people to floods?
v. Can Geodesign be an approach to reduce flood risk in the area?

Research objectives

The main objective of the study was to assess flood risk within the Ankobra estuary and how geodesign can be used as flood risk reduction strategy.

Specific objectives of the study were to:

i. explore the nature of flood hazards in Ankobra estuary;
ii. map the elements at risk to floods within the estuary;
iii. assess flood vulnerability of the elements at risk in the estuary;
iv. assess the coping strategies of people to floods in the estuary;
v. explore how geodesign can be used to reduce flood risk in the estuary.

Significance of study

This study assesses the flood risk situation in the Ankobra estuary. First, it could improve the understanding of floods in the study area such as spatial extent and intensity. Such information is necessary and important for proper land use mapping and planning in the area by using flood extent layer as an overlay for demarcating layouts. Also, the knowledge of flood zones could help the affected communities and the District Assembly as a whole to identify areas free of floods for settlement purposes (temporarily or permanently) when the need arises, thus making communities more resilient to flood hazards.

The study will also identify and generate vulnerability index for the communities in the Ankobra estuary. Information on vulnerability could aid disaster managers in the District to plan a disaster response. In addition to these, the vulnerability index will inform them about which areas of the communities to allocate more personnel in case of a flood situation and which households within the communities need more assistance during relief distribution.

The study seeks to categorise coping capacities of the communities. Based on their traditional adaptive capacity, NADMO can use this information to tailor disaster management strategies specifically for the study area.

Organisation of the study

The study is organised in five chapters. Chapter one presents the background to the study, statement of the research problem, research questions, research objectives and significant of the study. Chapter two discusses relevant literature related to the study. Topics discussed include flood hazard, types of flood and characteristics of flood, the concept of vulnerability and coping capacity to flood. Additionally, flood risk, flood reduction techniques and the geodesign concept as a flood reduction technique were reviewed. The methodology employed in the study comprises the third chapter of the work. It presents the study area, study design, data sources, sampling estimation and sampling technique, data processing and analysis, and ethical issues. The fourth chapter presents the results and discussions of the study. It presents the data and discusses them with literature based on these sub headings: flood hazard, vulnerability, coping capacity, flood risk and geodesign. Finally, chapter five presents the summary of the study, major findings, conclusions and recommendations.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter reviews literature on flood hazard, vulnerability, risk and geodesign. Issues discussed here include types of floods, characteristics of floods, flood effects and severity. The chapter also discusses the concept of vulnerability, types of vulnerability, elements vulnerable during and after floods and coping capacities of people affected by floods. Also, this chapter looks at risk, the various methods of assessing and measures in reducing it. Lastly the concept of geodesign is discussed.

Flood hazard

Floods are part of the earth's natural hydrological cycle which circulates water by maintaining a balance between water in the air, on the surface of the earth and on the ground (Federal Emergency Management Agency, 2009). The Australian Geosciences (2011) define flood as a general and temporary condition of partial or complete inundation of normally dry land areas from the overflow of inland or tidal waters. Definition of flood by Australian Geosciences (2011) is similar to that of the Illinois Emergency Management Agency (2008) who defined flood as general and temporary condition of partial or complete inundation of normally dry land from the overflow of inland or tidal waters, the unusual and rapid accumulation or runoff of surface waters from any source, mudflows or the sudden collapse of shoreline land. Flood is also defined as large amount of water covering an area that is usually dry (Olajuyigbe, Rotowa & Durojaye, 2012). The above definitions of floods all acknowledge that extensive covering of a dry land with water. A flood is considered a hazard when it has the capacity to inflict injuries and possibly, death to people, damage properties, halt social and economic functioning of a society and even lead to environmental degradation (International Strategy for Disaster Reduction, 2004).

Causes of floods

The causes of flood can be grouped into natural and anthropogenic factors (Davoli, Fredi, Russo & Troccoli, 2001). Natural causes of floods are due to the effects of climatic conditions like precipitation (rainfall), storms, catchment physiographic parameters such as: dimensions, shape, geology, relief, hydrography and land use (Alkema, Rusmini & Lubczynska, 2009). Anthropogenic factors are usually human interventions that narrow the river, the stream and their banks (Stefanidis & Stathis, 2013). Some of these human interventions include construction of structures on flood paths, blockage of drains by solid waste, deforestation of catchment basins and land reclamation (Nwafor, 2006).

Climate

Flood events can be caused by intensive rainfall, high tides, and storm surges (Zelenakova, 2011). Rainfall is one of the main climatic factors influencing the magnitude of runoff response leading to floods (Maca & Torfs, 2009). Temporal and spatial distribution of rainfall contributes significantly to the formation of peak discharge of rivers allowing them to release large water volumes which can cause floods. Areas where rains fall faster than the infiltration rate will experience excess overland flow leading to floods (Beven & Horton, 2004). Thus, the rainfall amounts needed for floods cannot be defined in absolute terms (Doswell, 2003) since a rainfall amount which can induce flood in one location might not be the same for another. Also, local storms are a major cause of floods. Storms are mostly accompanied by rainfall amounts which produce the heaviest short term rainfalls experienced in a place and are usually responsible for producing extensive damages (Capka & Capka, 1992).

In recent times, global temperature increase has heightened the effects of climatic conditions experienced in past years (Fernando, 2010). The result is world climatic changes in precipitation patterns, sea level rise, increase in storms and hurricanes and melting of glaciers (National Research Council, 2010). Precipitation which has the potential to cause floods in the world has been on the rise due to high water-holding capacity of the atmosphere, hence, inducing more rainfall (Kundzewicz, 2006). Also, climate change has led to the increase in frequency and intensity of storms (Trenberth, 2011). These storms have impacts hundreds of miles inland because they produce taller waves which have the potential to reach inland to cause floods. The National Oceanic and Atmospehric Adminsitration (2013) asserts that waves with height ranging from 15 feet to 20 feet were responsible for floods in North Orleans and Glaveston Island.

Physiography of the catchment

Physiography is the terrain condition of a tract of land which reveals the conditions of the surface of the land (Sazal, 2013). Physiographical parameters of a catchment have a large influence on time to peak and flood magnitude (Bryndal, 2014). The topography, which is a physiographic parameter, measures the height of a location above the geodetic datum of a place using the sea as a reference surface (Federal Emergency Management Agency, 2009). By this, if the topography is very low then it could be hit badly by flood (Singh, 2013). This is confirmed by the Environmental Protection Agency Ghana (2012) assertion that low elevation areas (thus areas below 200 meters) stand a higher risk of experiencing floods than high lands (places above 500 meters). Also when low elevation areas are close to the sea and drained by rivers, flooding would be a common event in such area. This is due to the backward effects caused by sea water which obstruct river discharge and also raising their surface upstream causing floods inland (Hidayat, Vermeulen, Sassi & Hointink, 2011). Consequently, coastal areas which are highly populated stand a greater risk of suffering floods due to their low elevation (International Institute for Environment and Development, 2007).

Settlements and human developments

Settlements influence all phases of the hydrological cycle from precipitation to infiltration rates and the hydraulics of overland flow (Devalsam, Atsu, Comfort & Innocent, 2011). Konrad (2014) claims that runoff from rainfall into rivers are influenced by human settlements increasing peak discharge of rivers and modifying the way the rivers flow. Konrad (2014) further explains that construction of roads and buildings often involves removing vegetation and soil. In such a situation, permeable soil is replaced by impermeable surfaces that reduce infiltration and accelerate runoff. Population growth has led to development of settlements close to rivers and extended development on flood plains. These hinder the free flow of rivers and therefore stimulate floods (Doocy, Daniels, Murray & Kirsch, 2013).

Types of floods

Floods can be grouped into riverine floods, flash floods, urban and coastal floods based on the source of the flood (Depue, 2010).

Riverine flood

Riverine flood can when a river overflows its bank leading to the overflow of water from a river channel to its banks (Nelson, 2012). During a riverine flood, excess water flows over a river's banks and out onto its floodplain. It is also called overbank flooding (Federal Emergency Management Agency, 2009). Due to overflow of a river onto its banks, government and development agencies prevent development along water bodies. In Ghana, the Department of Town and Country Planning allows a buffer zone of 300 meters around rivers (Ministry of Water Resources Works and Housing, 2011).

Riverine floods have been on the increase during the twentieth century due to global climate change (Macklin & Lewin, 2003). Groisman (2005), concluded that there is a widespread increase in precipitation in middle latitudes of the world mainly due to climate change. This has led to a number of recent flood events when river flow levels are broken (Kundzewicz, 2006). With river floods, areas downstream of the river which do not receive rains get flooded (National Flood Safety Awareness of the United States of America, 2013). Riverine floods also occur when rivers carry large amounts of sediments and are deposited in its lower courses, making river beds shallower resulting in the channel capacity being reduced and leading to flooding (Pareva, 2006). Large amounts of sediment loads in rivers are due to intense rainfall, tectonic dynamics of hill slopes and deforestation (Das, Chutiya & Hazarika, 2009).

Major riverine floods in the world include the Mississippi river flooding in 1992 which covered over 23 square miles of land and left over 250 people dead in what is called the Great Flood (Encyclopaedia Britannica, 2014). The Danube and Elba rivers have also produced over 100 major floods in Europe since 1998 (European Environmental Agency, 2014). Floods from these rivers (Danube and Elba) inundate countries like Austria, Czech Republic, Germany, Hungary, Poland, Slovakia, and Switzerland. In Asia, the Mekong River usually creates floods which affect its surrounding countries such as Cambodia, Thailand, Vietnam and the Philippines. The Birim river, on June 12, 2014 overflowed its banks after six hours of continuous rains in the Eastern Region of Ghana, rendering over 1,000 people in the Akyem-Oda Municipality homeless (Bampoe, 2014).

Flash floods

A flash flood is a local flood of short duration (usually less than six hours) with a relatively high peak discharge generally resulting from heavy rainfall in the immediate vicinity of which there is usually little or no advance warning (Miller, 1997). It is generally agreed that flash floods have the following characteristics: they occur suddenly with little time for warning, they are fast-moving and generally violent, high threat to life and severe damage to property, they are generally small in scale with regard to area of impact, frequently associated with other events such as river floods on larger streams and mudslides (Gruntfest & Handmer, 2001). The frequency with which flash floods occur differs in different areas but the influence of global climate change and regional environmental degradation, has increased its frequency and magnitude (Shrestha, Chapagain & Thapa, 2011). Flash floods bring about large toll (physical, environmental and economic losses) when there is less time for forecasts, warnings and preparation (Montz & Gruntfest, 2002).

Coastal floods

Flood exposure is increasing in coastal cities owing to growing populations and assets, the changing climate, and subsidence (Hallegatte, Green, Nicholls & Corfee-Morlet, 2013). This type of flood is caused by tides, surges and wave overtopping (Gallien, Schubert & Sanders, 2011). Gallien et al (2011), explain that tides vary in a predictable manner over time. Tides higher than average tides in any places occur every two weeks around the time of full and new moons when the gravitational pull of the moon and sun are aligned; this has the ability to cause floods in coastal zones. Tidal currents can movement towards shore or upstream which can last about 6 hours and 13 minutes (Federal Emergency Management Agency, 2009). Also, severe weather events create meteorological conditions that drive up the sea water level, creating storm surges (these are large waves driven by local winds or swelled from distant storms), raising average coastal water levels to produce large waves which cause floods when they reach land (National Oceanic and Atmospehric Adminsitration, 2013).

Urban flood

In many cases, floods are not caused by rivers overflowing their banks but by the inadequate drainage facilities and blockages of drainage facilities termed urban floods (German Technical Cooperation, 2006). Urban floods occurs in towns with flat or low-lying terrain especially where little or no surface drainage, or where existing drainage has been blocked with waste, refuses and eroded soil sediment. Also massive developments as a result of urbanisation aggravates this type of flood by restricting rain water flow especially when large parts of the ground are covered with roofs, roads and pavements (Action Aid, 2006). Most frequent flood occurrences in Delhi, India has been attributed to urban flood due to fast urbanisation which has increased paved areas and decreased agricultural land which used to act as a percolation zone in the catchment area of the Najafgarh. This causes increased water-flow during rainy seasons (Pareva, 2006). In Accra, Ghana, the introduction of the Structural Adjustment Programme (SAP) in 1980s saw spatial expansion and population growth. However, planning and management did not accompany this development, thereby exposing many urban dwellers to flood disasters (Kizito, 2005).

Characteristics of floods

The characteristics of floods are very important for planning and management purposes. The characteristics of floods are flood frequency, depth, duration, time of onset and spatial extent, knowledge about these characteristics helps in proper flood control and planning in order to minimize flood damages (Gamble & Meentemeyer, 1997).

One characteristic of floods that interests planners is the spatial extent of a flood. The spatial extent looks at the areas covered by flood waters (Marco, 1992). A spatial extent of a flood helps planning units in developing flood maps (Long, Fatoyinbo & Policellli, 2013). Flood water depth is also a necessary flood parameter to be identified (Rowsell & Green, 2000). This is because flood damages can be determined by water depth (Chang, Lin & Su, 2008). There is a direct positive relationship between flood damage and flood depth (Gissing & Blong, 2004); the higher the flood depth, the higher the likelihood of damages.

The time difference between the precursors of flood and the actual manifestation of flood is termed time of onset which is very useful for planning and designing flood emergency evacuation (Alkema, Rusmini, & Lubczynska, 2009). On small streams, floods induced by rainfall usually last from only a few hours to a few days, but on large rivers, flood runoff may exceed channel capacity for a month or more (Organisation of American States, 2010). Floods have a slow onset when it takes a relatively longer period, one or more weeks or even months after it is triggered by rains (Patil, 2010). Slow onset floods are less likely to sweep away property although they may still cause damages (Oblack, 2014). On the other hand, when floods inundate quickly, then it has a rapid onset time (Becker, Johnstone & Lence, 2011).

Flood frequency is an important attribute of flood which is described by the average interval in years between occurrences of successive floods (Bureau of Meteorology Australia, 2013). Flood frequency is usually expressed in probability terms as the chance of occurrence of a flood is in at least a year (Ogtrop, Hoekstra & Meulen, 2005). Studies by Wolman & Leopold (1997) indicate that rivers of different sizes flowing in diverse physiographic and climatic regions are subject to flooding at least once a year, making most rivers have a flood probability of one. In qualitative teams flood frequency can be expressed as none, rare, occasional, common, frequent and ponded (Miller, Fenton, Tijffany, & Burras, 2010).

Effects of floods

In terms of the consequences of flooding, most flood risk assessments are limited to the detrimental effects (damages) although there are positive consequences as well (Merz, Kreibich & Thieken, 2004). Flooding has four important benefits (Attz, Mercel, Ghimire & Hanson, 2009). Attz, Mercel, Ghimire and Hanson (2009) explain that floods inundate floodplains leaving the soil moist which is usually good for agriculture. Secondly, floodwaters replenish groundwater aquifers and thirdly, they contribute to increased soil fertility. Floods increase soil fertility through organic matter deposit and phosphorus or nitrogen. Egypt is one country which has benefitted from flood activities over five thousand years from deposition of nutrient-rich sediment from the Nile River (Gore, 2006). Lastly, flooding can benefit floodplain fisheries. In spite of the benefits, floods usually generate various levels of harm to people and properties, environment and the socio-economic wellbeing of people (Poussin,Ward & Bubeck, 2010). The Floodsite Consortium (2009) divides these damages into direct and indirect.

Direct damages of flood

Direct damages are those that occur due to physical contact of floodwater with humans, property or any object (Smith & Ward, 1998). Tangible elements are buildings, contents within the buildings and infrastructure (Flood Consortium, 2009). Flood waters enter buildings through masonry and mortar joints, cracks in external walls, doors and windows (Pickles, 2010). They make buildings suffer structural damages which become very dangerous to people (Hartford Loss Control Department, 1999). Buildings made of earth (mud) may literally melt away but those made of more resistant materials (blocks) can withstand for several days (Tiepolo, 2014). Floods which swept through Calgary in Canada in 2013 brought with it intense damage to over 100 buildings which were demolished by the Calgary's Emergency Management Agency since they were unfit and poses risk serving as accommodation facilities (Schneider, 2013). In August 2007, after two days of heavy rainfall within the White Volta water catchment, 20,000 homes were fully or partially destroyed in the Upper East Region of Ghana (Integrated Regional Information Networks, 2007). The Integrated Regional Information Networks (2007) explained that the high number of buildings affected was highly due to the adobe type of buildings in the region. This means that building materials influence the extent of damage a building suffers from flood. Most often, it is not the building which is destroyed or damaged, but the contents within. Household items especially electrical appliances, paper, furniture, stored harvest and livestock are mostly damaged by flood water (Salzer, 2009).

Also, service infrastructure such as roads and bridges are affected by flood waters (Alam & Zakaria, 2002). Alam and Zakaria (2002) observed that roads can develop pot holes and cracks or even have sections washed away by floods, disrupting movement of vehicles. The flooding of Shiting River in 2012 collapsed the Shiting bridge, hindering the movement of people and goods across China (Xiaomei, 2013). Another direct tangible damage caused by floods is the destruction of farm lands. In 2010, the Water Development Board (2010) recorded over 2,660 and 1,280 hectares of rice, lentils and vegetable farms destroyed when the Brahmaputra River in Bangladesh broke its levees. In Ghana, floods destroyed over 538 acres of farmlands in Bunkpurugu-Yunyuo district on August 29, 2013 (International Federation of Red Cross, 2013).

Direct intangible damages range from death or loss of lives to health effects and ecological and environmental losses (Flood Consortium, 2009). Severe flooding can result in the death and displacement of people (Nwakpa, 2012). It is estimated that, in Europe, floods killed more than 1,000 people and displaced 3.4 million people between 2000 and 2009 (Fussel, 2012). Between 1992 and 2011, estimates of over 6224 people were killed by floods in Africa, with over 17 million people affected by floods (Guha-Sapir, 2012). Countries such as India, Bangladesh, Indonesia and China have high records of death pertaining to floods. China has suffered the worst death toll in floods history with the record of 3.7 million to 4 million deaths for a single flood event when the Huang Hun (Yellow) River overflowed its banks in 1931 (Winchester, 2004). In Shrinagar, India monsoon rains caused floods which led to the death of about 5,700 people (Commercial Broadcast Television, 2013). Venezuela is the country with the highest deaths with a million people per year (Boro, 2004). This high ratio is a result of the over fifty thousand deaths recorded in 1999 when heavy rains caused rivers to over flow their banks and trigger landslides.

Health issues such as injuries, hypothermia and animal bites are also direct intangible effect of floods (Du, Fitzgerald, Clark & Hou, 2010). There are three stages of chronological public health effects on injured people and survivors of floods (Kouadio, Aljunid, Kamigaki & Oshitani, 2012). The impact phase or first phase (lasting up to 4 days) is usually the period when victims are extricated and initial treatment of disaster-related injuries is provided. The second phase, the post-impact phase (4 days to 4 weeks), is the period when the first waves of infectious diseases (air-borne, food-borne and/or water-borne infections) might emerge. The last phase (after 4 weeks), is the period where victims who contracted infections may become clinically apparent.

In many cases, environmental losses are either short term or long term but they are direct intangible damages of flood (Gautam & Van der Hoek, 2003). Animals, at almost all stages of the food chain, from insects to small mammals and birds are killed through drowning or from lack of food during and after floods (Badwen, 2014). Since earthworms, snails and beetles can be decimated, a decline in their population can be problematic for the food chain as it causes a reduction in the food supply for birds (Shardlow, 2014). In relation to flora, most plants can tolerate a couple of days of flooding during the growing season, but for other plants, a week or more of flooding can cause severe injury and death, particularly for sensitive trees and shrub species (Laura, 2010). Ecologically, flood hazards pose the greatest risks to coastal morphology due to their complexity and dynamic nature (Balica, Wright & Meulen, 2012). Coastal habitats such as coastal wetlands and estuaries are at risk of floods (Gallien, Schubert & Sanders, 2011). Wetland and estuaries have a large biological diversity to which floods can destroy. Most fauna within wetlands such as frogs, fish, reptiles and crabs can easily be washed away by a high velocity floodwater (Environment and Heritage, 2013). In coastal areas, flooding can also lead to serious coastal erosion of beach sands as well (Nicholls & Wong, 2007).

Indirect damages of floods

Indirect tangible damages are disruption of public services which incur production losses to companies outside the flooded area (for example, suppliers of flooded companies). Other losses result from cost of traffic disruption and loss of tax revenue due to migration of companies as an aftermath of floods (Merz, Kreibich, Schwarze & Thieken, 2004). Also, essential services vital to human survival are disrupted, as reported by Zhenglan (2013) that floods in China Zhejiang Province cut off residents from roads, paralysed telecom services, schools and factories being shut down.

The Health Protection Agency (2011) asserts that flooding brings about indirect intangible effects on people of all ages and can exacerbate or provoke mental health problems. The stressing experiences that the majority of people experience transiently or for longer periods after disasters can be difficult to distinguish from symptoms of common mental disorders. There are, however, indications that both children and older people suffer Post Trauma Stress Disorder (PTSD) after flooding and that the prevalence figures may well be greater than those that are found for adults of working age. This is because parents' and caretakers' wellbeing affects the quality of their parenting; people's direct experiences and those that affect their caretakers may separately and in interaction either protect them or intensify the negative effects on children and older people (Stanke, Murray, Amlôt, & Williams, 2010). Other indirect intangible damages of floods in flood area are mostly diseases such as dengue fever (borne by mosquitoes, which lay eggs in fetid water), as well as respiratory illnesses (such as the flu) and plain-old diarrhea (Winn, 2013).

Flood severity

Flood damages are useful information in determining the severity of a particular flood event. It is through flood damages that the National Weather Service of the United States of America (2011) categorises flood into minor flooding, moderate flooding, and major flooding. They explain minor flooding as minimal or one with no property damage but possibly some public threat or inconvenience. Moderate flooding occurs when there is some inundation of structures and roads near streams whereby evacuations of some people and transfer of property to higher elevations. Lastly, major flooding involves extensive inundation of structures and roads prompting significant evacuations of people and/or transfer of property to higher elevations.

Elements at risk to flood (Exposure)

Exposure refers to the inventory of elements in an area where hazards may occur (Cardona, 2004). Exposure (elements at risk), are therefore things which are directly situated within a hazard (flood). These elements at risk are:

population, infrastructure and economic resources located in potentially dangerous zone (flood) (Cardona, Aalst, Birkmann & Sinh, 2012). There are various ways elements which are at risk can be catergorized. The most common categorization is by the Asian Disaster Preparedness Center (2006) and Villagran de Leon (2006). The Asian Disaster Preparedness Center (2006) categorizes elements at risk into physical, economic, societal and environmental. Physical elements at risk encompass roads, airports, machinery, power plants, buildings; hospitals, houses, historical monuments. Economic elements are trade and business activities, access to work, agriculture lands, productivity and opportunity cost while environmental elements are air, water, fauna and flora. Income groups, gender, disable persons and households are under societal elements at risk (Asian Disaster Preparedness Center, 2006). Villagran (2006) classifies elements at risk based on sectors such as housing, health, education, agriculture, energy, commence and telecommunication.

Flood vulnerability

Persons and agencies from different academic and professional backgrounds use the term vulnerability differently (Woodward & Hinchliffe, 2000). This is because the term has non-universal definition (Downing & Patwardhan, 2003). In defining vulnerability, agencies skew towards people and social groups. Social scientists move towards social structures and differential access to resources, while physical scientists are much biased towards physical property and its effects (Adger, 2006).

Vulnerability can be defined as the diminished capacity of an individual or group to anticipate, cope with, resist and recover from the impact of a natural or man-made hazard (International Federation of Red Cross, 2013). The United Nations Development Programme (2012) defines vulnerability as a human condition or process resulting from physical, social, economic and environmental factors which determine the livelihood and scale of damage from the impact of a given hazard. The International Strategy for Disaster Reduction (2004), sees vulnerability as the condition determined by physical, social, economic and environmental factors which increase the susceptibility of a community to the impact of hazard. Van Niekerk (2005), explains that vulnerability refers to the extent to which a community will degrade when subjected to a specified set of hazardous conditions. Vulnerability was defined by Pelling (2003) as exposure to risk and an inability to avoid or absorb potential harm. One important thing stands out from all the definitions. All the definitions open up important dimensions such as exposure to a hazard which may be physical, social, economic or environmental. Also, the definitions of vulnerability usually acknowledge as conditions based on a specific hazard and it is therefore useless to discuss vulnerability independent of a hazard (Birkmann, 2006).

Physical vulnerability

Physical vulnerability is the potential for physical impact on the built environment and population. The degree of loss to a given element can be expressed on a scale of 0 (no damage) to 1 (total damage) per element (Westen & Kigma, 2009). It also deals with the level of damage or loss that physical elements at risk or built up environments suffer from the occurrence of flood (Salaga, 2006).

Physical vulnerability of buildings to flood can be conducted through an experiment by assessing damages that will happen to a building's walls, floors, doors, windows and interior contents after it has been inundated (Aglan, Wendt & Livengood, 2004). Another way to assess physical flood vulnerability is to recode reported damages that occurred from the occurrence of a flood hazard (Dutta & Tingsanchli, 2003). What stands out in physical vulnerability analysis is the relationship between the flood characteristics and physical damage (Smith & Ward, 1998). Smith and Ward assert that there is positive relationship between flood depth and flood damages to physical elements.

Economic and social vulnerability

Social vulnerability mostly results from factors such as social inequalities and accessibility which affect and increase susceptibility of individuals, groups and communities to a hazard or harm. The characteristics of a given area such as type of settlement (urban or rural), economic activities, level of development and growth all have a role in increasing or decreasing vulnerability. There are other factors which can also affect social vulnerability. These may include but not limited to: access to resources, political power and representation, social capital, aged physically challenged persons.

The economic dimension of vulnerability looks at possible or potential hazards that has diverse effects on the economy of a region or community (Comfort, Wisner, Cutter, & Oliver, 1999). Cutter, Borfuff & Sherley (2003) gives a comprehensive number of variables which largely affect socio-economic vulnerability. Cutter et al (2003) explains that some of these variables increase people's vulnerability while others reduce vulnerability (Table 1).

Table 1: Factors which affect socio-economic vulnerability

Concepts	Description	Impact social vulnerability Increase(+) Decrease (-)
Income	Helps ability to absorb losses and recover from losses more quickly	Low income status (-)
Gender	Women can have a more difficult time during recovery than men	Male (+) Female (-)
Ethnicity	Language and cultural barriers on ethnicity affect access to post disaster funding	Natives (-) Non-native (+)
Age	Extremes of the age spectrum affect the movement out of harm's way	Elderly (+) Children (+)
Occupation	Some occupations may be severely impacted by a hazard event.	Professional or managerial (-) Clerical or laborer (+) Service sector (+)

Table 1 Continued

Family Structure	Families with large numbers of dependents are vulnerable	High birth rates (+) Large families (+)
Education	Lower education constrains lifetime earnings and the ability to understand warning information	Little education (+) Highly educated (-)
Social Dependence/ Special needs	People totally dependent on social services for survival are marginalized	High dependence (+) Low dependence (-)

Source: Cutter, Boruff & Shirley (2003)

Environmental vulnerability

The environment is vulnerable to various forms of hazards. This affects the way they cope and recover from the hazard (Kumpulainen, 2006). Environmental vulnerability is the inability of an ecosystem to tolerate a hazard or stressors over a given suffers loss of diversity, extent, quality and function of the ecosystem (Klay, Pratt & Micthell, 2004). Environmental vulnerability is dependent on the type of flora and fauna because flora and fauna which are water dependent have low vulnerability while those which are not have high vulnerability (Office of Public Works, 2011). Also, environmental vulnerability cannot be assessed independently from social and economic spheres because of the mutuality between human beings and the environment:

human beings shape their environment and in turn, the environment plays a major role in shaping the economic activities and social norms of human beings (Renaud, 2006). With rapid human population, economic and technology developments, environmental diversity has greatly been reduced which affects the capacity of the environment to protect people during flooding (Renaud, 2006).

Flood risk

The concept of risk has been changing with time (Blaikie & Cannon, 1994). Blaikie and Cannon (1994) assert that risk has moved from the initial stage of equating it to hazards by natural sciences to a period of explaining risk as hazard and vulnerability and later to hazard, vulnerability and coping capacity of vulnerable elements affected by a hazard. Crichton (1999) defines risk as the probability of a loss which depends on a hazard, vulnerability and exposure. This definition leaves out the component of coping capacity of vulnerable elements since capacity to cope can increase risk or reduce risk. Others such as Sayers, Gouldby and Hall (2002) conceptualise risk as a combination of the chance of a particular event and its impact if it occurred. Sayers et al (2002) see risk as a product of probability and consequence contrary to Blaikie et al’s (1994) assertion of the dynamic shift in the definition of risk. Bollin, Cardenas, Hahn & Vatsa (2003) considers risk as the sum of hazard, exposure, vulnerabilities and capacity measures (depicted in Figure 1) which is in accordance with Blaikie et al’s (1994) concept of risk. Bollin et al’s (2003) concept of risk as shown in Figure 1 encompasses all the various definitions by having four components, it was adopted for this project. Bollin et al's (2003), in explaining the components of risk, define hazard as a product of probability and severity of 30 years flood or the worst flood that had occurred in 30 years.

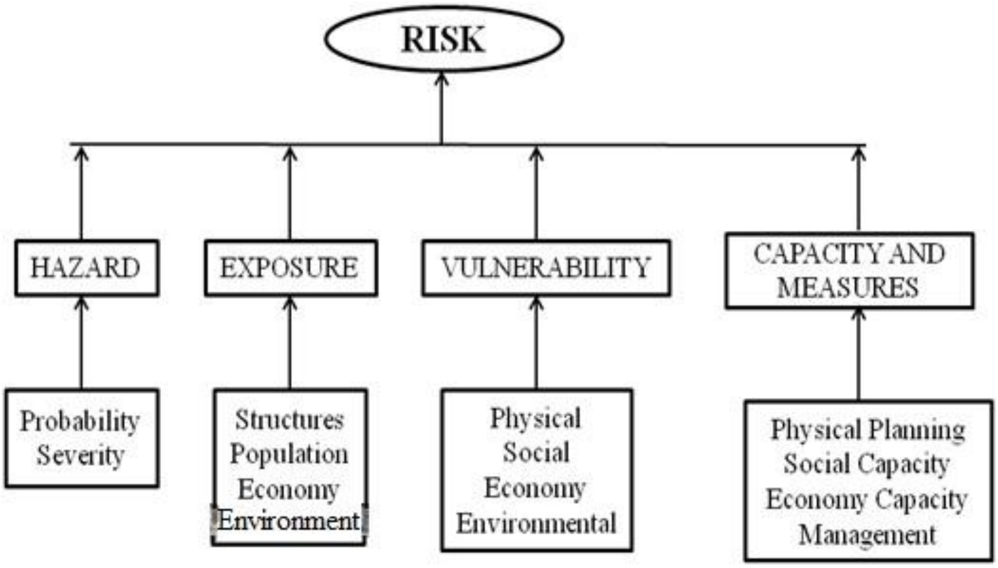

Figure 1: Adopted conceptual framework of risk

Source : Bollin,Cárdenas, Hahn & Vatsa, (2003)

Exposure is the interaction of the hazard and structures, population, economy and environment (Bollin et al, 2003). The International Strategy for Disaster Reduction (2004) sees vulnerability as the condition determined by physical, social, economic and environmental factors which is same as that of Bollin et al (2003). Factors affecting coping capacity as explained by Bollin et al (2003) cover availability of physical plans, societal plans, economic plans and management to be able to deal with a hazard (German Technical Cooperation, 2006).

Types of flood risk assessment

A risk assessment involves a quantitative or qualitative analysis of understanding risk and its physical, social, economic, and environmental factors and consequences (International Strategy for Disaster Reduction, 2004). A quantitative approach usually looks at flood risk as the product of a hazard, thus the physical and statistical aspects of the actual flooding (Meyer, Haase & Scheuer, 2009). Quantitative flood risk assessment methods usually use probability models in estimating flood risk (Unami, Abagale, Yangyuoru & Alam, 2010). Probability models evaluate the statistical likelihood that a specific event will occur. It also determines what losses and consequences will result from such events by incorporating historical information data (Li, 2013). In a quantitative risk approach, risk is usually expressed numerically (Yazar, 2002). The most common quantitative risk assessment methods are Hazus risk assessment by Federal Emergency Management Agency (2009), Monte Carlo framework for risk assessment and the fuzzy probability risk assessment (Apel, Thieken, Merz & Bloschl, 2004).

Hazus is a standardised methodology that contains models for estimating potential losses from floods using geographic information systems technology to graphically illustrate the limits of identified risk locations (Federal Emergency Management Agency, 2009). It is valuable for the systematization of possible causes and consequences of a flood hazard but ignores scenarios in flood risk assessments; thereby, underestimating risks (Thieken, Merz, Kreibich, 2006). Although the Monte Carlo flood risk assessment includes scenarios (20, 50 and 100 years) by modeling their flood exceedance probability, its weakness is assigning uncertainty values to factors which influence risk randomly. Because feasibility and reliability problems exist in terms of issues of assignment of uncertainties with Monte Carlo risk assessment, fuzzy probability is preferred by some risk assessors since it considers fuzzy mathemematical set-value methods to offset these information deficiencies (Li, 2013).

In sum, all probability models in flood risk assessment have these common challenges, they are time consuming; for analysis, one needs to have a better understanding of mathematical modules, more computer processing units (CPU) and limit assessments to direct flood damages (Apel, Thieken, Merz & Bloschl, 2004).

Consequently, people express risk qualitatively in their environment and daily activities due to limited skills and the amount of time or resources needed to undertake the kind of quantitative modeling that goes on in major projects (Joint Information Systems Committee, 2014). Qualitative approach has no numeric value and is usually opinion based with results summarised in words like low, medium and high (Yazar, 2002). Qualitative approaches are based on evaluation models dependent on the functions of hazards and vulnerabilities which are usually influenced by economic, social, environmental and physical factors. A comprehensive assessment of risk using evaluation models is a challenge because there are numerous factors which affect risk that have to be identified and their interactions, defined. Examples qualitative evaluation models are classification and regression tree models, multi-criteria evaluation models, CCTA Risk Analysis and Management Method (CRAMM) (Yazar, 2002).

Although, qualitative and quantitative approaches are often presented as distinct risk assessment methods, they are not exactly opposites (Smith & Petley, 2009). The integration of both approaches (semi qualitative) is more desirable to practitioners and decision-makers because it involves local stakeholders and the public (Brilly & Polic, 2005). With the semi-qualitative approach, indices are used to explain or express risk, usually, on a scale which ranges from zero (0) to one (1) or zero (0) to hundred (100) percent (Westen et al, 2009). An advantage of the semi-qualitative assessment is that various factors affecting risk can be placed onto a sort of map (scale) making it possible for the most important risks to be separated from the less important ones.

A type of semi-qualitative approach most favoured by geospatial experts is spatial multi-criteria assessment (Kienberger, Land & Zeil, 2009). This is because of its advantage over other assessment techniques in the ability to make decisions based on the identification of several components influencing risk and combining them in a geographic information systems software through and overlay analysis (Marrero, Toro, Scalley & Baez, 2010). Spatial multi-criteria assessment uses a simple scoring technique to rate components of risk based on their influence and then sums up these scores to indicate flood risk zones (Pullar, 1998). Results from spatial multi-criteria assessments in numeric values usually range from zero (0) to one (1) with values closer to one highlighting high risk zones while those closer to zero (0) indicate less risk zones (Musungu & Motala, 2012).

Flood risk reduction

Risk reduction is a systematic effort to reduce the risk of a disaster through the reduction of exposure of elements at risk of hazards, lessened vulnerability of people and property, better land management practices and improvement of preparedness for hazards (International Strategy and Disaster

Reduction, 2004). Measures which are used to reduce flood risk are grouped into structural and non-structural. The Washington County Emergency Management Agency (2010) explains structural measures as any physical construction to reduce or avoid possible impacts of hazards; these include engineering measures and construction of permanent facilities. This measure of flood risk reduction tries to reduce the probability of flooding occurrence and the consequences of flooding (Floodsite Consortium, 2009). Some structural measures include modification of river channels, bypass channels, dykes, bridge construction and levee (Office of Disaster Preparedness Emergency Management, 2000). These measures have often times not been able to hold flood waters which lead to large scale spillages into communities they are to protect.

Non-structural measures refer to policies, awareness and knowledge development, public commitment, methods and operating practices including participatory mechanisms and the provision of information which can reduce risk and related impacts (Washington County Emergency Management Agency, 2010). This measure focuses on influencing behaviour usually through building capacity in all stakeholders by active learning and effective engagement (Taylor & Wong, 2002). They range from land use plans, zonings, building codes, flood forecasting and warning systems (Federal Emergency Management Agency, 2009).

McMillan and Brasington (2008) argue that due to the changing nature of river flow characteristics resulting from climate change, has render already existing structural and non- structural measures inadequate in reducing flood risk. There is, therefore, the need to find new measures to reduce flood risk.

Geodesign

In reducing flood risk, most measures have centered on storage dams, sea barriers, land use plans, flood proofing of buildings, land reclamation and flood forecasting and warning (Dutta & Tingsanchali, 2003). MacMillan and Brasington (2008) assert that these measures are inadequate considering the constant changes in river dynamics and climate. As such, there is a need for new approaches to solve flood issues (Foley 2013). Geodesign is a new approach which is gaining momentum in the field of geospatial technology with capabilities to solve complex environmental issues by finding the right balance between settlements and nature (Dangermond, 2010).

Geodesign is geography (geo), by design (Steinitz, 2010). Mathur (2010) states that geodesign is the intersection of geography and design. Flaxman (2009) defined geodesign as a design and planning method which combines the creation of design proposals with impact simulations informed by geographic contexts. Impact simulation abilities of geodesign are what most flood reduction measures lack. As the Southern Tier Central Regional Planning and Development Board (2014) of the New York comments, most flood risk reduction measures alter dynamics of hydrological systems of rivers thereby enhancing water flow to adjoining lands, thereby increasing flood risks which was not thought of at the implementation stage. Geodesign helps in averting these problems by envisioning possible future scenarios with predictive alternatives whose consequence can be evaluated before implementation (Fisher, 2010). Geodesign, then, is an interventionist approach in contrast to the more detached and dispassionate approaches (Goodchild, 2010). Stenitz (2010) developed a framework for geodesign, using his understanding of landscape architecture which can be grouped into the assessment phase and the provision of intervention phase as depicted in Figure 2.

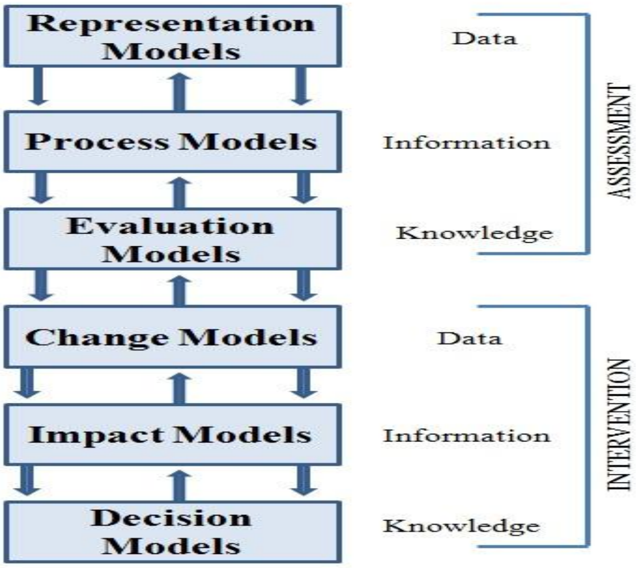

Figure 2: Geodesign framework

Source: Steinitz (2010)

According to Steinitz (2010), the assessment phase deals with the modeling of the environment, understanding it and the assessing of the elements in the environment while the intervention phase looks at changing the modeled environment, analyzing its impact and making a decision. By this, you sketch an idea, find out its implications, make adjustments and try again; often, many times within a single work session with the freedom of trying many alternatives with their advantages and disadvantage (Abukhater & Walker, 2010).

Geodesign in flood risk reduction

Practitioners in the field of geographic information systems have been able to use geodesign to solve diverse environmental problems since it provides an excellent concept for proposing change to the geographical area

(Dangermond, 2010). In 2008, geodesign was employed by the town Charleville, Queensland in Australia to help reduce flood risk (Hydro Response Limited, 2008). Geodesigners were able to remodel the town's landscape and the impact of their new model which informed them to construct a 375 meters of geodesign pallet barrier serving as a flood defence wall. Since the flood defence wall was constructed in January 28, the town has been safe from spillages coming from Waitaki River. Also, geodesign barriers were constructed in the River Calder at Hebden Bridge, West Yorkshire, UK. This diverts water from an old riverside wall reducing and preventing flooding.

In February 2004, River Severn caused havoc when torrential rain raised its level in Ironbridge town, United Kingdom. In less than 5 hours, a 550m geodesign steel barrier which was 1.8m high was erected by the United Kingdom Environment Agency along the Wharfage in Ironbridge Gorge. The result was a complete blockage of flood waters from the town as shown in Plate 1A (Geodesign AB, 2004).

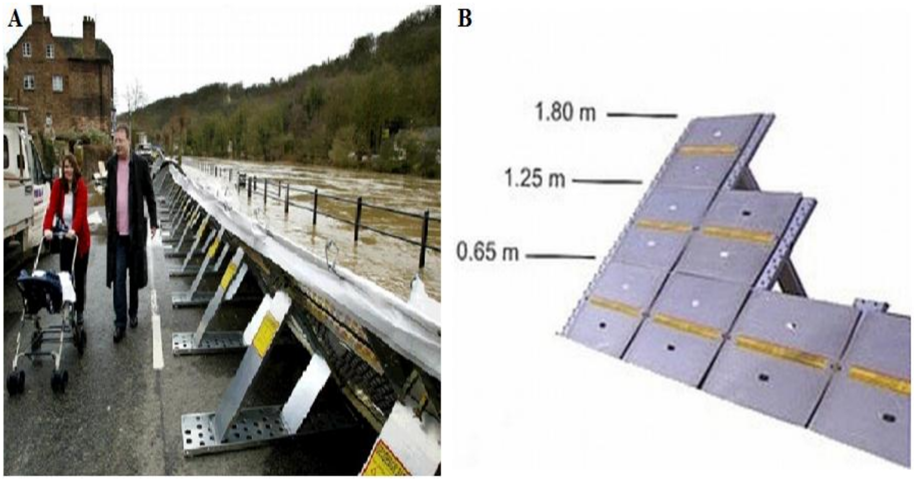

Plate 1: (A) A family walking safely beside a Geodesign barrier (steel) which is preventing flood water from entering Ironbridge

(B) Geodesign barrier showing its height and interlocking ability

Source: Hydro Reponse Limited (2008)

Geodesign barriers have a standard protection height of 0.65m, 1.25m and 1.8m with the ability to interlock (Plate 1B), making it easy to superimpose them to increase their height as against flood walls which are static (Hydro Reponse Limited, 2008). These examples show the ability of geodesign to aid conventional structural flood reduction approaches. Geodesign was applied as a non-structural flood reduction approach, in Cape Cod, Massachusetts in the United States of America when the town, threatened by sea level rise and coastal flood, employed geodesign to solve the problem through changes to the city's landscape (Snyder & Lally, 2009). Through alternative scenarios modelling, Snyder & Lally (2009) were able to find zones fit for human developments free from coastal and sea level rise in the future. China, a country with flood problems costing billions of dollars yearly have resorted to geodesign by remodelling its urban landscape ecologically to help reduce flood at a low cost (Ball, 2014).

Geodesign flood reduction strategy has challenges like any other intervention. Field experience shows that when geodesign steels are not firmly installed and the plates, properly locked, high pressure waters can topple over them (Dempsey, 2010). On non-structural use of geodesign, Ervin (2012) argues that there are some ethical issues which will emerge in the future about geodesign since it does not have a set of ethics.

CHAPTER THREE

RESEARCH METHODOLOGY

Introduction

This chapter focuses on the methodology used in assessing flood risk within the Ankobra estuary. It is organised under these themes: study area, study design, data collection, sampling techniques, data processing and analysis, ethical issues and limitations.

Study area

Site selection and geographical location

The Ankobra coastal estuary lies within 4^{0}54'55"N and 2^{0}17'44"W to the upper left, 4^{0}54'55"N and 2^{0}15'58"W to upper right, 4^{0}53'41"N and 2^{0}15'58"N to lower right and 4^{0}53'41"N and 2^{0}17'44"W to the lower left.

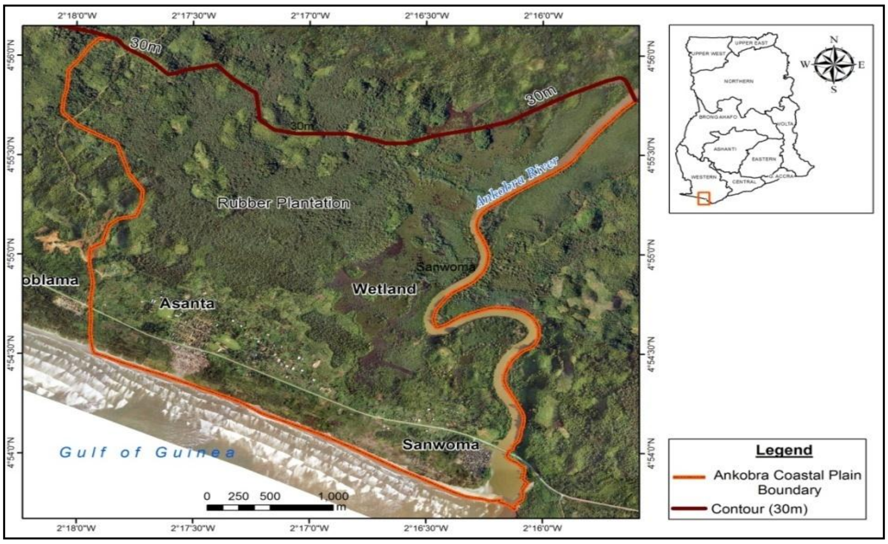

Figure 3: Map of Ankobra estuary

Source: Google earth; processed by Geographic Information Systems, Remote Sensing and Cartography Section, Department of Geography and Regional Planning.UCC (2014)

The study area is bounded to the west by Boblama and to the east by Nzema East district as depicted in Figure 3. The study area is borded to the south by the Gulf of Guinea and north up to 30m contour (coastal zone as defined by Boateng, 2009). There are two communities in the Ankobra estuary which are Asanta and Sanwoma. The location of these communities is close to a major river (Ankobra River) and a wetland making them highly susceptible to inundation. This reason influenced the choice of the area for the study.

Climate

The study area is within the South-Western Equatorial Climatic Zone of Ghana. The estuary has a bi-modal rainfall (April to July and September to November) and a dry season from December to February within the year. The mean annual rainfall is between 1500mm and 2000mm (Tanu, 2008). This high precipitation means the area can easily be subjected to flood. The months of March and April record the highest mean temperature of 31°C with the lowest mean temperature of 20°C experienced in August. High precipitation is one of the major causes of flood in the area (Maca & Torfs, 2009). Other climatic factors which induce precipitation are temperature and relative humidity. Relative humidity in the area is very high, averaging between 75% to 85% in the rainy season and 70% to 80% in the dry season. High relative humidity in an area means more water vapour in the air that can form into clouds to give rain (Umoh, Akpan & Jacob, 2013).

Topography, geology and soil of Ankobra estuary

Topographically, Ankobra estuary is low lying with most areas below 10m above sea level. A digital elevation model of the study area shows over 80%

of the landmass lies below 14m above sea level (United States Geological Survey, 2011). Its low lying nature has contributed to the meandering nature of the Ankobra River where the river course tends to move through areas with very low elevation. This has contributed to the development of wetlands, a characteristic of lowlands. Also, landscapes with low elevation close to rivers and the sea indicates that such areas are at risk of flooding (McGranahan, Balk & Anderson, 2013). The geology of the area is of metamorphosed lava, pyroclastic rock and hypabyssal formed during the Birimian Era (Minerals Commission Ghana, 2011). The soil type is ferralsols which is low in fertility, has low infiltration and is highly prone to erosion (Minerals Commission Ghana, 2011). Ferralsols in the estuary has a potential to cause flood because of their low infiltration capacity is low therefore is easy for excess water to pond a land surface (Emeribe, 2011). Along the shores of the estuary are fine sandy beaches formed from years of disintegration, deposition and smoothening of rocks by the action of the sea and the Ankobra River.

Vegetation

Ankobra estuary lies within the strand and mangrove type of vegetation. This is a prominent vegetation cover of most coastal areas in Ghana. Within the Ankobra estuary are patches of grass and shrubs from the beach to about 370 meters inland. Also, this zone harbours coconut trees dotted along the beach. After the 370 meters inland, the vegetation cover changes to the two most dominant landcover; wetland and fields of rubber plantation. The rubber plantation covers approximately an area of 3,699,875 meters square (Google

Earth, 2013) with the wetland, mostly of mangrove forest, covering 2,144,675 meters square adjourning the Ankobra River (Figure 3).

Settlement and population

Settlements within the study area are of a rural nature. This has a large influence on the nature of settlement pattern and houses of the two communities (Asanta and Sanwoma) within the area. The settlement pattern in the area is of two folds: the nucleated and dispersed patterns which are influenced by the main Takoradi and Elubo highway. Houses left of the Takoradi-Elubo road are of a nucleated pattern with footpaths in between them. However, those to the right of the road are generally of a dispersed pattern. A possible reason for this dispersed settlement pattern can be attributed to people building not based on cadastral maps. There is a sharp contrast in the nature of houses within the two communities in the area. Sanwoma, which is close to the Ankobra River, has most of its houses made of raffia with aluminium roofs while houses in Asanta are made of blocks and aluminium roofs. There are a total of 1,328 houses and structures inhabited by over 4,069 people in the estuary (Ghana Statistical Service, 2010). The population consists of 2,141 females and 1,928 males. The average household size in the Sanwoma community is 5 while that of Asanta is 4.9 people per house (Ghana Statistical Service, 2010). The prime occupation of the inhabitants is fishing related businesses. Fishing in these communities is however male dominated. Fishing is mostly offshore with very few people engaged in river fishing in the Ankobra River usually through setting of traps. The women are mostly engaged in the processing and marketing of the fish. Also, some of the population are engaged in subsistence agriculture while a small percentage are into petty trading and manufacturing.

Study design

This study adopted a descriptive design. It is a descriptive research because the study seeks to assess flood risk within the Ankobra estuary and ascertain whether geodesign can be used as a flood risk reduction measure. A descriptive study is carried out when a researcher wants to obtain information concerning a particular phenomenon, in this case, floods (Arj, Jacobs & Razaiveh, 1990). Descriptive design helps the researcher to collect accurate data on a phenomena, understand and provide a clear picture of the phenomena (Mouton & Marais, 1996). Also, a research based on descriptive design focuses on the status of a given population at a particular time; hence its adoption in this study.

Vulnerability of people in the estuary is a major aspect of risk which is not static and can only be described based on the time of study. In addition to this, geodesign is a new concept in the field of geospatial technology; as such, the descriptive research approach was adopted to enable the researcher understand and gain insight into the concept (Cuthil, 2002). Also, the study used a sample population to make inferences for the whole population which, Lietz (2008), claims is one of the characteristics of a descriptive design. Lastly the descriptive research design was employed as it allows the use of questionnaires or interviews as a means of data collection (Bryman, 2004).

One main disadvantage of descriptive research is the difficulty in ensuring that interviewed persons do not delve into personal and emotional matters in their responses (Fraenkel & Wallen, 2000). In spite of this disadvantage, the study still employed questionnaires and interviews because it provided a means to collect the socio-economic data of respondents.

The researcher also employed qualitative and quantitative, methods in gathering and analysing data. Qualitative methods give a holistic perspective in understanding human experiences by providing rich and in depth knowledge about participants' reality and social context (Holloway, 2005). Rich and in depth knowledge about participants is very useful in studying and understanding the vulnerability and experiences of participants with respect to floods in the study area. Also, the adoption of qualitative methods allowed flexibility in data collection as reports of key respondents and community members were captured verbatim. The qualitative data collected for the study include respondents' socio-economic data, their knowledge of floods in the study area, their experiences and coping capacity to floods.

The quantitative method employed was geographic information system (land use mapping, spatial multi-criteria evaluation and geodesign). It helped in modelling the Ankobra estuary, the modelled estuary was merged with the qualitative data in order to assess vulnerability and risk through a spatial approach.

A major challenge of employing both qualitative and quantitative methods, as Creswell (2003) states, that it is time consuming. Nevertheless, it is still one of the best approaches to be adopted because it looks at a situation from several angles rather than from a single perspective (Neuman, 2003).

Data and sources

The study used both spatial and non-spatial data. All non-spatial data (respondent's information) collected were grouped into tables and made geographic by associating them with their corresponding geographic elements. The merging of the spatial and non-spatial data was possible through the spatial joining tool in ArcMap software which allows spatial data and tables (non-spatial) to be joined.

Spatial data

The spatial data were grouped as secondary and primary. The modes of collecting the primary data were community participatory mapping, field survey with handheld GPS, and on-screen digitisation of orthophoto (2013). Primary spatial data generated were structures/building footprints, land use, roads, wards and flood extent maps. Through community participatory mapping, members of the community identified and mapped the spatial extent of the worst flood experienced according to Bollin et al's 2003, on a transparent (mylar) overlay with an orthophoto (2013) of the study area. The coordinates for the study area were marked on the transparency material (mylar) before the drawing this was to help in easy georeferencing as these coordinates served as control points. Onscreen digitising was employed to capture the flood extent mapped by the community using the ArcGIS software version 10.1. Also, the onscreen digitising was used to map the land use in the estuary, the roads, building footprints and wards from a 2013 orthophoto of the area. Handheld navigation systems aided in verifying and updating the features digitised onscreen. These primary spatial data collected were stored as a vector layer in an Esri geodatabase 10.1 format.

The secondary spatial data were data that have already been generated by government agencies and other institutions which were useful for the study. The mode of collecting the secondary data was mainly through internet download. Shuttle Radar Topography Mission (SRTM) digital elevation model of the study area was downloaded from Earth-Explorer website which is one of the several data depositories for the U.S. Geological Survey satellite images. The resolution for the digital elevation model was 30 meters by 30 meters. A digital elevation model is a raster layer which models geographic features as pixels or grids based on the uniqueness of the feature being continuous in space.

Non-spatial data

Non-spatial data were collected using interview schedule, in-depth interviews, observation and field measurements. Interview schedules were used for collecting data from the respondents. Data collected included their opinions on the causes of flood in the estuary, demographic characteristics and their coping capacity to flood hazards. In-depth interview was used to source expert knowledge about the flood hazard. The respondents engaged in the in-depth interview were the District Planning Officer, the District NADMO Coordinator and the Chiefs of Asanta. Observation was employed to verify whether the land uses captured by the onscreen digitising corresponded with reality on the ground. Also, through observation, information about buildings, including: the building material used for walls, foundation and roof type, were gathered. A tape (measure) was used to measure the foundation height of buildings as well as the height of buildings themselves. All these non spatial data were joined with their corresponding spatial data using the join tool in ArcGIS Software 10.1.

Target population

In this study, the population was household heads. There were a total of 1,237 household heads in the study area (Ghana Statistical Service, 2010). The household heads were targeted because they are the breadwinners of the various households. Their social and economic wellbeing, therefore, has enormous effects on members of their households, consequently, their vulnerability and risk. In an instance where the household head was not available, an adult (18 years and above) who manages the household in the absence of the household head was selected for the study.

Sample size estimation

It was necessary to estimate the number of the target population to be used as respondents in this study because of budgetary and time constrains. As a result, Fisher, Lang, Stoeckel & Townsend (1998) formula for determining sample size was adopted (Appendix A). A total sample size for the study was 169 respondents out of 1,237 household heads.

Sampling technique

The sampling technique adopted was a multistage sampling. The first stage was a cluster sampling procedure where the communities Asanta and Sanwoma in the Ankobra estuary were divided into wards. Wards are the smallest unit of demarcation of an area for easy administration (North Delhi Municipal Corporation, 2013). The communities were divided into 65 wards using accessibility (road, footpaths) as the main factor in demarcating them because in a flood scenario, it is critical to identify road segments so that rescue and response routes can be determined and rescue personnel and supplies distributed promptly and in a timely manner (Cai, Rasdorf & Tilley, 2005). Also, in order to get a spatial representation of the estimated sample size, it was necessary for the demarcation of the communities into wards so that the researcher gets spatial data within the area in order to create a risk map for the estuary. Asanta had a total of 40 wards while Sanwoma had 25 wards.

The second stage of sampling was the adoption of the proportional sampling technique. The proportional sampling technique was used to allocate the number of respondents each community should be allocated. Based on the number of wards in each community, Asanta had 104 household heads to be sampled and Sanwoma, 65 household heads. Also, in order to allocate the number of respondents each ward was to get in a community, the researcher again adopted proportional sampling technique in the third stage of sampling process. This time, the number of buildings in each ward was used as the basis for this proportional allocation of respondents. The number of buildings (digitised on-screen from the 2013 orthophoto) was chosen as the unit for the proportional allocation of respondents (Asanta 104 and Sanwoma 65) for the wards because, each building has a household and all things being equal, it can be said that the more the buildings in a ward the more the household heads in that ward. By computing the number of respondents a ward was to get based on buildings, wards that got values with decimals below 0.5 were run down to the nearest whole number while those above 0.5 were round up to the nearest whole number (Appendix B and C).

A random selection method was used at the fourth stage of the sampling process. This was used to select the specific buildings in the wards to be visited. The researcher assigned numbers to buildings in each ward, these numbers were written on small sheets which were folded and picked at random. The number picked was the building visited during data collection. In order to know the specific buildings selected and to be visited, spatial extent of all the selected buildings were loaded onto a Tremble Juno SD navigation systems which directed the researcher to the actual building on the field. This was possible, by using the "find tool" of ArcPad software 7.3 installed on the Tremble Juno SD navigation system. Lastly, the random sampling technique was used to select the household heads to be interviewed. This was because some buildings had more than one household head, so once the building was entered the researcher randomly selected any household and inquired of the head. Appendix D shows a diagram of all the stages used in sampling the household heads. However, buildings which had no occupants available at the time of the research and those in which no adult was in charge of the household in the absence of the household head were excluded. The next building with a household head available was then selected as a replacement.

In addition to the 169 household heads sampled, purposive sampling technique was used to select three (3) key informants: the District Planner, District NADMO Coordinator and the Chief of Asanta.

Data processing

Non spatial data

Non-spatial data comprised of interviews with respondents which were coded and entered into Statistical Package for the Social Sciences (SPSS) software version 21 based on the wards in the study area. The Statistical Package for the Social Sciences (SPSS) software version 21 was used to process these responses. The results generated from the analyses were, afterwards, presented in tables and figures. Interviews with key respondents were also transcribed and used to support the results. The spatial data processing phase involved data interoperability.

Spatial data

Data interoperability is the process of translating, transforming and integrating data from numerous sources and formats. The process involves the assignment and transformation of coordinates and also spatial formats of data. In coordinate assignment, flood extent map drawn by the community members on a transparent material (mylar) was georeferenced into the Ghana Metre Grid coordinate system. Georeferencing was performed (using the coordinates marked on the transparency material as control points) to make the transparent material (mylar) spatial so that it could be overlaid with the rest of the spatial data collected for this study. The georeferencing tool in ESRI ArcMap software 10.1 was used for this process by adopting the first order polynomial transformation, with a root mean square error of 0.001. In the activity of coordinate transformation, the downloaded digital elevation model was in a World Geodetic System (WGS) coordinate system unprojected (1984) while the rest of the spatial data was in Ghana Meter Grid coordinate system. The World Geodetic System is a geographic coordinate system which is not conducive for working in a small area at a localised scale. It was, therefore, converted into Ghana Meter Grid through the interoperability tool in ArcMap software 10.1. Another major aspect of the data interoperability was the merging of non-spatial data coded in Statistical Package for the Social Sciences (SPSS) software version 21 with the spatial data (wards, buildings, land uses). These two types of data were merged using the spatial join tool in ArcMap 10.1 where the non-spatial data were given numbers and merged with their corresponding numbers in spatial form (thus, interview data from respondents in wards were put into tables with the ward numbers and the tables with ward numbers together with the actual ward, which is spatial, joined using the spatial join tool).

Data analysis

Data analysis of processed data were in two folds: the assessment phase and the intervention phase. Assessment phase of the data analysis was guided by Bollin et al (2003) framework for risk assessment using spatial multi-criteria evaluation analysis (SMCE) tool. While the intervention phase was performed using Steinitz (2010) intervention phase of geodesign framework.

Assessment on flood vulnerability risk

Vulnerability and risk analysis was performed using the Spatial Multi Criteria Evaluation (SMCE) tool in the Integrated Land and Water Information

System software (ILWIS). Spatial Multi Criteria Evaluation (SMCE) process involves four stages: problem definition, standardisation, weighting and slicing.

The problem definition stage entails creating a criteria tree with the main object as a goal while the factors which determine the main goal lie beneath. In this research, the main objective is flood risk while flood hazard, vulnerability and coping capacity are the factors which influence risk. Bollin et al (2003) also explains that these factors which influence risk are also influenced by other variables, example, flood hazard is influenced by probability and severity of flood in an area. As such these variables flood probability, severity which influence the determinants of risk were included in the criteria tree underneath the factor they influence as raster data.

The multi analysis of all maps generated were performed through standardisation and weight assignment. Standardisation takes the form of assigning a single domain for all the input maps. For instance, distance is in meters while income levels are in Ghana Cedis. In order to compare these in a sensible manner, they were standardised, thus transformed to the same unit using a scale of 0-1. Once the maps that had been generated were standardised, they were assigned weights based on a pairwise comparison method. Also known as analytical hierarchy process (AHP), in the process of pairwise weight assignment, one must indicate for each pair of factors which one is the most important. Subsequently one must indicate in qualitative terms to what extent a factor is more important than another. The pairwise comparison method converts these comparisons of all pairs of factors to quantitative weights for all factors. For example, if three elements, A, B, C were to be compared, and A is greater than B and B greater than C, it is logical to expect A to be greater than

C. Once this process was done, the software generated the outputs (vulnerability and risk maps) of the study. These output maps had values ranging from 0-1 to indicate vulnerability and risk levels for the Ankobra estuary.

In order to make these values meaningful and communicate the results better, slicing was performed on the outputs generated. Slicing is the process of classifying or grouping the values of a raster map (outputs generated) into categorise.. The vulnerability and risk levels which were in values were categorised into low (0- 0.24), medium (0.25- 0.49), high (0.5- 0.74) and extreme (0.74- 1) based on Bittner (2010) classification of risk areas and countries. Methods and stages undertaken in the spatial multi-criteria evaluation (SMCE) are presented in a flow diagram in Appendix E.

Geodesigning the Ankobra estuary

The flood risk map was used as the basis for remodelling the landscape to reduce flood risk in the study area. The intervention phase of Steinitz (2010), geodesign framework was adopted. The first part of the intervention phase of geodesign deals with change models. Steinitz (2010) explains that change models require remodelling of the landscape. That is, the geodesigner changes some physical features which have contributed to improper functioning of a zone. In meeting this requirement, some landscape features in the Ankobra estuary had to be changed or remodelled. The first change model of the geodesign undertaken was increasing the foundation heights of buildings in the study area above the worst flood depth experienced in the communities. The second geodesign model was also undertaken thus, change of existing channels and drains to help reduce flooding in the future. In this regard a hydrological model was run for the Ankobra estuary from the digital elevation model. The hydrological model tool in ArcMap 10.1 ESRI software was used.

The processes for generating the hydrological model were: checking for sinks in the elevation data, filling these sinks and running a flow direction function as well as a flow accumulation function. Lastly, the hydrological tool (flow accumulation algorithm) was run to determine where runoffs are likely to move downslope in the Ankobra estuary. This helped in generating a drainage network of the Ankobra estuary. The drainage network of the landscape, the researcher remodelled some part of the land use in Ankobra estuary, channelling away from the communities the excess water which mostly causes floods. After the remodelling or the change model process, the impact model stage was reached. This stage ascertained whether the landscape model of the estuary designed has the ability to reduce risk. Appendix F is a workflow showing the stages involved before producing the results of this study.

Ethical issues and limitations

Social science investigates complex issues which involve cultural, legal, economic, and political phenomena (Freed-Taylor, 1994). This makes ethical issues an important component of research especially for graduate students who are expected to complete independent research to fulfil degree requirements (Michelle, McGin & Bosacki, 2004). Due to this, before administering the interview schedule, the researcher first introduced himself and briefed the respondents on the purpose of the research and sought their consent on whether they would want to take part in the research or not.

Participants exercised their rights voluntarily by accepting or refusing to participate in the study. The privacy and anonymity of respondents were observed by numbering them. This made it difficult to trace specific responses to any particular respondent.

A major limitation of the work was respondents refusing to partake in the research. Also, some buildings selected randomly did not have household heads at home during the research. In solving this problem, the researcher chose other buildings close by but within the same ward as the originally selected building. Another challenge experienced during the data collection was respondents' inability to quantify their properties which had been destroyed by flood as a result of the numerous floods experienced.

CHAPTER FOUR

RESULTS AND DISCUSSION ON FLOOD RISK ASSESSMENT IN ANKOBRA ESTUARY

Introduction

This chapter presents and discusses results from analysis performed using spatial and non-spatial data collected in the course of the research. The chapter is presented based on the objectives of the study. It gives results and discussions on the flood hazard in the study area, the various aspects of vulnerability (physical, socio-economic and environmental) and floods risks (areas and levels of risk). The results are presented in the form of statistical graphs (bar chart, pie chart), tables and maps.

Types of flood hazard in Ankobra estuary

Analysed data in this study indicates that floods in Ankobra estuary are damaging events which often cause destruction to property, disrupt social and economic activities and result in environmental degradation.

The Ankobra estuary experiences three types of floods based on Depue's (2010) categorisation of floods according to their originating source. They are riverine flood, coastal flood and urban flood (Table 2). These types of flood were identified with the aid of NADMO Officers, the District Planners and community members.

Table 2: Types of flood and causes in the Ankobra estuary

Type of Flood	Locality	Causes and Description
Riverine (Worst in June 1987)	Sanwoma	Elevation (Max 120m, Min 4m) Excess rainfall Increase in discharge of Ankobra river Closeness of buildings to Ankobra river
Coastal	Sanwoma	Tides & waves Mouth of Ankobra river is wide
Urban (Worst in June 1993)	Asanta	Construction of Axim-Elubo road preventing free water flow

Source: Fieldwork, 2014.

In the Ankobra estuary, riverine flood affects only Sanwoma and wetlands north east of the estuary. It is the most frequent of all the types of floods in the area. Riverine floods come from two sources; the Ankobra River and a stream west of Sanwoma township (Figure 4). The stream is a seasonal one, which inundates the community in the rainy season. Ankobra River inundates the community when the volume of water exceeds the river channel, allowing water to flow to areas with very low elevation.

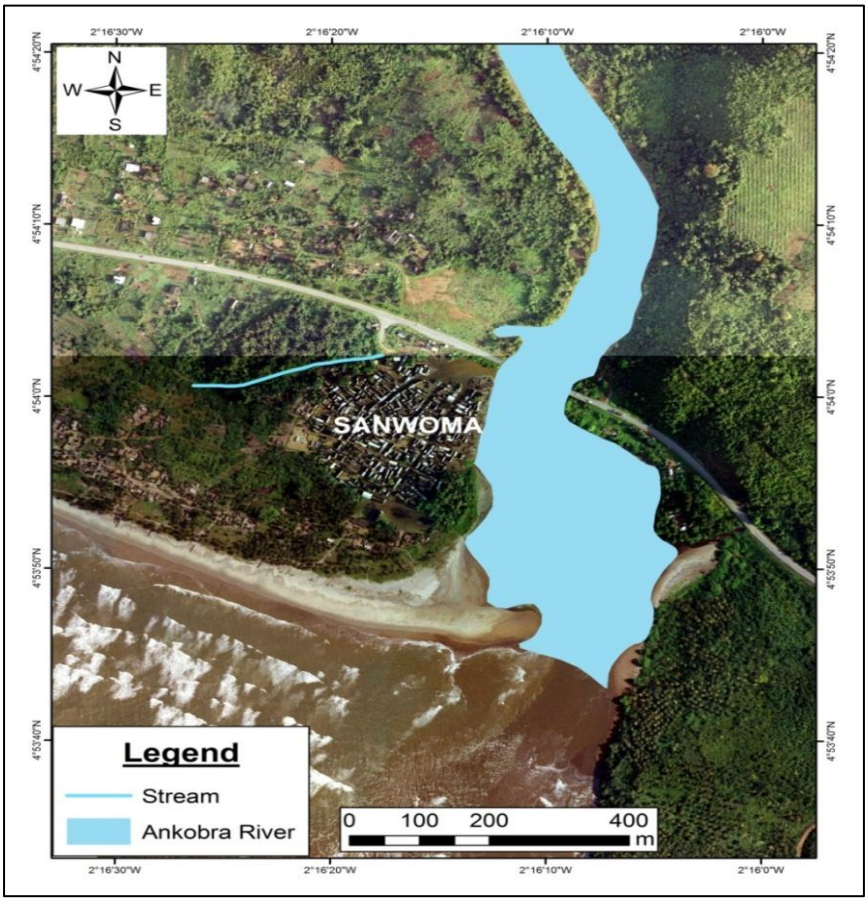

Figure 4: Sources of riverine floods in Sanwoma

Source: Fieldwork, 2014

The Sanwoma community has a maximum elevation of fourteen (14) meters and a minimum of six (6) meters above sea level making it susceptible to inundation by the Ankobra River. Eleuterio (2012) explains that riverine flood flows out through its floodplain, meaning everything within the floodplain is likely to be inundated. Thus, the reason for the frequent occurrence of riverine floods in the study area is due to the closeness of Sanwoma community to the Ankobra River. Figure 5 shows the distance of buildings in Sanwoma to the Ankobra River. A total of 341 buildings lied within the distance of 300 meters to the Ankobra River. They were within the 300 meter buffer zone of the Town and Country Planning Department of Ghana, which should be left undeveloped to help prevent flood related disaster.

Only 16% of the buildings in Sanwoma community were away from the buffer zone. The mean distance of all buildings and structures away from the Ankobra River was 182.44 meters.

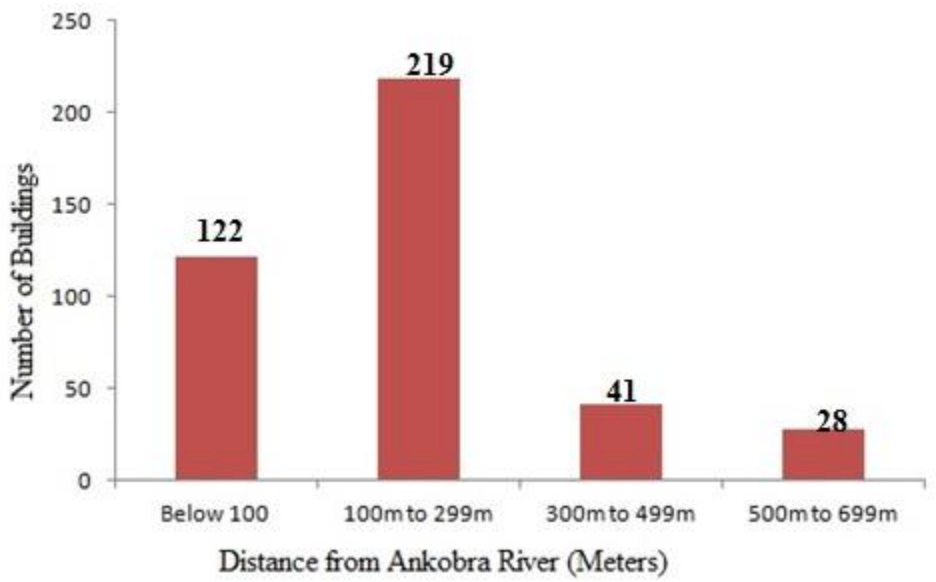

Figure 5: **Distance of buildings away from Ankobra River in Sanwoma**

Source: Fieldwork, 2014

The Asanta community is situated far away from the Ankobra River. Figure 6, shows the distance of buildings in Asanta away from the Ankobra River. No building was found within the buffer zone of 300 meters as stipulated by the Town and Country Planning Department of Ghana. Only six (6) buildings were within a distance less than 1,000 meters (one kilometer) while 51 buildings were between a distance of 2,000 to 2,499 meters. The mean distance for all buildings away from the Ankobra River was 1,769.55 meters far greater than Sanwoma. This explains why Asanta does not experience riverine flood compared to Sanwoma.

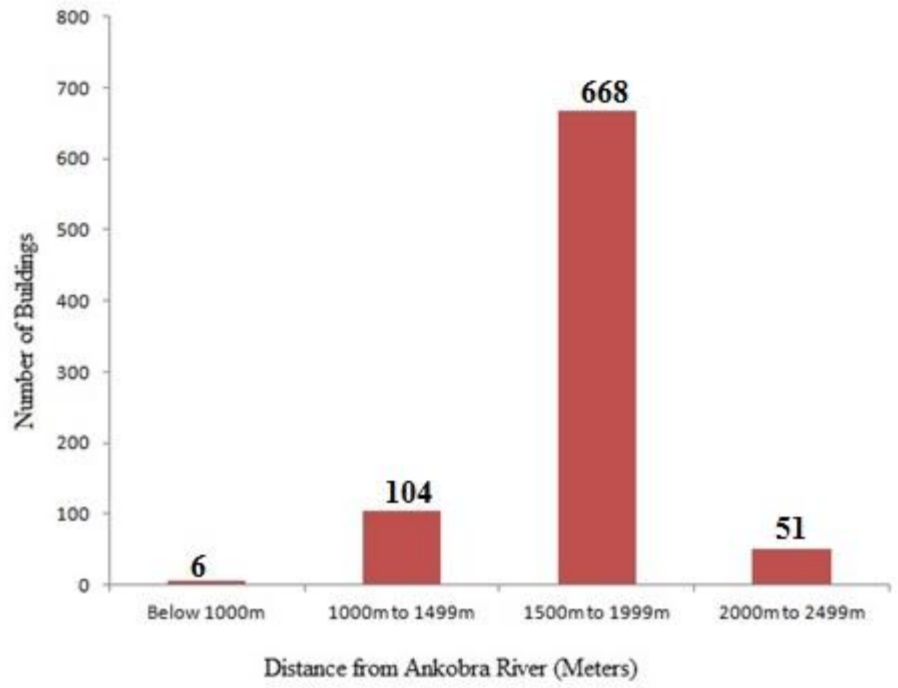

Figure 6*:* **Distance of buildings away from Ankobra River in Asanta**

Source: Fieldwork, 2014

Like any other floodplain, the Ankobra estuary was affected by coastal floods. This type of flood is caused by high tides and ocean storms with high velocity which causes the water level of Ankobra river to rise, preventing discharge of water from Ankobra River into the sea. The highest tide recorded in Western Region, within which the study area lies, was 1.78 meters, with a lowest tide being 0.17 meters. A tide with 1.78 meters high has the capacity to block any amount of water from the Ankobra River to the sea thereby inducing floods in the estuary.

The last type of flood that affected the estuary was urban flood. This type of flood occurred mainly in the Asanta community and was a result of a human development which was the construction of the Axim-Elubo road. In the development of the main Axim - Elubo road through Asanta, engineers raised the road level above the normal elevation of the land. As a result, the road has divided the community into two low areas lying beside the road (Axim-Elubo) impeding free flow of rain water. Hence, allowing rainwater to move into adjacent buildings. This type of flood is similar to floods experienced in Delhi as reported by Pareva (2006) and Action Aid (2006). Plate 2 shows the road that serves as a barrier for water to freely flow from one side of the community to the other.

Plate 2: Axim- Elubo road through Asanta which causes flood

Source: Fieldwork, 2014

Causes of floods in Ankobra coastal estuary

The factors that caused floods in the study area were grouped based on Westen et al's categorisation of causal factors; endogenous and exogenous (Westen et al, 2009). The cause leading to a riverine flood is from an endogenous source, which is rainfall or precipitation. This confirms Alkema et al (2009) assertions that rainfall is the main cause for riverine flood. During the months of May, June and July (rainy seasons) river average discharge in the

Ankobra channel and the stream west of Sanwoma increases, with the month of June recording the highest discharge of 136.83 m3/ sec (Center for Sustainability and Global Environment, 2010)). The increase in river discharge accounted for floods during the rainy seasons.

The reason for the high discharge of water flow was the result of high levels of water discharge from adjourning tributaries such as Mansi, Fure, Nhwini and Bonsa Rivers (Figure 7).

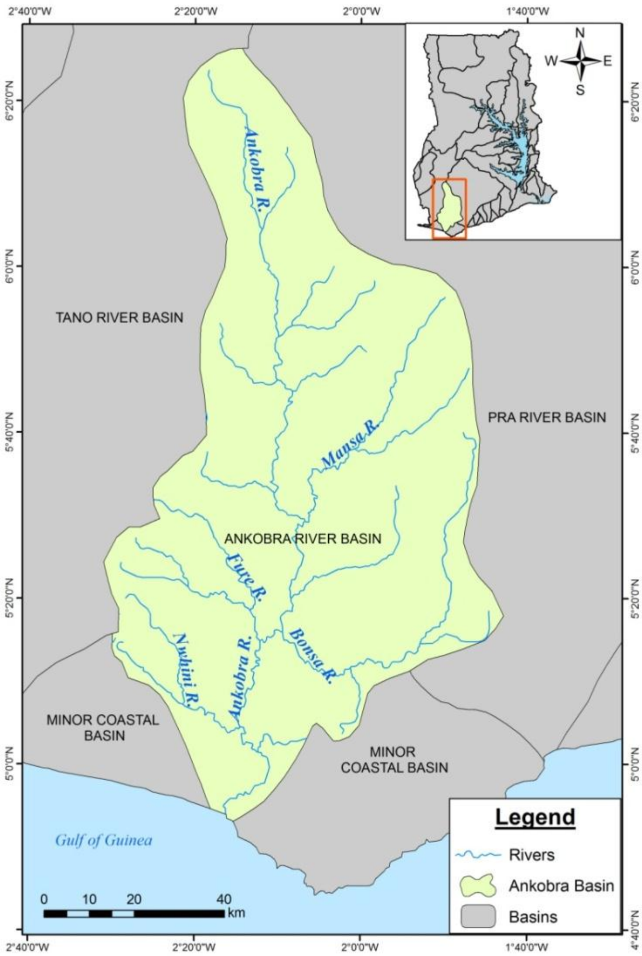

Figure 7: Map showing major rivers adjourning Ankobra river

Source: GIS analysis, 2014.

These rivers are located far upstream from the Ankobra estuary. This is in line with the National Flood Safety Awareness of the United States of

America (2013) assertion that rainfall causing riverine flood might not necessarily come from the flood catchment area but far upstream. The quantities of discharge from these rivers are very high since they lie in the wettest climatic zone in Ghana with annual rainfall between 1500mm and 2000mm (Tanu, 2008).

Another triggering factor of flood as gathered from the community participatory mapping is human development. Inhabitants of Sanwoma believe that the magnitude and frequency of riverine floods they have experienced in recent times have increased due to the construction of the Ankobra bridge which replaces a former culvert. From the community participatory mapping a participant claimed:

> *There was a culvert not a bridge which prevented free flow of water downstream into the sea hence excess water spilled into the wetland causing floods there with little of the excess water coming into the community. But with the bridge it allowed free and direct flow of the river downstream which also moves directly into the community.*

Triggers causing coastal floods in the study area take their source from tides and wave actions which are of an endogenous origin. The estuary is the entry point of the Ankobra River to the Gulf of Guinea. The mouth of the Ankobra River is 197 meters wide and it lies vertical to the wave action and tides which makes it easy for a large quantity of sea water to enter the Ankobra river channel through wave and tidal actions. This means sea water moves directly upstream the river channel, altering the estuary of the river. At high tides and in times of strong wave actions, sea water can move to about 1,153 meters preventing flow of water from the Ankobra River into the sea, thus pushing the river water into the Sanwoma community (Hen Mpono, 2013). A respondent in Sanwoma commented on this triggering factor as follows:

> *When the waves move into the Ankobra River, the water level in the river begins to rise because the river water is blocked from moving into the sea leading to frequent flooding in this community.*

Figure 8 shows, respondents' perspection about causes of flood in the study area. Fifty-five percent (55%) of the respondents attributed floods to sea tides and waves, thirty percent (30%) attributed floods to rainfall while fourteen (14%) attributed it to human developments.

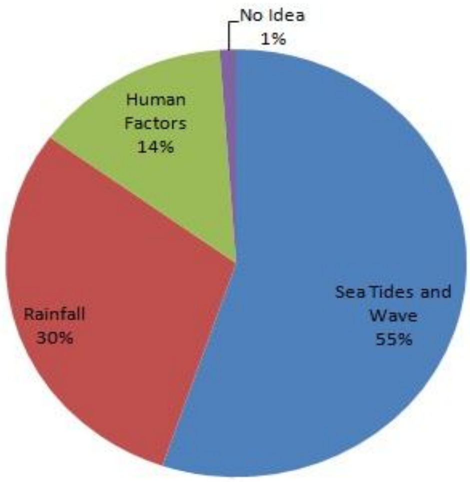

Figure 8*: *Respondents perception on causes of floods

Source: Fieldwork, 2014

Among the respondents who attributed floods to human factors some viewed it as a result of poor drainage system, sand winning and the construction of the Ankobra bridge. Only one percent of respondents did not have an idea of the cause of floods in the estuary. A respondent in Asanta comment on human factors influencing floods:

> *The gutter has not been effective in channeling rainwater into the sea, after the construction of Axim-Elubo road. This has even worsened with the new constructions undertaken by engineers; they have started to widen the road thereby blocking a large part of the gutter.*

Flood characteristics in Ankobra estuary

Gamble and Meentemeyer (1997) believe that if the appropriate flood frequency, depth, duration, time of onset and spatial extent are known, they can significantly aid in planning and reducing flood damages in the future. The study, therefore, identify these characteristics of floods within the Ankobra estuary (Table 3).

Spatial extent of the worst flood in Ankobra estuary

A spatial extent of flood looks at areas covered in the occurrence of floods and helps planning units in developing flood maps (Long, Fatoyinbo & Policellli, 2013). Spatial extent of floods also aid in proper land use demarcation. It is important, then, to always capture the worst flood experienced within 30 years in an area (Bollin et al, 2003). The spatial extent of the worst flood within the estuary was generated from a community participatory mapping conducted separately in Asanta and Sanwoma. Zein (2010) and McCall (2008) claim that flood assessments are mostly done by technical experts without community involvement. In Sanwoma, the worst flood agreed on was a riverine flood which occurred in June, 1987, whereas that of Asanta was an urban flood which occurred after the construction of the Axim-Elubo road in June 1993 (Table 3).

Participants of the community mapping chose one person, who they all guided to draw (using permanent marker) on the transparency, the boundary of affected areas during the worst flood in both communities. Plate 3 depicts participants drawing the flood extent of the worst flood experienced.

Plate 3: Community participatory mapping

Source: Fieldwork, 2014

The flood area was generated automatically by the ArcMap 10.1 software after the digitising and it covers an area of 2,533,218.14 meters square which represents about 24.9 percent of the total area of the Ankobra estuary. In Sanwoma the total built environment was 54,377.22 meters square of which a total of 51,119.46 meters square (94%) were within the flood zone.

Table 3: Flood spatial characteristics/ features in Ankobra estuary

Type of Flood	**Flood Characteristics**			
	Year of Worst Flood	Spatial Extent	Time of Onset	Flood Depth
Riverine	June, 1987	54,377.2m^2	Rapid	2.9ft
Urban	June, 1993	29,665.78m^2	Rapid	4ft

Source: Fieldwork, 2014.

In the case of Asanta, an area of 29,665.78 meters square (4%) of a total 721,925.04 meters square of the built environment lied within the flood zone.

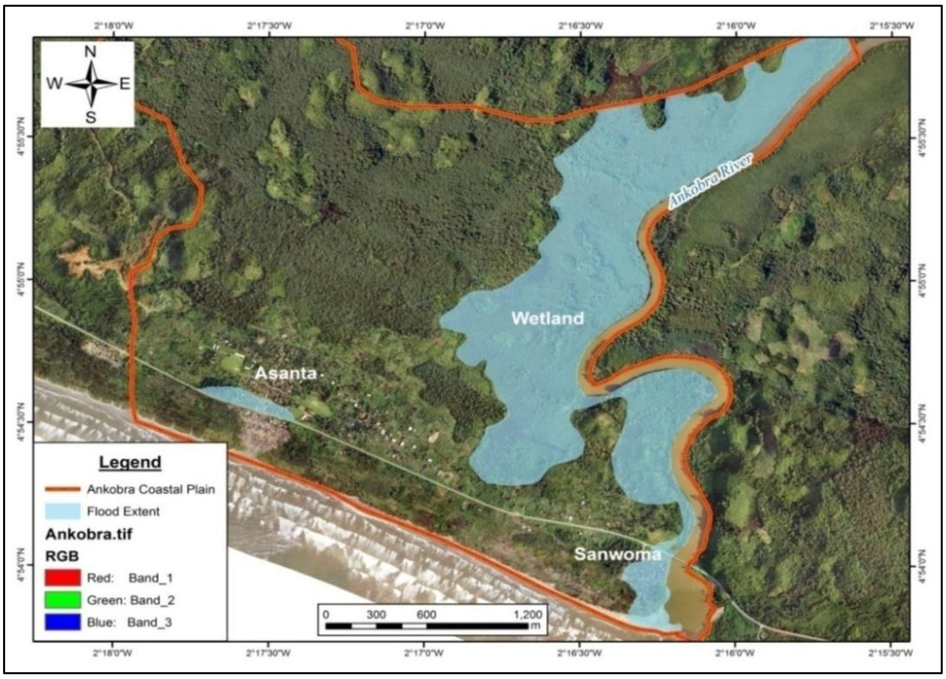

Figure 9*:* Spatial extent of the worst flood in the Ankobra estuary mapped during community participatory

Source: Fieldwork, 2014

The largest area within the Ankobra estuary subjected to flood is a mangrove wetland covering an area of 234,1419.43 meters square; thus the entire wetland. This is due to its low elevation and the meandering nature of the Ankobra River which tend to release more water into the wetland when channel capacity is exceeded. Nelson (2012) contends that channels with meandering nature encourage discharge of water and sediments in flat and low elevation areas, thereby causing floods.

Time of onset and flood duration

Time of onset of floods is the time difference between the precursors of flood and the actual manifestation of flood (Alkema et al, 2009). Information about time of onset can aid in emergency planning and evacuation of people during floods. Flood duration within the estuary differs with the type of flood. Time of flood onset was identified in the study area: slow and rapid based on Becker, Johnstone & Lence (2011) classification. A slow onset is experienced in the Ankobra estuary when tides or waves triggering the flood have a relatively gentle flow into the river channel of the Ankobra River. Likewise, if the flow of the tides or waves is rough with high speed then the onset time is categorised as rapid. The flood onset for riverine floods in Sanwoma has a rapid onset rate. This is because the wetland acts as sponge which holds heavy rain water for a long time and once it exceeds its capacity, water starts gushing into built-up areas. A community member commented that;

> *If floods will take place, just within minutes as we are talking, flood water would have started to move pass our knees.*

In the case of flood duration, flood waters can persist for months before receding. According to a participant in the community mapping, *It can take days and even months. In the 1987 flood (the worst flood experienced in Sanwoma), it took about one month before the water receded; people who traveled along the road were asking why we stay here, and that the government should relocate us. This place was like a tourist attraction point, travelers used to alight from their vehicles to watch the community during that time. Also during this time some community members left to stay with their relatives in other communities.*

Flood depth in Ankobra estuary

Flood depth is an important characteristics of flood because it can help show relationship between floods and its damage (Gissing & Blong, 2004); the higher the flood depth, the higher the likelihood of damages. In the community participatory mapping it was gathered that the type of flood experienced influences the flood depth within the Ankobra estuary. Sanwoma community which is inundated by coastal and riverine floods have experienced the worst flood depth of 2.9 feet (88.39cm or 0.88m) while Asanta, affected by human induced flood, have the worst flood depth of 4 feet (121.92cm or 1.219m). This figure for flood depth was arrived at when community mapping participants selected one participant and all agreed on the level the water reached on him during the flood. This level was measured by a tape to get the figure of flood depth as indicated above. According to respondents, this high flood depth usually induces floating of materials, thus carrying inhabitants' belongings such as furniture, clothes and utensils when they move into buildings. A comment by respondents about the flood depth and things it carries away.

> *Flood levels can be high above your knee, which usually makes it easy to float and carry household belongings like bowls, utensils and clothes.*

Flood depth and house foundation were analysed since there is always a correlation between flood depth and flood damage in respect to the foundation of building. Chang et al (2008) argue that flood damage is determined by flood water depth. Thus when flood depths are higher than foundation of buildings, water easily moves into buildings, destroying properties. Figure 10, shows the height of foundation of buildings. There were about 53 buildings with foundations below 19 cm while only 7 buildings had foundation above 50 cm. These foundations were all below flood depths of all the types of flood in the study area.

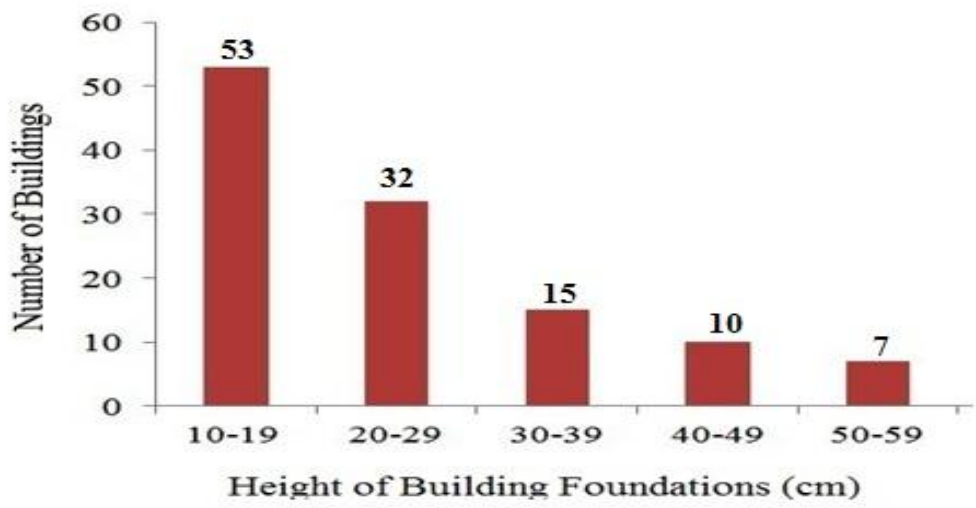

Figure 10*:* Height of building foundations

Source: Fieldwork, 2014

Also, the high flood depths in the Ankobra estuary stall movement, hence, posing risks to human life. The Department of Environment, Food and

Rural Affairs (2003) of United Kingdom shares this assertion. Plate 4, shows a resident of Asanta moving in flood waters.

Plate 4 : A resident of Asanta walking in the flood water

Source: Fieldwork, 2014

Flood frequency

Flood frequency helps in knowing the average interval of successive floods and also for forecast future possible floods in an area (Bureau of Meteorology Australia, 2013). Flood frequency in the estuary is influenced by the type of flood. The riverine flood has a yearly return period. A respondent remarked *every year this place (*Sanwoma*) gets flooded, it is normal.*

This is consistent with Wolman et al (1997) flood dynamics studies. Wolman et al (1997) discovered that rivers in coastal plains are likely to inundate their plains once a year. This means that it is likely that every year

Sanwoma which is close to the Ankobra river will be inundated. In relation to the worst flood experienced within the flood plain which was 30 years ago, the probability of return is 0.033. This was arrived at by dividing the worst flood period by one.

Coastal floods have a different probability of return which was difficult to assess. This is because its occurrence is so frequent that the community members found it difficult to give the number of times the area got flooded. As a result, the researcher adopted Miller et al (2010) qualitative classification of probability of flood events for the area. Miller et al's (2010) classifies flood probability as; none (flooding occurrence is not probable), rare (flooding is unlikely but possible), occasional (flooding occurs on an average of 50 times or less in 100 years), common (flooding is likely under normal conditions), frequently (flooding occurs on average of more than 50 times in 100 years) and ponded (water standing on soils in closed depressions). By using the qualitative approach coastal floods in the study area can be classified as frequently flooded. This is because coastal flood in the Ankobra estuary occur on an average of more than 50 times in 100 years as gathered from the community participatory. As a participant claimed coastal floods occurs more than riverine flood. Therefore, if riverine flood has a return period of one then in 100 years it will occur hundred times. So for coastal floods which occurs more than riverine flood, it can said to occur more than 100 times in 100 years. A community mapping participant comment;

> *The coastal floods can occur anytime especially when the sea waves increases. This occurs more frequently*

than the riverine flood which usually occurs during the rainy season.

Flood damages and effects in Ankobra estuary

Flood damages and effects represent various levels of harm to people, their socio-economic wellbeing, properties and the environment (Poussin, Ward & Bubeck, 2010). Merz et al (2004) believes that flood effects are not always negative but have some positive sides. Based on this respondents' perception on flood benefits were explored and the results are presented in Figure 11.

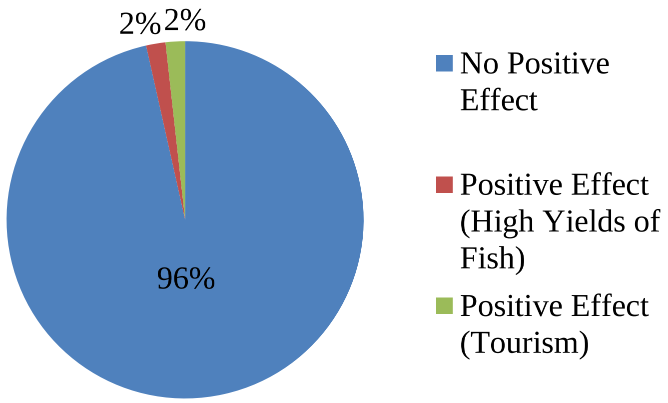

Figure 11*:* Responses on positive effects of floods

Source: Fieldwork, 2014

Ninety six (96) percent claimed floods have no positive effect on them and the environment. Only four (4) percent indicated that floods have benefits on the community through tourism promotion (since travellers stop over to watch how flooding has affected the community) and that it also increases fish yields in the Ankobra estuary.

On the other hand, negative effects on the study area were numerous. These were categorised into direct and indirect damages based on Floodsite Consortium (2009) classification. Floodsite Consortium (2009) explained direct damages as those damages which occur due to physical contact of floodwaters with people, property and any object. While indirect damages are damages to intangible things. Direct damages experienced by people in the Ankobra estuary included the collapse of buildings, damage of buildings' foundation (Plate 5), damage of building walls and damage to fish smoking chambers.

In addition, when flood waters move into rooms, things such as mattresses, furniture and clothing are destroyed while cooking utensils are carried away by flood waters. One respondent claimed;

> *I was sleeping and the bed was spinning, I thought I was sick. I got up from the bed and I was standing in water. Nana (Chief of Asanta) gave me this place (the place of interview) to settle when I abandoned my flooded house. You see the furniture there (Plate 5) ; it got spoilt during that time with clothes and materials for my wife.*

Plate 5*:* Abandoned house and furniture destroyed by flood

Source: Fieldwork, 2014

The prominent indirect experience after floods is increase of mosquitoes within the community. Flood water also pushes rubbish from dumping sites into the community and snakes and frogs find their way in houses. This is consistent with Montana Department of Public Health and Human Services' (2005) research where they found that floods increased the number of mosquito-borne diseases such as malaria, dengue and West Nile fevers. As a respondent commented,

> *The floods always bring rubbish; yes rubbish and mosquitoes.*

Flood severity in Ankobra estuary

The National Weather Service (2011) in the United States of America after assessment of the damages and effects of a flood event categorises it into severity levels. The National Weather Service (2011) grouped flood severity into minor (minimal or no property damage but with some public threat and inconvenience), moderate (inundation of some structures, roads and evacuation of some residents and property), and major (extensive inundation of structures, roads prompting significant evacuation of people and properties). Based on this, the worst flood experienced in Sanwoma community flood severity can be termed; major flood since from the account of the community participatory mapping, the flood map shows 83% of structures in the community were inundated and people even had to travel and stay with other relatives and friends in other communities. Migration of some community members due to flood, is consistent with Dun (2011) research in Vietnamese Mekong Delta region where floods stimulated exodus of people from the area in 2007.

Mapping elements at risk to flood in Ankobra estuary (Exposure)

Elements at risk as explained by Cardon et al (2012) are things within a hazard zone which includes population and infrastructure (buildings). In order to know these exposed elements at risk in the Ankobra estuary, it was necessary to model the Ankobra coastal landscape into a land use map and map buildings within the study area and population data.

However, the land uses generated from the on-screen digitisation procedure was validated through field observation. Figure 12 depicts, land use map overlaid with flood hazard map (worst flood experienced) to identify land uses at risk (Figure 12).

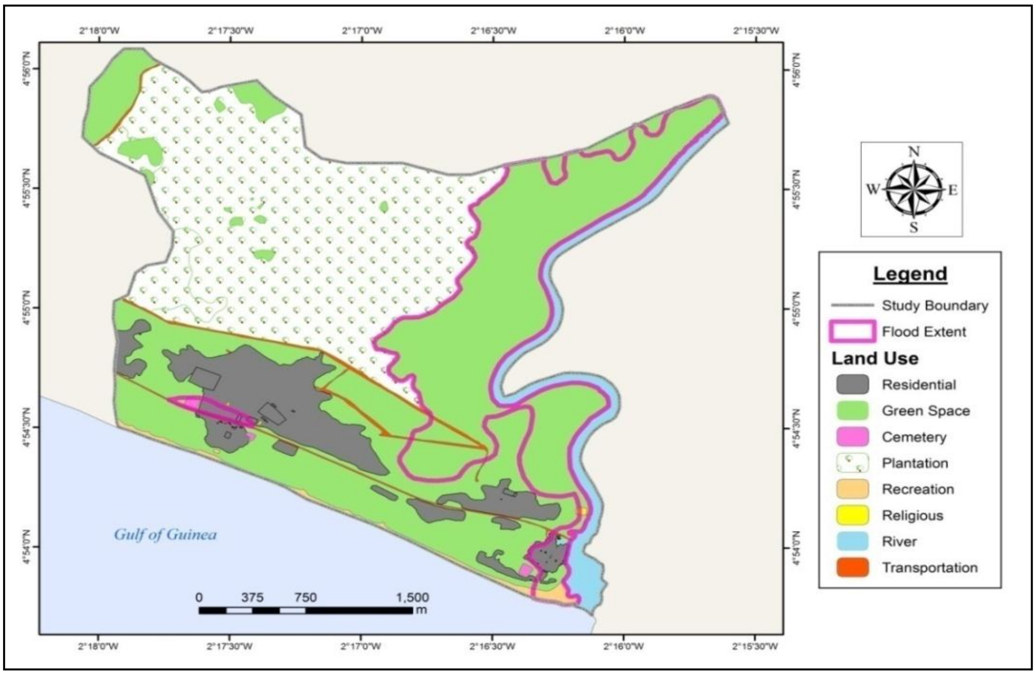

Figure 12*: Land use affected by flood in the Ankobra estuary*

Source: Fieldwork, 2014

The land uses affected by floods were cemetery, recreation areas, religious sites, residential, transport and green spaces (Table 4).

In total an area size of 2,528,930.79 meters square is inundated by flood as shown in Table 4. The largest land use affected by flood is green space while the smallest is cemetery. Flooding of a cemetery can have serious health problems for inhabitants. As Chicora Foundation (2012) states, vaults and coffins may be washed out of graves exposing human remains, which pose public health threats. Within the residential land use, three hundred and ninety four buildings are affected by floods; this includes, one (1) public toilet, two (2) schools, three (3) local bars (spots/pubs), six (6) convenient shops, two (2) chemical shops, the community center and chief's palace and more than six (6) fish smoking houses.

Table 4: Land use inundated by floods

Land Use	Flood Area (m^2)
Green Space	2,381,090.00
Residential	85,429.90
Recreation	30,909.60
Religious	2,681.98
Transport	21,505.70
Cemetery	7,313.61
Total	2,528,930.79

Source: Fieldwork, 2014

In order to determine the population likely to be affected by floods, the research relied on two methods; a review of a report drafted by the National Disaster Management Organisation, Ellembele (2013) titled "Communities with Flood Prone Areas" and geographic information systems overlay analysis (see Figure 13 for the results of these analyses).

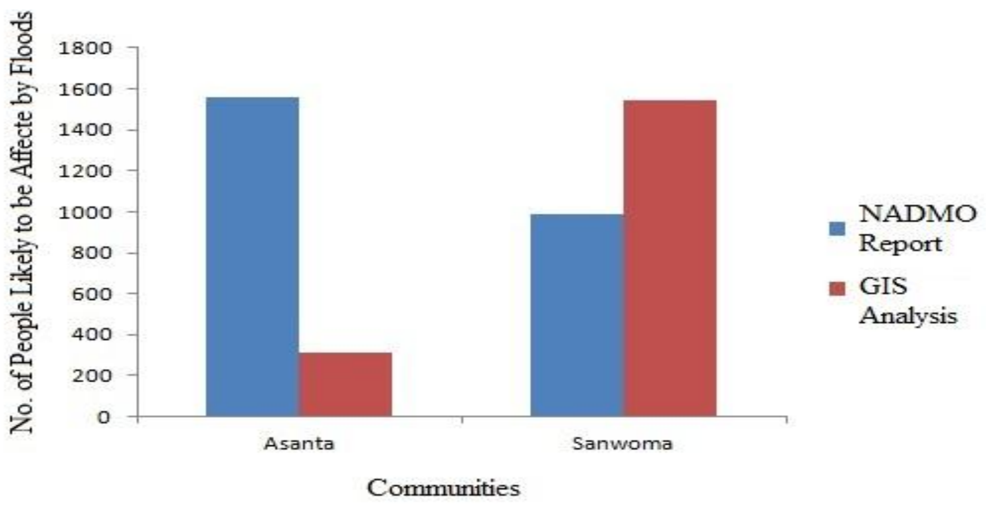

Figure 13: People likely to be affected by flood

Source: Fieldwork, 2014

The report by the Ellembelle NADMO office states that the possible number of people likely to be affected by floods in the Ankobra estuary was 2,550 (1,560 people in Asanta and 990 people in Sanwoma).

In an interview with the NADMO coordinator, it was revealed that the number was reached through field survey by NADMO officers who know the estuary very well. He remarks;

> *We have this officer, who visited the place in November, 2012. He made the assessment of buildings and people likely to be affected based on his experience and many flood hazards he has witnessed in the area. The assessment is not based on sophisticated analysis that is why we have been requesting for help from Regional NADMO office for a more comprehensive analysis.*

However, geographic information systems overlay analysis indicated that 1,852 persons are likely to be affected by floods (1,542 people at risk in Sanwoma and 310 people in Asanta). In the process of the overlay analysis, the flood map (generated from the community mapping) and buildings (digitised from orthophoto) were loaded into the ArcMap 10.1 software. It indicated the buildings within the flood area graphically, hence to derive the number of buildings a spatial query (selection by location) was employed which automatically selected the number of buildings in the flood area. The number of buildings identified by the ArcMap 10.1 software within the flood zone was 394; this figure was multiplied by the average house size (4.7) in the study area (how the average household size was arrived at is explained under the heading socio-economic vulnerable in Ankobra estuary , page 93). The difference in the two results (NADMO estiamte and GIS Analysis) is mainly due to the method of analysis. The NADMO estimate was from purely a qualitative and subjective analysis while GIS estimate was a quantitative based approcah. This implies that persons in charge of disaster management in the study area are not technical orientated in assessing risk which can affect long term disaster management.

Assessment of flood vulnerability of the elements at risk in Ankobra estuary

Vulnerability to flood was analysed by using respondents' data from interview schedules, field observations, community participation, measurements and interviews with opinion leaders. The analysis was based on components of vulnerability (physical, social, economic and environment) as highlighted by the International Strategy for Disaster Reduction (2004).

Physical vulnerability

The level of damage or loss that physical elements suffer from a hazard can be assessed using physical characteristics of the element (Aglan, Wendt & Livengood, 2004). In analysing physical vulnerability within the study area, the whole area was demarcated into wards based on roads. The importance of the demarcation was to help in identifying which wards were more vulnerable since vulnerability levels differ within a community. Cai et al (2005) indicate that it is critical to identify road segments and areas that are flooded so that rescue and response routes can be determined and rescue personnel and supplies distributed promptly and in a timely manner. The analysis considered the characteristics of buildings such as age of buildings, foundation types, wall materials, elevation and number of people with the results (degree of loss) expressed on a scale from 0 (no damage) to 1 (total damage) as described by Westen et al (2009).

Figure 14 shows processed digital elevation model downloaded from the earth explorer website overlaid with the digitised wards. A total area of 5,326,613.6 meters square of the estuary is below 10.6 meters, while a small area of 128,066.4 meter are above 64.95 meters found at the upper part the study are (indicated red in Figure 14). All the wards were below 10.6 meters above sea level, making them more susceptible to flood.

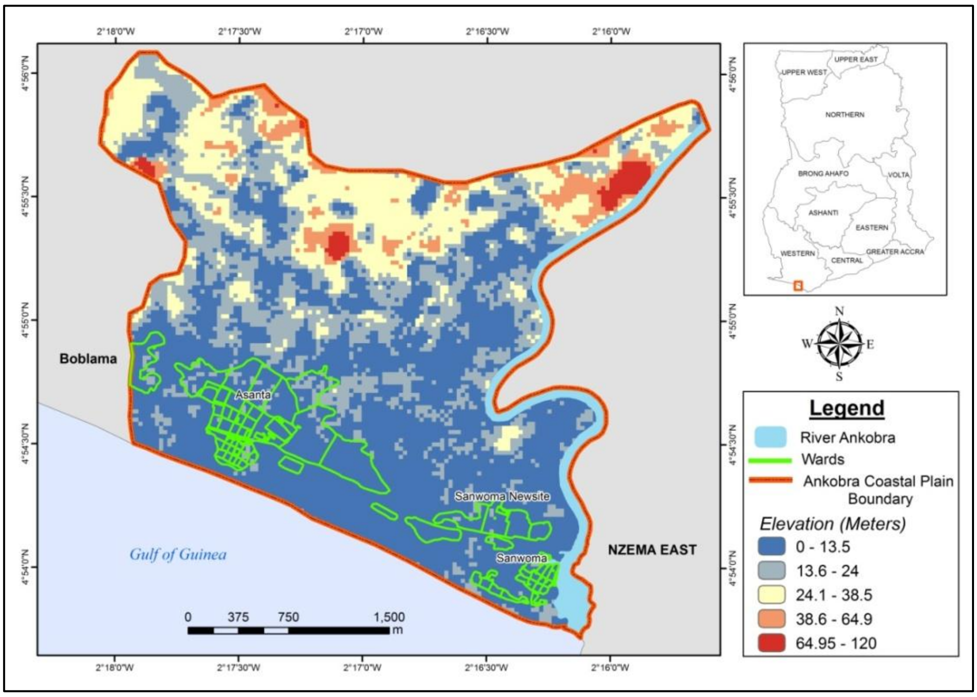

Figure 14: Elevation and wards in the Ankobra estuary

Source: Fieldwork, 2014

Vulnerability of a building is also influenced by the foundation type on which it is constructed. Buildings on concrete foundations are more likely to be resistant to floods than buildings with no foundation, mud foundation and blocks. The number of buildings with block foundation is eighty nine (89) and those with no foundation are nineteen (19) as depicted in Figure 15. Erecting blocks and putting up a structure on it is the preferred foundation type in the area since it is less costly than a concrete foundation. Sanwoma, which is the community mostly affected by floods, has over 54% of its buildings on block foundations and are therefore less resistant to flood waters as compared to buildings in Asanta, of which 64.7% have concrete foundations.

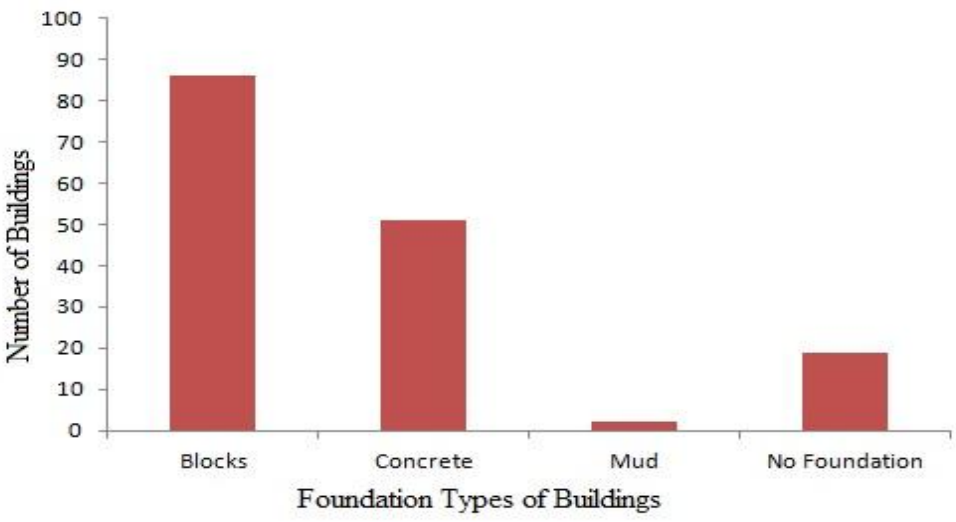

Figure 15*: Foundation types of buildings in the Ankobra estuary*

Source: Fieldwork, 2014

Wall materials of buildings and structures are essential to understanding physical vulnerability (Tiepolo, 2014). Figure 16 shows the materials used to construct the walls of buildings.

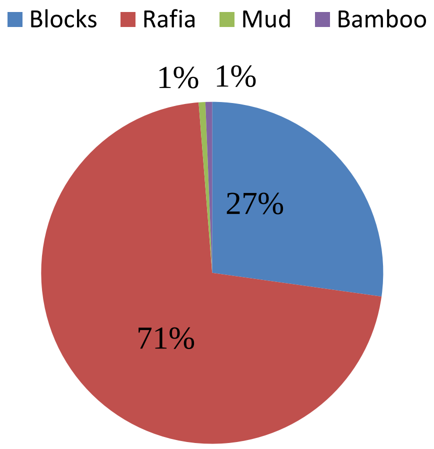

Figure 16*:* Wall types of buildings in the study area

Source: Fieldwork, 2014

The most dominant was raffia, with 71% of buildings using it as wall. This was followed by blocks which constitute 27%. Raffia was the preferred material in the area due to its low cost as compared to blocks. A respondent commented on raffia usage saying;

> *If you want raffia, it is easily accessible and far cheaper than buying cement and sand to make blocks. It's durable too, since it can last for about 30 years.*

But comparing raffia to blocks, raffia which is a wood material is more vulnerable to floods. Wood materials have a hygroscopic property so when exposed to water (rain and floods), they swell as they absorb water and shrink in dry conditions. A repetition of this process leads to splitting, cracking and decay of the wood (Hermann, Vogel & Leekley, 2013; Catalan Energy Institute, 2004). Also, a study by Clausen & Glass (2012) confirms that houses made of wood materials in the eastern part of the United States of America decay and deteriorate faster than houses in the western part due to frequent rains and floods in the eastern states. The decay, cracks and splitting of wood material makes it easy for floodwaters to move through holes into people's rooms, thereby destroying their property.

Building materials have their own life expectancy which affects the ability of the material to withstand weather conditions and floods. Wood materials have a limited life, but when built correctly, should last more than 20 years (Aycock, 2012). Block masonry usually can last for more than 100 years if the right amount of sand and cement are mixed in its formation (International Association of Certified Home Inspectors, 2006). Figure 17 shows the age of buildings in the communities based on the type of material used as wall.

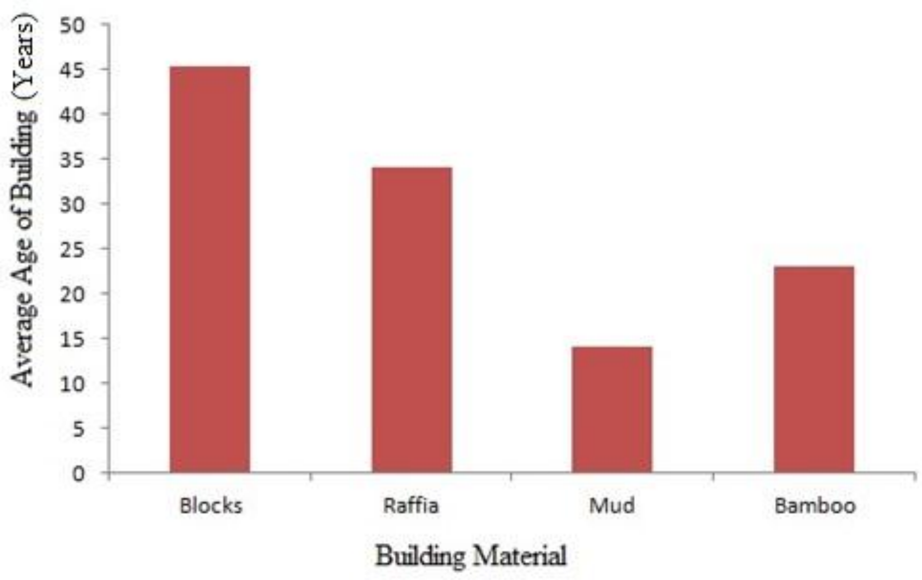

Figure 17: Average age of buildings in the study area

Source: Fieldwork, 2014

It can be said that most of the raffia have outlived their limited lifespan as stated by (Aycock, 2012). The mean age of the raffia buildings in the study area is 34.1 years. Even if the remarks by the respondent who claims raffia is the preferred building material in the area because it is cheap and can last 30 years is to be considered, raffia as a building material for buildings in the estuary have outlived their limited lifespan by 4 years on the average. This makes them even more vulnerable. The bamboo buildings have a mean age of 23 years which is also above the limited life as explained by Aycock (2012). Buildings made of blocks have a mean age of 45.5 years which are likely to be more resistant to flood waters than the rest of the buildings in the estuary.

Components such as elevation, building types, age, foundation types and wall material were combined with flood depth to generate the physical vulnerability of the study area. The results show a physical vulnerability map of Ankobra estuary (Figure 18 and 19).

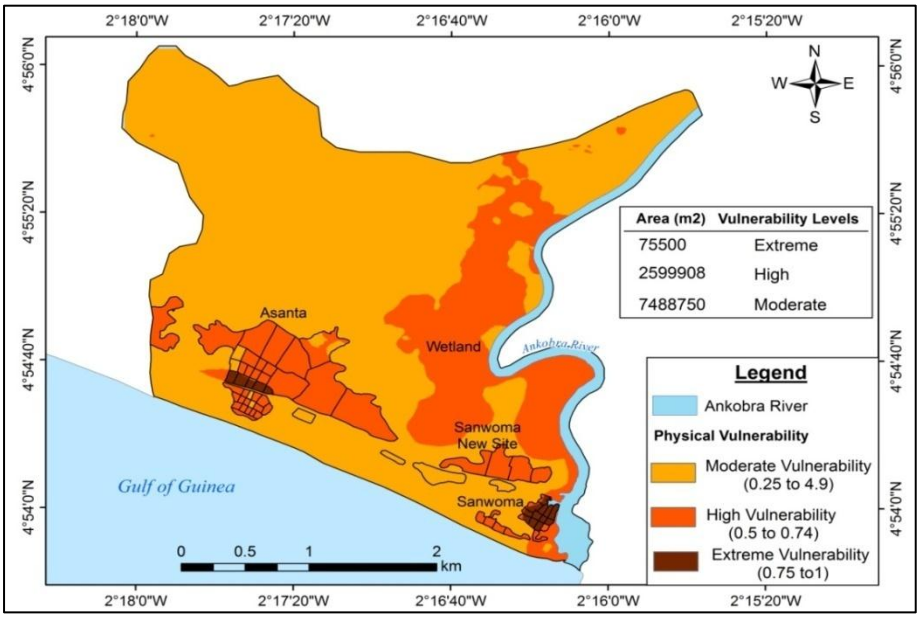

Figure 18*:* Map showing physical vulnerability within the study area

Source: Fieldwork, 2014

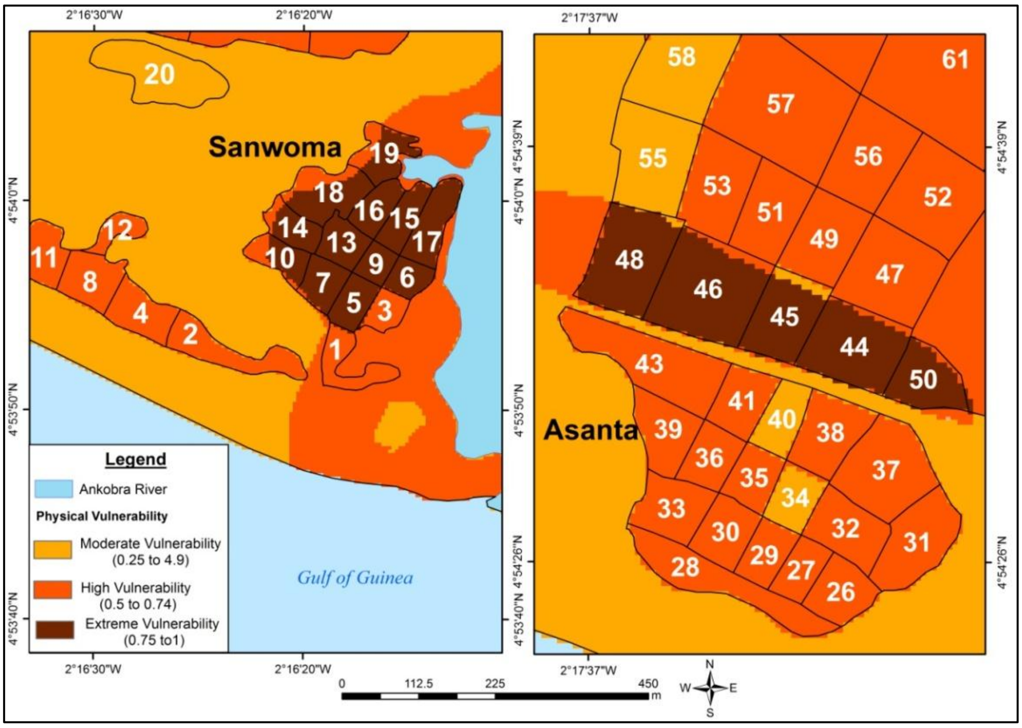

Figure 19: Physical vulnerability within wards in Asanta and Sanwoma

Source: Fieldwork, 2014

In Figure 18, an area of 75,500 meters square of the study area was within the zone of extreme physical vulnerability. High physical vulnerability zone covers 2,599,908 meters square while moderate physical vulnerability zones constitute the largest area with 7,485,750 meter square meters. Twelve (12) wards (5, 7, 6, 9, 10, 13, 14, 15, 16, 17, 18, 19) in Sanwoma and five (5) wards (44, 45, 46, 48, 50) in Asanta were within the extreme high vulnerability zones (Figure 19) while seven (7) wards (1, 2, 4, 6, 8, 11, 12) in Sanwoma, four wards (21, 23, 24, 25) in Sanwoma Newsite and sixteen wards (26, 27, 28, 29, 30, 31, 32, 33, 35, 36, 37, 38, 39, 41, 42, 43) in Asanta were within high physical vulnerability zone. Also, three wards (20, 22, 60) in Sanwoma and five wards (34, 40, 55, 58, 65) in Asanta were in moderate physical vulnerability zone.

In order to determine the causes of the differences in the physical vulnerability levels of the wards, the researcher linked physical vulnerability levels generated from the spatial multi-criteria evaluation with the elevation, building types, age, foundation types and wall material in Table 5. In terms of elevation, extreme physical vulnerability zones had a maximum elevation of 14 meters, lower than high physical vulnerability zone with an elevation of 20 meters and moderate physical vulnerability zone which had 15 meters (Table 5). Also from Table 5, the height of foundation of buildings in extreme physical vulnerability zones had a mean height of 0.135 meters as high and moderate physical vulnerability zones had 0.18 meters and 0.2 meters respectively. In terms of age of buildings, moderate vulnerable zones had the lowest mean age of buildings as 26.6 years while extreme and high physical vulnerability zones had mean age of buildings to be 34 years and 39.5 respectively. Another contributing factor leading to the vulnerability of the three physical vulnerability zones is foundation type. Sixty eight percent (68%) of buildings in extreme physical vulnerability zones have blocks as foundations, 19.5% have concrete, 2.43%, raffia and 9.75%, no foundation at all while 66.6% of the buildings in moderate physical vulnerability zones have concrete foundations and 33.3%, that of blocks. Lastly, all building walls in moderate physical vulnerability zone are of blocks which are more resistant to flood as against extreme physical vulnerability zone where only 21. 75% of building walls are of blocks with the majority being raffia (75.6%).

Table 5: Characteristics of physical vulnerability zones

Factors		Physical Vulnerability Levels			
		Extreme	High	Moderate	Low
Elevation	Meters (Unit)				
	Minimum	6.00	4.00	5.00	-
	Mean	10.00	12.00	9.20	-
	Maximum	14.00	20.00	15.00	
Height of Foundation	Meters (Unit)				
	Minimum	0.00	0.12	0.12	-
	Mean	0.14	0.18	0.22	-
	Maximum	0.60	0.30	0.30	-
Age of Building	Years				
	Minimum	1.00	1.00	8.00	-
	Mean	34.00	39.50	26.60	-
	Maximum	70.00	100.00	60.00	-
Foundation Type	Percentage (Unit)				
	None	9.75	6.97	-	-
	Blocks (Percent)	68.29	61.62	33.30	-
	Concrete (Percent)	19.51	29.06	66.60	-
	Rafia (Percent)	2.43	-	-	-
	Mud (Percent)	-	2.32	-	-
Wall Material	Percentage (Unit)				
	Blocks (Percent)	23.00	30.23	100.00	-
	Raffia (Percent)	73.60	68.60	-	-
	Mud (Percent)	3.40	1.16	-	-

Source: Fieldwork, 2014

Social and economic vulnerability

In order to know the social and economic vulnerability of the population in the Ankobra estuary, it was necessary to obtain some background information about the respondents; this was gained through interview schedule. A total number of 158 household heads were interviewed instead of the estimated sample size of 169. This was a result of the unavailability of people at home and the opting out of others from the research. The 158 respondents were composed of 102 females and 56 males. The total number of people in all the households was 965. The average household size obtained was 4.7. The large household size can be attributed to the fact that in most families in Sub-Sahara Africa, a large family size is desirable (Wusu & Abanihe, 2006). This is opposite to a household size of 2.4 in most European countries where people usually prefer smaller family sizes (European Union Statistics on Income and Living Condition, 2014). The number of children (persons below 18) was 405, representing 41.9 % of the entire number of people in the households while elderly (60 years and over) represented 17.9% of the population within the household. This shows that 40.2% of the people were within the working age. Population in the study area is a youthful one, which confirms Ghana Population Stabilisation Report by the National Population Council of Ghana (2011) that Ghana, as a country, has a very youthful population.

The summation of the children and elderly percentage of the household population indicates a high dependency rate on the remaining working population (18 - 59 years). By this, the population is much susceptible to socio-economic vulnerability since 387 people of the working class have to support themselves in addition to 578 children and elders. Another component of the population which increases the susceptibility to socio-economic vulnerability is persons with special needs. Cutter et al (2003) remarks, persons with special needs are affected during disasters and are mostly ignored during recovery because of their invisibility in communities. The number of people with special needs is very small within the study area were 11 people.

Other variables considered in the analysis were ethnicity and social groups. Ethnicity affects socio-economic vulnerability as migrants are the most hardly hit. In terms of accessibility as well, they are the least to be granted resources like land. This increases the vulnerability levels of migrants. Ninety one percent (91%) of the residents were natives. This is good because it reduces the individuals' socio-economic vulnerability because non-natives usually settle in high hazard areas and have less access to post disaster funding (Cutter et al, 2003). Social groups are cushions for its members; where a vibrant social group exists, members can seek assistance in difficult times. Eighty percent (80%) of the respondents did not belong to any social group such as a clubs, hence, are limited with respect to seeking assistance (either financial or psychological) in times of difficulties.

Also, another factor that influences socio-economic vulnerability is literacy rate. Research has shown that high literacy skills can lead to better jobs, increased incomes and greater productivity (Osberg, 2000). Figure 20 shows that only 4% of the respondents have tertiary education; 36 % had Junior High School (J.H.S) education, 7% had Senior High School (S.H.S) education and 30%, no formal education.

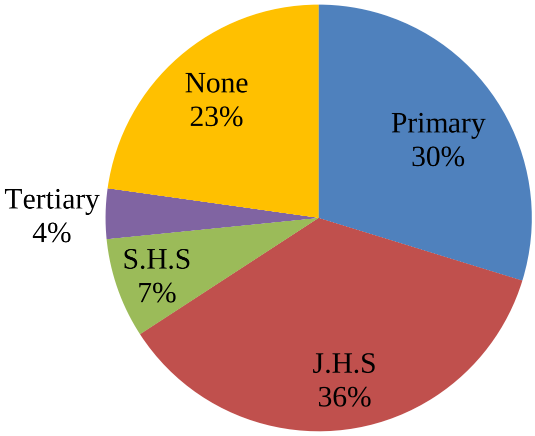

Figure 20: Educational levels of respondents

Source: Fieldwork, 2014

The low number of respondents who had Senior High School education as compared to Junior High School can be explained by the unavailability of secondary schools in the study area which causes people to move to Esiama and Axim to access secondary education. This assertion is corroborated by that of the Ghana Statistical Service (2010) that the low level of secondary education among rural folks in Ghana is due to the unavailability of senior high schools within the localities as well as poor infra-structural facilities.

Figure 21 shows that seventy seven (77) respondents were engaged in agricultural activities. Out of these, sixty percent (60.6%) are in the fish industry; the men are fishermen while the women are fishmongers. This reflects the coastal nature of the settlement and confirms Kruijssen and Asare (2013) livelihood analysis of four (4) coastal communities in Western Region where fishing and fishing related activities was the most important source of livelihood for households.

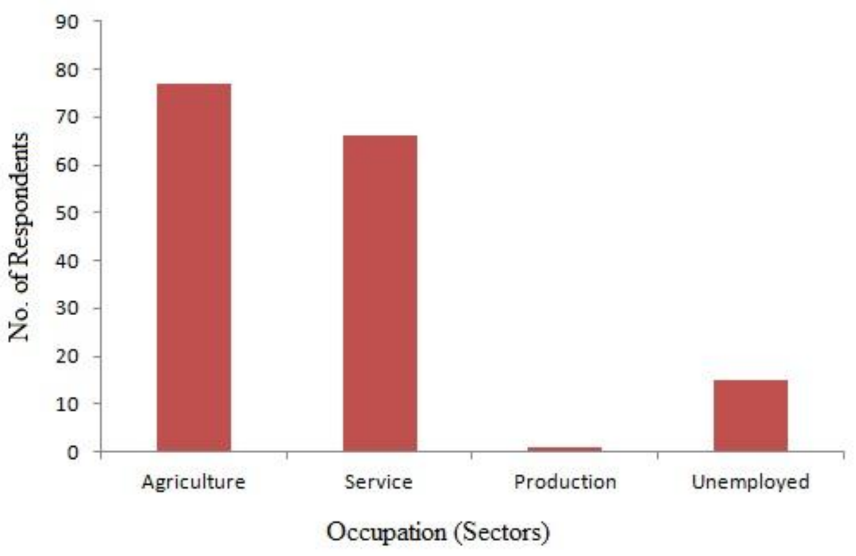

Figure 21: Occupation of respondents

Source: Fieldwork, 2014

The high number of respondents directly involved in fishing businesses can be used to explain the low level of income and poverty in the study area as revealed by Krakah (2009) in his study "Dynamics of poverty in Ghana". He concludes that of all livelihood activities in Western Region, households which engaged in fishing had the worse poverty headcount status. This reflects in income levels depicted in Table 6 where ninety five (95) of respondents had income levels below 299 Ghana Cedis per month. Contrary to Krakah (2009), four (4) respondents in the fishing industry earned a monthly income more than nine hundred (900) Ghana Cedis. They claimed to be owners or part owners of fishing boats.

Table 6: Monthly income of respondents

Income Range (Ghana Cedis)	No. of Respondents	Percent
Unemployed/ No Income	29	18
Below-299	95	60
300-599	25	16
600-899	5	3
900- Above	4	3
Total	**158**	**100.00**

Source: Fieldwork, 2014

Another agricultural activity undertaken by respondents is subsistence farming, on which 25% of the seventy seven respondents engaged in agricultural activities depend for their livelihood. Also, illegal artisanal gold mining (galamsey) is another activity undertaken in the study area. All the respondents engaged in gold mining were migrants. This confirms studies by Nyame, Grant & Yakovleva (2009) that mining in Ghana is mostly feed by migrant labour. These migrant workers in gold mining (galamsey) had mean monthly income of 350 Ghana Cedis, which is higher than the mean income of the study area (250.76 Ghana Cedis). Production is the least occupation and it was bakery. Only 29 respondents interviewed were not employed. In analysing the income levels, the mean income for female respondents was 162.6 Ghana cedis while male respondents were 402.9 Ghana Cedis. Income disparity among sexes is a common phenomenon in Africa as in South Africa men earn averagely 58.95 Rand hourly while women earn 41.17 Rand hourly on the average (Statistics South Africa, 2011). This explains why women are more economically vulnerable than men.

After combining all these socio-economic inputs spatially, a socio-economic vulnerability map was generated based on the wards. The categories ranges from low socio-economic vulnerability (0-0.24) to extreme socio-economic vulnerability (0.75-1). Low socio-economic vulnerable areas are likely to have low risk to flood while high socio-economic vulnerable areas will have high risk levels (Cespedes, Cachadina & Lopez, 2012). Figure 22 shows the socio-economic vulnerability levels within the study area, with Figure 23 depicting the socio-economic vulnerability levels of wards in Asanta and Sanwoma.

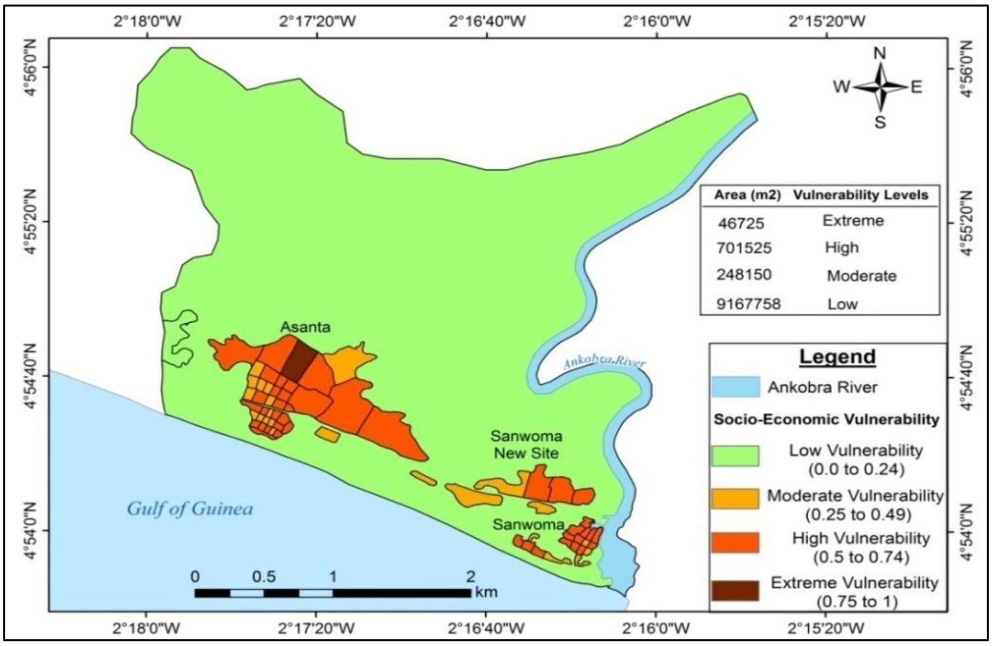

Figure 22: Socio-economic vulnerability in the study area

Source: Fieldwork, 2014

Low socio-economic vulnerability areas which are not inhabited cover about 9,167,758 meters square. Only one ward, ward number 61, fell within extreme socio-economic vulnerability area with an area of 46,725 meters square. Forty-two wards fell within the high vulnerability zone with an area of 701,525 meters square.

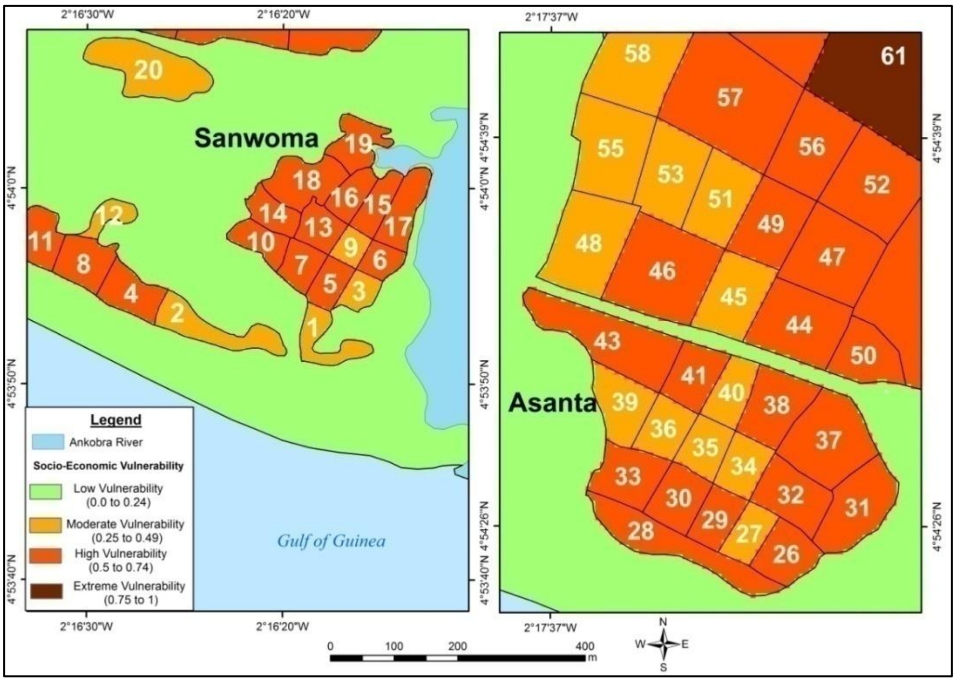

Figure 23: Socio-economic vulnerability within the wards Asanta and Sanwoma

Source: Fieldwork, 2014

The characteristics of the levels of socio-economic vulnerability of the Ankobra estuary is depicted in Table 7. The only ward (61) with extreme socio-economic vulnerability had a high ratio of female respondents (75%) higher than the rest of the zones which were in the range of 60%. Also, this ward had a high mean family size of 5.2 which is above the mean family size of the study area (4.7). Zones of high and moderate socio-economic vulnerability areas have 4.7 and 4.4 respectively. The mean income level in extreme socio-economic vulnerability ward (61) was 122.5 cedis less than high (200 Cedis) and moderate (316.91 Cedis) socio-economic vulnerability areas.

Table 7: Characteristics of households within socio-economic vulnerability zones

Factors		Socio-economic Vulnerability Levels			
		Extreme	High	Moderate	Low
Gender	Percentage				
	Male	25	40	40	-
	Female	75	60	64	-
Household size					
	Minimum	2.00	1.00	1.00	-
	Mean	5.20	4.70	4.40	-
	Maximum	13.00	17.00	8.00	-
Ethnicity	Percentage				
	Native	88.00	92.25	93.28	-
	Migrants	12.00	7.75	6.72	-
Social groups	Percentage				
	Yes	9.50	28.00	20.93	-
	No	90.50	70.00	79.70	-
Special needs	Percentage	2.85	1.39	3.57	-
Education	Percentage				
	Primary	29.70	24.69	38.41	-
	J.H.S	26.30	33.98	32.00	-
	S.H.S	4.50	5.87	4.60	-
	Tertiary	-	2.77	6.71	-
	None	39.50	32.69	18.28	-

Table 7 Continued

Occupation	Percentage				
	Agriculture	75.50	58.73	46.80	-
	Service	12.00	20.00	41.02	-
	Production	12.50	11.17	7.00	-
	Unemployed	0.00	10.10	9.72	-
Income	Ghana cedis				
	Minimum	30.00	50.00	50.00	-
	Mean	122.50	200.00	316.19	-
	Maximum	800.00	1500.00	1500.00	-

Source: Fieldwork, 2014

Environmental vulnerability

In measuring environmental vulnerability, the framework looks at the percentage of area under forest cover, degraded land and over used agricultural lands as explained by Bollin et al (2003). Within the study area, the percentage of forest cover was 36 % of the total size of the Ankobra estuary and was derived from the digitised land use map. Forest cover has the ability to negate the effects of flood by reducing its flow velocity and the materials it carries. This is very good because it delays time of flood onset and gives people time to find shelter or a safe place. The percentage of degraded land was 1.3% and is limited to areas within the rubber plantation. Degraded land refers to lands whose biophysical environmental value has been affected by direct human processes or human induced processes such as cutting of vegetation, overgrazing and soil erosion (Conacher & Conacher 1995). In the study area, degraded lands were burnt areas and areas where the entire vegetation had been cut down. Overused agricultural lands were very hard to find within the study area because inhabitants' farms were outside the Ankobra estuary. Bollin et al (2003) described overused agricultural lands as farms whose soil quality and quantity have been destroyed through over continuous farming and misappropriation of chemicals and fertilizers. Another reason for the difficulty in analysing overused lands was the researcher's lack of the technical ability required in testing the quality of the soils of these farms even if they were within the study area. The researcher, therefore, did not consider overused agricultural lands.

Analysing the factors affecting environmental vulnerability, a spatial map was produced as the end product shown in Figure 24. An area of 664,888 meters square fell within the low environmental vulnerability zone and is confined to the rubber plantation. The high environmental vulnerability zone, on the other hand, was limited to the beach. The beach is an ecosystem which is fragile and can easily be washed by high flood velocities (Priyalakshmi & Menon 2014). This makes such environments highly susceptible to the impact of floods.

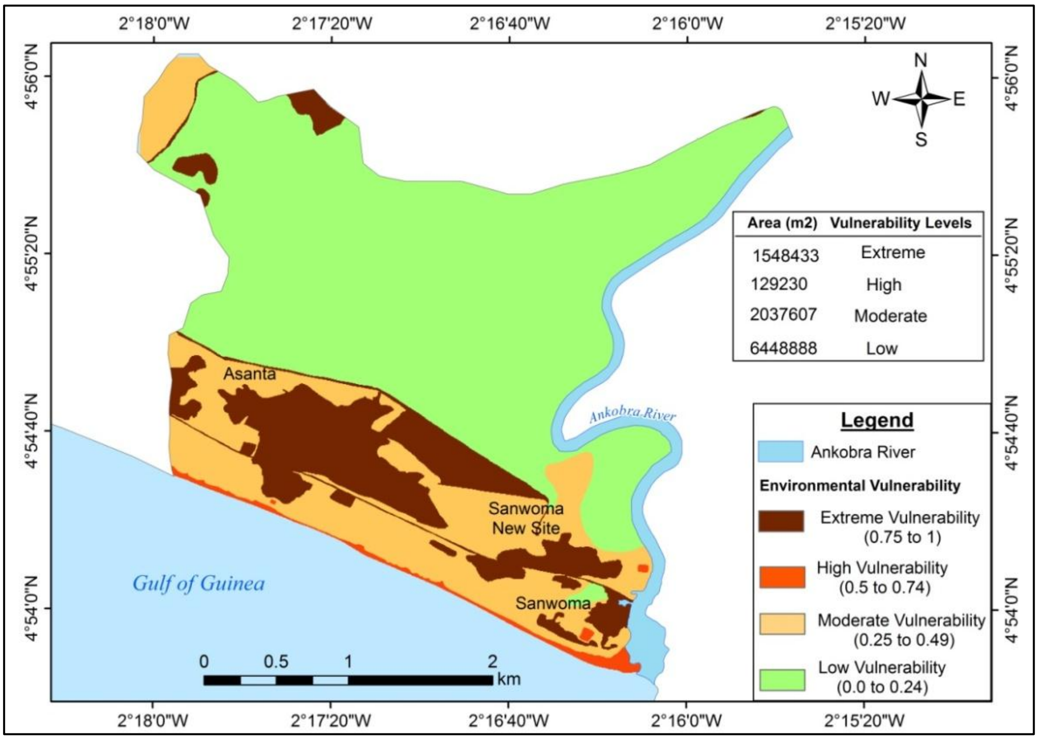

Figure 24*: Environmental vulnerability within the study area*

Source: Fieldwork, 2014

Extreme environmental vulnerability zones were specifically limited to built up environments (vegetation cleared to serve as residential areas) such as buildings and roads and parts of the rubber plantation that had been burnt. They covered an area of 154,833 meters square of the study area. Built areas in extreme environmental vulnerability zones can be explained using the definition of degraded land by Conacher et al (1995). That is, the humanly built environment has decreased the biophysical value of the environment in coping during floods; rain infiltration is decreased by concrete surfaces, runoffs are blocked and their acceleration, rather increased (Konrad, 2014). All these factors make built environments more vulnerable than other areas.

Assessment of coping capacity of people to floods in Ankobra estuary

Coping capacity of an entity looks at plans by the entity to deal with and withstand a hazard (German Technical Cooperation, 2006). This can be grouped as physical, social, economic and management capacity (Bollin et al, 2003). Physically, land use maps do not exist in the study area, meaning people have the choice to put any type of development at any place without checking the suitability and risk of the place. Even though the Department of Town and Country Planning in the district (Ellembelle) has cadastral map (layouts) and building codes to help regulate development and type of use of land, it is limited to Asanta and Sanwoma New Site. The nature of the buildings, their sizes and height testify to the fact that building codes are not adhered to. In an attempt to increase coping capacity physically, the District Assembly representative dredged the eastern part of Sanwoma where the second type of riverine flood takes it source to link Ankobra River. This channel was to carry excess water in the wetland; it worked for a while until the depth of the channel decreased with time due to sand deposition. Another approach to physically cope with flood is explained by a respondent as;

> *In order to raise the elevation level of our homes and surroundings, what we do is instead of throwing our household waste at a designated refuse dump, we rather gather them around areas or near houses which have low elevation and sweep sand on them to increase the elevation. This is to help reduce the depth of floods.*

Also, what others resort to is erecting vertical blocks in front of their rooms to make it difficult for flood water to easily enter their rooms (Plate 6).

Plate 6: Erected structure in front of a door to prevent flood waters from entering the room

Source: Fieldwork, 2014

Through the community participatory mapping it became evident that there was little social capacity for the inhabitants of the Ankobra estuary. In Sanwoma community, the people are fully aware that they are living in a flood zone. A warning system which they use to inform themselves of a possible occurrence of flood was stated by a respondent during the community mapping:

Monitor your kid well; the flood is coming

Once such a statement is heard, people's attention is drawn to the possibility of a flood occurrence. Also, socially, there is no assistance from people, organisations and the district assembly for the communties during and after floods. This was what one respondent had to say:

> *The Assembly does not help us because they want us to move to a new site where it is expensive to buy a plot that may cost about three thousand (3000) Ghana Cedis*.

Economically, people with savings, availability to credit facility and insurance are more able to cope better after a flood (Cutter et al, 2003). This is not the case for people in the study area. Houses in the area had no insurance policy against flood. This problem is a national problem since houses lack any form of insurance for any form of risk. In Ghana the majority of people and houses remain unsecured because people are ignorant of the importance of insuring their properties (Ghana Homes, 2013). Saving and access to credit, which can be of assistance to recovery after floods, were also inadequate in the study area. Only fifty (50) respondents saved a part of their income while twenty three (23) respondents said they had access to credit. In percentage terms respondents who save are 31% which is a bit higher than the national rural coastal savings which is (24.8%) as compiled by the Ghana Statistical Service (2008).

Management capacity to deal with flood was very low. The district NADMO office had only four workers. This number was too small to deal with an emergency situation considering that there exist no emergency plans. Due to this limitation, the district NADMO Coordinator explained that every year during rainy seasons, periodic announcements are made through radios and community information centres to alert people of floods and to get them prepared in case they happen. With respect to a flood risk map which is a useful tool in risk management, none existed a situation that can be attributed to the level of expertise and technical background of the District Planners and Town and Country Planners in the district to develop it. Ellembelle District Planners remarks:

> *There have been training workshops by Coastal Resource Center and Town and Country Planning National Office on using geographic information systems for mapping land use and street naming but not doing flood risk maps.*

Coping capacity map for the Ankobra estuary was derived by combining physical, social, economic and management capacity in the spatial multi-critera evaluation tool in Ilwis software. Figure 25 shows the coping capacity for the areas within the Ankobra estuary.

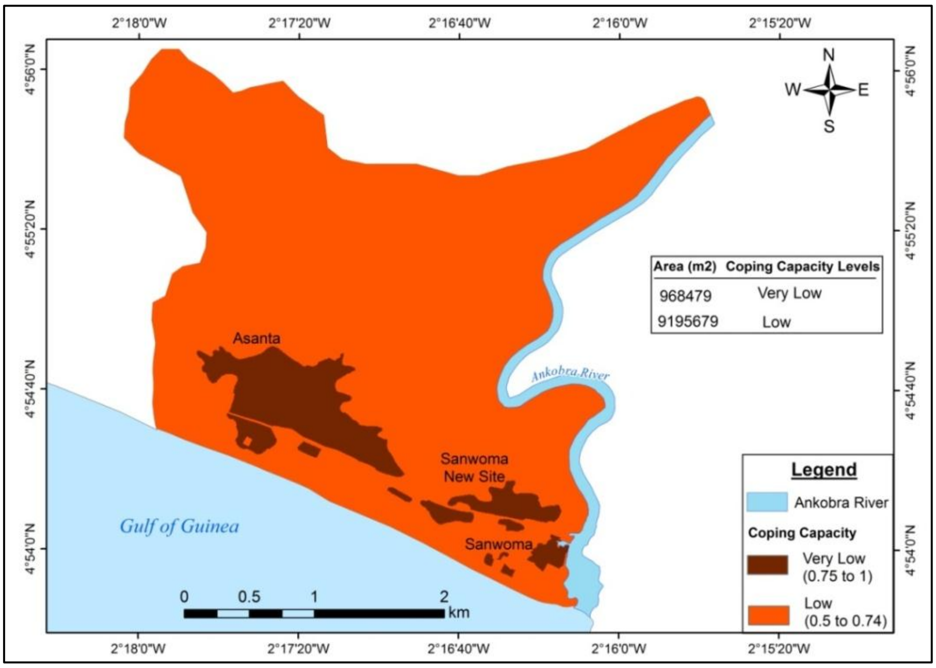

Figure 25: Coping Capacity to flood in the study area

Source: Fieldwork, 2014

Flood risk in Ankobra estuary

In order to generate the risk to flood for the Ankobra estuary, the conceptual framework for risk which was adopted from Bollin et al (2003). This framework defines risk as a function of hazard, exposure, vulnerabilities and capacity measures. This means all the results generated for these four variables were assessed through a semi-qualitative approach using spatial multi-criteria evaluation tool. The approach uses indices to express risk in numerical values (probability terms), ranging between 0 and 1 (Westen et al, 2009).

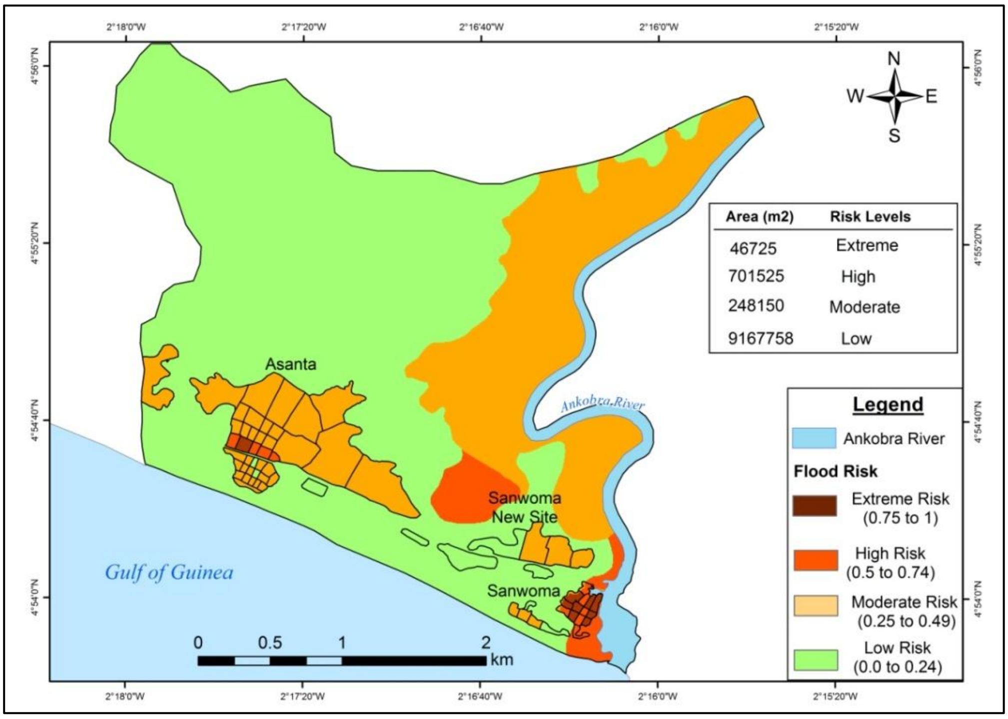

Figure 26*:* Flood risk of the Ankobra estuary

Source: Field work and Desktop Analysis, 2014

The output was sliced into categories extreme risk zone (0.75-1), high risk zone (0.5 -7.4), moderate risk zone (0.25-0.5) and low risk zone (0.0-0.25) based on Bittner (2010) classification of risk levels (Figure 26). Extreme risk zone covers an area of 46,725m^2. A total of 246 structures are within the extreme risk zone. Using a mean household size of 4.7 derived from field analysis of household data, an estimate of 1,156 people are living within this zone. People in this extreme risk zone will suffer severely than all other risk zones during floods, this is because they are physically and socio-economically vulnerable than all other risk zones (Table 8, Table 9). In terms of physical characteristics (Table 8), buildings in extreme risk zones has a mean foundation height of 0.12 meters, on an elevation of 10 meters above sea level, foundations of buildings are mostly of blocks (72.72%) without concrete while the preferred wall material is raffia (92.9%) making buildings more at risk than low risk zones. This means that during floods these attributes of buildings in extreme risk zone makes people and buildings highly prone to damages than any other risk zone. On the contrary, only 33 structures with an estimate of 155 people are leaving in low risk zone. The low risk zone covers an area of 9,167,758 meters square. Low risk zones have elevation of 10.58 meters, 50% of the buildings are on concrete foundations with a mean height of 0.22 meters and the building walls are mostly of blocks (58%). These wards are safe and free from flood risk, hence, appropriate for settlement and infrastructure development. Also Table 8 and 9 gives a summary of all the characteristics of risk levels in Ankobra estuary.

Table 8: Physical characteristics of elements in risk zones

Factors		Extreme Risk	High Risk	Moderate Risk	Low Risk
Elevation	Meters				
	Minimum	5.00	6.00	5.00	5.00
	Mean	10.00	10.00	12.00	10.58
	Maximum	14.00	14.00	17.00	19.00
Foundation	Meters				
	Minimum	0.00	0.04	0.01	0.08
	Mean	0.12	0.15	0.22	0.22
	Maximum	0.06	0.33	2.00	0.40
Age of Building	Years				
	Minimum	1.00	1.00	3.00	8.00
	Mean	28.57	39.82	34.47	24.12
	Maximum	70.00	70.00	100.00	60.00
Foundation Type	Percentage				
	None	11.78	-	8.49	12.50
	Blocks	72.72	52.94	47.18	37.50
	Concrete	15.50	35.29	42.45	50.00
	Raffia	-	11.77	-	-
	Mud	-	-	1.88	-
	Total	100.00	100.00	100.00	100.00
Wall Material	Percentage				
	Blocks	7.10	12.52	29.40	58.00
	Raffia	92.90	81.68	68.03	42.00
	Mud	-	5.80	2.60	-
	Total	100.00	100.00	100.00	100.00

Source: Fieldwork, 2014

Also by socio-economic factors (Table 9), extreme risk zones have bigger family sizes (a mean of 5.3 persons per household), less involved in social groups (6.06%), low levels of education compared with the other zones, low income with low saving habits (16%).

Table 9: Socio-economic characteristics of respondents in the risk zones

Factors		Extreme Risk	High Risk	Moderate Risk	Low Risk
Gender	Percent				
	Male	30.30	41.18	36.00	37.50
	Female	69.70	58.82	64.00	62.50
Household size					
	Minimum	2.00	2.00	1.00	2.00
	Mean	5.30	4.90	4.40	4.20
	Maximum	13.00	15.00	8.00	9.00
Ethnicity	Percent				
	Native	93.94	82.36	91.51	98.00
	Migrants	6.06	17.64	8.49	2.00
Special needs	Percent	1.65	0.98	2.43	0.60
Education	Percent				
	Primary	41.40	21.76	58.80	22.00
	J.H.S	24.24	36.17	33.01	50.00
	S.H.S	6.06	4.80	4.20	-
	Tertiary	-	4.63	4.20	-
	None	30.30	33.4	-	28.00

Table 9 Continued

Occupation	Percent				
	Agriculture	63.63	53.05	68.22	55.8
	Service	23.27	27.09	20.38	27.6
	Production	-	9.6	1.8	12.2
	Unemployed	13.1	10.3	9.6	4.4
Income	Ghana Cedis				
	Minimum	30	20	50	50
	Mean	272.14	220	298.23	352.5
	Maximum	800	1000	1500	1500

Source: Fieldwork 2014

In terms of coping capacity, low risk zones has low family sizes (4.2 persons per household), 25 % of respondents in this zone are members of social groups, they have the least uneducated respondents (28%) with the highest income levels (1500 cedis) while they save more than the other zones. One common attribute of all the risk zones is they do not have insurance for their properties. Extreme risk zones tend to have the worst of all the variables through physical, socio-economic and coping ability while low risk zones have the least.

CHAPTER FIVE

RESULTS AND DISCUSSION ON GEODESIGN OF ANKOBRA ESTUARY

Introduction

This chapter presents and discusses results from the analysis performed using spatial data collected from geodesigning the Ankobra estuary and analyses results such as flood risk and landscape models obtained from the assessment phase. The results are presented in graphs, tables and maps.

Change, impact and decision models in the Ankobra estuary

In an effort to reduce the flood risk in the area, the research adopted the interventionist part of the geodesign concept. Steinitz (2010) explains that change model is the first stage of the intervention phase of geodesign which deals with remodelling the landscape. That is, the geodesigner changes or modifies some physical features which have contributed to improper functioning of an area. In this regard, the researcher changed two different models to ascertain their outputs separately so that the best output could be adopted for the estuary. This function of change model is the hallmark of geodesign. As asserted by Abukhater and Walker (2010), a geodesigner must always change the current models; find out their implications; make adjustments to the change models, if necessary, until a desired result with the greatest advantage is derived.

The first model element changed for evaluation was the foundation parameters of buildings in the Ankobra estuary. This is because risk is an interplay of a hazard and vulnerable elements together with their coping

Table 10 shows an area of 327,818 meters square within high risk zone, 668,582 meters square within moderate risk zone and a low risk zone of 9,167,758 meters square. Extreme risk zone completely diminished to zero when compared with the original flood risk map, the high risk zone decreased by 53.27%, moderate risk zone gained by 169.42% and low risk remained the same. The changes in the new flood risk as against the original (flood risk) can be attributed to the fact that a building foundation above flood depth will prevent flood waters causing direct damages to buildings and their contents. This will have an enormous effect on physical vulnerability and therefore reduce flood risk areas.

Table 10: Area size of flood risk levels before and after changed foundation parameters

FLOOD RISK LEVELS	Area of flood risk Levels before Geodesign (m^2)	Area of flood risk levels after changed foundation parameter (m^2)	Differences (m^2)	Percentage Change
Extreme	46725	-	- 46725	-100
High	701525	327818	-373707	-53.27
Moderate	248150	668582	+420432	169.42
Low	9167758	9167758	-	-
Total	10164158	10164158		

Source: Fieldwork, 2014

A second change model undertaken was re-modelling of the flow channel in the Ankobra estuary. The flow channels were identified as one of the factors causing floods in the study area. In Asanta community, the main cause of flood is blockage of excess rain water by the Axim-Elubo road, hence no proper drainage to carry excess run-off. In Sanwoma, a stream west of the community mostly causes floods as there are no flow outlets which would divert the water from the community. It was, therefore, important to generate flow channels in the study area (Figure 28) to know how they interconnect.

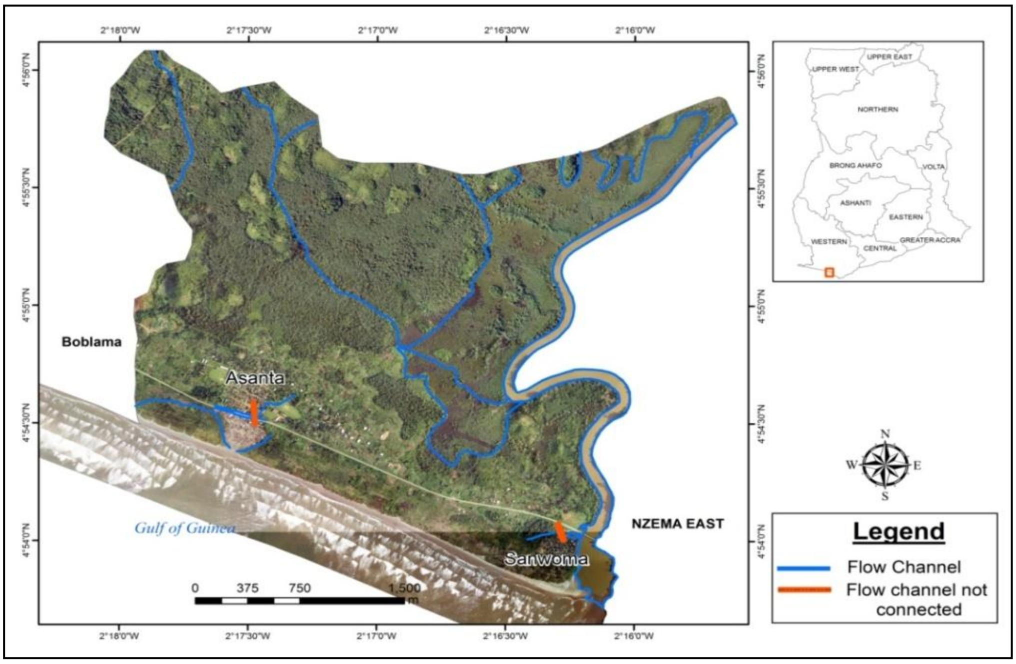

Figure 28: **Flow channel of Ankobra estuary generated from DEM**

Source: Fieldwork 2014

The result showed improper functioning of the water flow system in the Ankobra estuary, the flow in Asanta and Sanwoma. As such, the flow channel were modelled again by adjusting the land use and introducing a water outflow channel to connect the channels which were not linked and also to channel water from the settlements to the sea. In Sanwoma a channel was constructed to link the Ankobra River to the stream west of the community which sometimes causes flood during the rainy season. The length of the newly modelled channel was 98.23 meters from the stream to the Ankobra River. Also an artificially closed lagoon was constructed to serve as the drain point for the two channels joined at the south west of Sanwoma. This is because a closed lagoon will prevent direct contact between the sea (waves and surges) and the channel water which can lead to flooding. As Hidayat, Vermeulen, Sassi, and Hointink (2011) claim, water discharge of rivers in coastal areas are obstructed by backward effects of sea water leading to floods. The area of the closed lagoon modelled was 1347.85 meters square with a depth of 242 twice the depth of the worst flood in Asanta. Figure 29 shows the new modelled landscape with the channel. In Asanta, the main cause of flood is blockage of rain water by the Axim-Elubo road. In order to solve the problem the researcher created a new channel within the community (Figure 28) from the northern part of the community to the southern part of the community. The length of the new channel in Asanta is 103.24 meters.

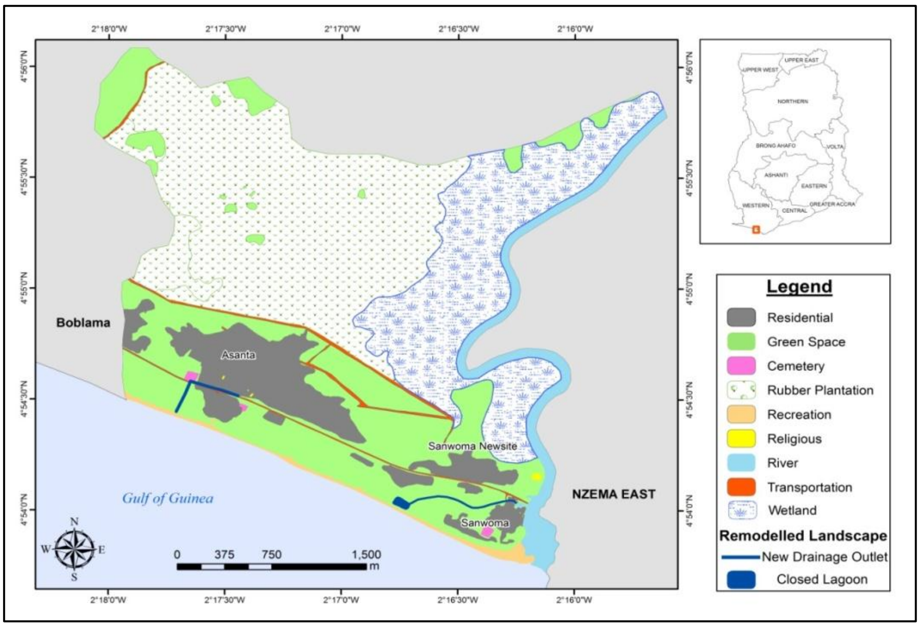

Figure 29: Remodeled landscape and the new channels

Source: Fieldwork, 2014

The second stage of the intervention phase of geodesign was again employed where the new landscape was fed into the spatial multi criteria evaluation to ascertain its impact. The impact assessment of the newly modelled landscape shows a new flood risk map with flood levels reduced (Figure 30).

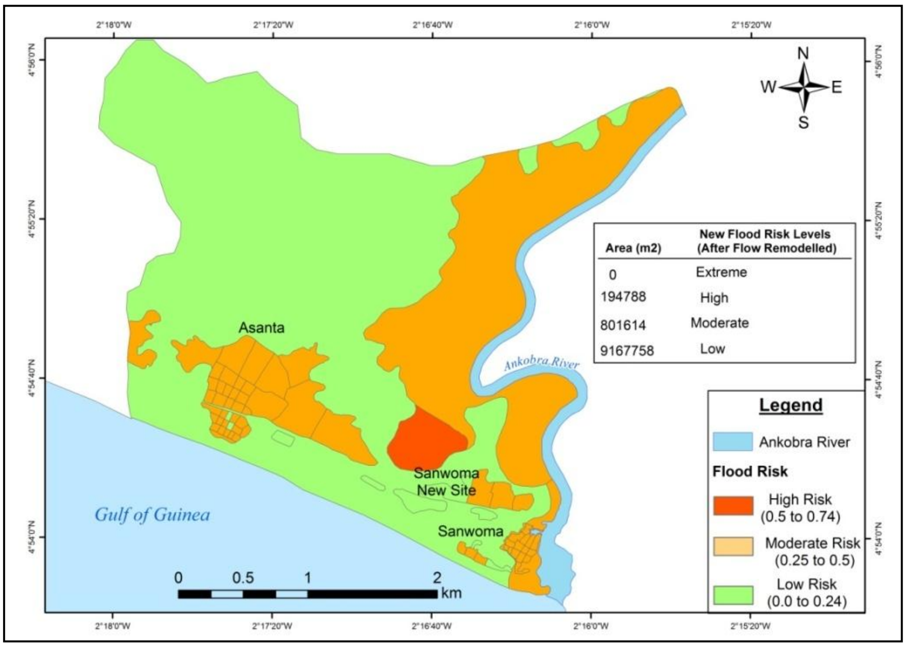

Figure 30: Flood risk reduced map after remodelled landscape and drainage

Source: Fieldwork, 2014

The new flood risk zones from the remodelled landscape and drainage were high, moderate and low risk zones without extreme risk zones. Also, the area covered by these flood risk levels changed, the low risk zone remained the same in area size, moderate risk zone increased while high and extreme risk zones decreased. Table 11, shows differences in area sizes of the risk levels before and after the geodesign application. The extreme flood risk area diminished from 46,725m^2 to zero (0) while the high risk zone decreased by 72.23%. The moderate risk zone also gained 223.03% while the low risk zone remained the same. In the outputs of the first change model (foundation) and this new change model (remodelled landscape and drainage system), the low risk zones remained the same because the researcher did not apply the interventions in these areas as they were already safe from flood risk.

Table 11: Area size of flood risk levels before and after remodelled landscape and drainage

FLOOD RISK LEVELS	Area of Flood Risk Level Before Geodesign (m^2)	Area of Flood Risk Level After Geodesign (m^2)	Differences (m^2)	Percentage Change
Extreme	46725	-	- 46725	-100.00
High	701525	194788	-506739	-72.30
Moderate	248150	801614	+2927044	223.03
Low	9167758	9167758	-	-
Total	10164158	10164158		

Source: Fieldwork, 2014

It can be concluded that the impact assessment of the change models (foundations parameters and remodelled landscape and drainage) reduced flood risk levels in all the various risk levels. But as Fisher (2010) remarks, after the last part of geodesign is the decision making stage where whether the impact was desirable and should be accepted or rejected by the geodesigner is determined. Taking into account the two results (statistics of flood risk reduced map) in Table 10 and Table 11, the researcher decided to adopt the results (flood reduced map) of the remodelled landscape and drainage system as the best intervention compared with remodeled foundation of buildings for the estuary since the flood risk reduction map from the change of building heights still had some wards (3, 6, 7, 13,14,15,17 and 18) in high risk zones. Another reason for this decision is that, it would be easier to create channels in the estuary since those areas where the channels are to be created are not developed. Also, unlike the first change model (change of building parameters), physically changing the building foundations laterally will mean demolishing buildings for new buildings with higher foundations to be put up. Most of the buildings had their foundations in the ground. Furthermore, this activity (physically changing the building foundations) will put much financial burden on inhabitants in the Ankobra estuary considering the fact that their socio-economic vulnerability is high. Analysis and results from the geodesign confirm Fisher (2010) assertion about geodesign capabilities and Dangermond (2010) belief that geodesign can help men live in harmony with nature.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter is devoted to the summary of the findings, conclusions, recommendation and suggested areas for future research.

Summary

The research involved the assessment of flood risk and reduction within the Ankobra estuary. Spatial and non-spatial data were gathered for the study. Spatial data consisted of modelled landscape of the Ankobra estuary into land use, building foot prints, digital elevation model and a flood map obtained through community participatory mapping. Non-spatial data were gathered through interviews with opinion leaders and 158 randomly selected respondents. The spatial and non-spatial data were merged through data interoperability using the spatial join tool in ArcMap ESRI software. A spatial overlay function was performed on the merged data through iteration procedures of problem definition. Standardisation and weighting in Spatial Multi-Criteria Evaluation tool of the Integrated Land and Water Systems (ILWIS) software. The results generated were or comprise a series of maps on physical vulnerability, socio-economic vulnerability, environmental vulnerability, coping capacity and flood risk. In addition, an interventionist approach of geodesign was introduced and its impact was assessed. The result was a map showing reduced flood risk levels in the Ankobra estuary.

Summary of major findings

The following are the major findings of the study:

Ankobra estuary was inundated by three different types of floods which include: riverine floods, coastal floods and urban floods. These had caused damages and disruption of the socio-economic wellbeing of the people.

The study showed that forty five percent (45%) of the population, and 29% of buildings/structures within the Ankobra estuary were situated in flood zones.

Vulnerability levels were low in areas where there are no human settlements and high in areas where human settlements exist. High vulnerability of communities in the Ankobra estuary was attributed to closeness of buildings to the Ankobra River, less flood resistant materials used for building houses, weak materials or no foundation of buildings, predominant agriculture based economy, low income levels, high dependency ratio and low level of education.

Coping capacity to floods among residents within the study area was very low because there was no land use map or flood risk map which informs planning and building construction.

Even though there are building codes to inform building of structures, they were not enforced by the District Planners. This led to the building of structures less resistant to floods. In addition to this, the District NADMO office did not have flood emergency plan and adequate man power with the technical ability to deal with floods.

Flood risk zones of the Ankobra estuary ranges from low, moderate, high and extreme risk zones. The low flood risk area is larger than the extreme risk zone, but the extreme risk zone was rather the most inhabited in the estuary.

The application of geodesign helped in reducing the flood risk within the area based on the categories of the flood risk. Risk levels reduced across the various risk zones with the extreme risk zone, for example, decreasing to moderate risk zone.

Conclusions

The following conclusions have been made based on the major findings from the research.

- All types of flood that had occured in the Ankobra estuary caused damages to properties and disrupted the socio-economic livelihood of inhabitants.
- In spite of the effects of floods in the area, most people still live in flood prone areas while there are vast areas which are not flood prone.
- The coping ability of residents to floods is very low. Additionally, NADMO officials who are to provide assistance to the people during and after floods are limited in terms of number of workers and technicalities required to deal with floods.
- Even though areas with low flood risk cover the largest part of the estuary most people live in extreme flood risk zones due to high cost of land.

  The application of Geodesign has the ability to reduce flood risk in the study area.

Recommendations

The following recommendations are based on the conclusions and major findings of the study.

In order to reduce flood occurrences within the Ankobra estuary, the Ellembelle District Assembly should initiate plans to contract a hydrological construction firm to develop channels within the estuary. This will help control floods within the area.

To reduce vulnerability levels within the study area, parents should be encouraged to send their children to senior high school when they complete junior high because there is direct relation between education, occupation and income. This will improve the socioeconomic levels of people in the future.

The District Planning Unit must enforce all building codes of the Department of Town and Country Planning to the letter by demolishing all new houses under construction which do not meet the building codes and also ensure that new buildings have foundations high enough above the worst flood depths in the estuary. Also all stakeholders should make an effort to reduce vulnerability in the area.

All persons within extreme risk zones should be relocated by the District Assembly to areas with low risk levels within the study area if the geodesign intervention is not adopted. This would be successful if the chiefs in Asanta and Sanwoma communities can reduce the price of lands in these areas to entice people to move to low risk zones.

Also, the District Assembly and National Disaster Management Organisation should support persons within extreme and high risk zones financially by providing and building materials including roofing sheets to those who would agree to move to low risk zones.

Areas for further research

The researcher proposes that a detailed hydrological study on Ankobra River should be undertaken in the future. This will help in understanding the river dynamics such as flow velocity, sedimentation and deposition as well as how it affects flooding. Also, studies on sea erosion would be appropriate in understanding the vulnerability of the Ankobra estuary to global sea level rise.

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APPENDICES

Appendix A: Fisher, Laing, Stoeckel and Townsend (1998) sample size estimation for the Study

Fisher et al. (1998) provided a formula, which is

$$n_f = n / (1 + (n / N))$$

n_f= the desired sample size when the population is less than 10000

n= the desired sample size when population is greater than 10,000

N= the estimate of the population size

To determine n_f, n must first be calculated by determining the sample size of the population greater than 10,000 using the formula

$$n = \frac{z^2 pq}{d^2}$$

n = the desired sample size (when the population is greater than 10000)

z = the standard normal deviation, usually set at 1.96 which corresponds to 95 percent confidence level

p = the proportion of the target population have particular characteristics;

q = 1.0-p; and

d = the degree of accuracy desired, this is usually set at 0.05

With (z) statistic being 1.96, degree of accuracy (d) set at 0.05 percent and the proportion of the target population with similar characteristic (p) at 85 percent which is equivalent to 0.85, then "n" is:

$$n = \frac{(1.96)^2 (0.85) (0.15)}{0.05^2}$$

$$n = 196$$

By using the total number of household heads in the study area which is 1,237 from the 2010 population Census of Ghana, nf was estimated at

$$n_f = n/ (1 + (n/ N))$$

$$n_f = 196/ (1 + (196/ 1237))$$

$$n_f = 169$$

Appendix B: Number of household heads sampled in Sanwoma

Ward	No. of Buildings	Estimated No. of Respondents	No. of Respondents Sampled
1	10	1.41921	1
2	12	1.70306	2
3	6	0.85153	1
4	15	2.12882	2
5	21	2.98035	3
6	27	3.83188	4
7	26	3.68996	4
8	13	1.84498	2
9	16	2.27074	2
10	13	1.84498	2
11	19	2.69651	3
12	10	1.41921	1
13	40	4.96725	5
14	23	3.26419	3
15	24	3.40611	3
16	24	3.40611	3
17	32	3.9738	4
18	36	5.10917	5
19	20	2.83843	3
20	9	1.27729	2
21	13	1.84498	2
22	6	0.85153	1
23	26	3.68996	4
24	7	0.99345	1
25	12	1.41921	1
65	9	1.27729	1
Total	458	65	65

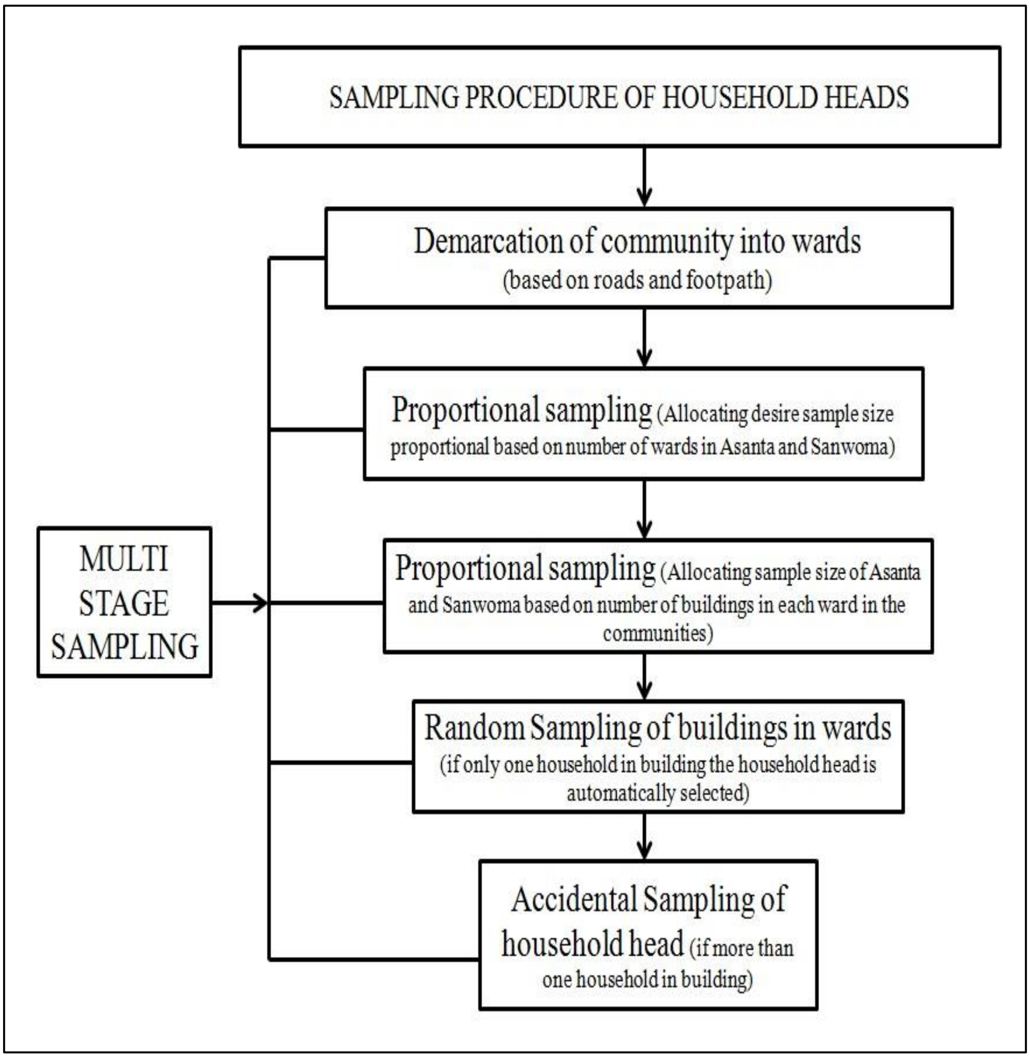
Source: Fieldwork (2014)

Appendix C: Number of sampled household heads in Asanta community

Ward	No. of Buildings	Estimated Respondents	Respondents Sampled
26	25	3.241895	3
27	18	2.334165	2
28	33	4.279302	4
29	14	1.815461	2
30	17	2.204489	2
31	17	2.204489	2
32	19	2.463840	2
33	18	2.334165	2
34	5	0.648379	1
35	14	1.815461	2
36	15	1.945137	2
37	25	3.241895	3
38	15	1.945137	2
39	10	1.296758	1
40	11	1.426434	1
41	12	1.556110	2
42	25	3.241895	3
43	21	2.723192	3
44	18	2.982544	3
46	28	2.334165	2
47	16	3.630923	4
48	8	2.074813	2
49	23	1.037406	1
50	18	2.982544	3
51	11	2.334165	2
52	19	1.426434	1
53	12	2.46384	2
54	53	1.556110	2
55	4	6.872818	9
56	25	0.518703	1
57	33	3.241895	3
58	9	4.279302	4
59	47	1.167082	1
60	8	6.094763	6
61	64	1.037406	1
62	27	8.299252	8
63	61	3.501247	4
64	4	0.518703	1
Total	804	104	104

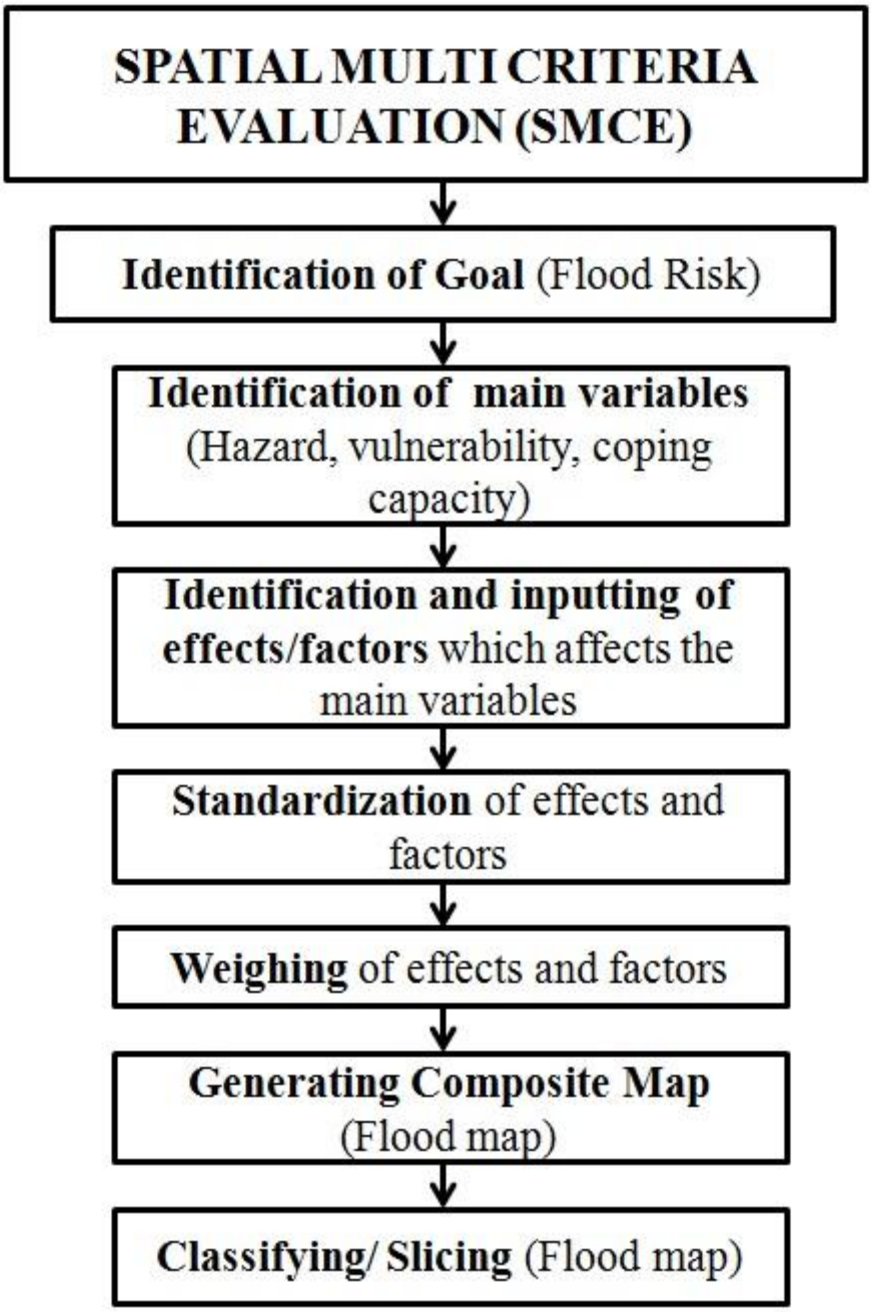
Source: Fieldwork (2014)

Appendix D: Schematic diagram of sampling approach



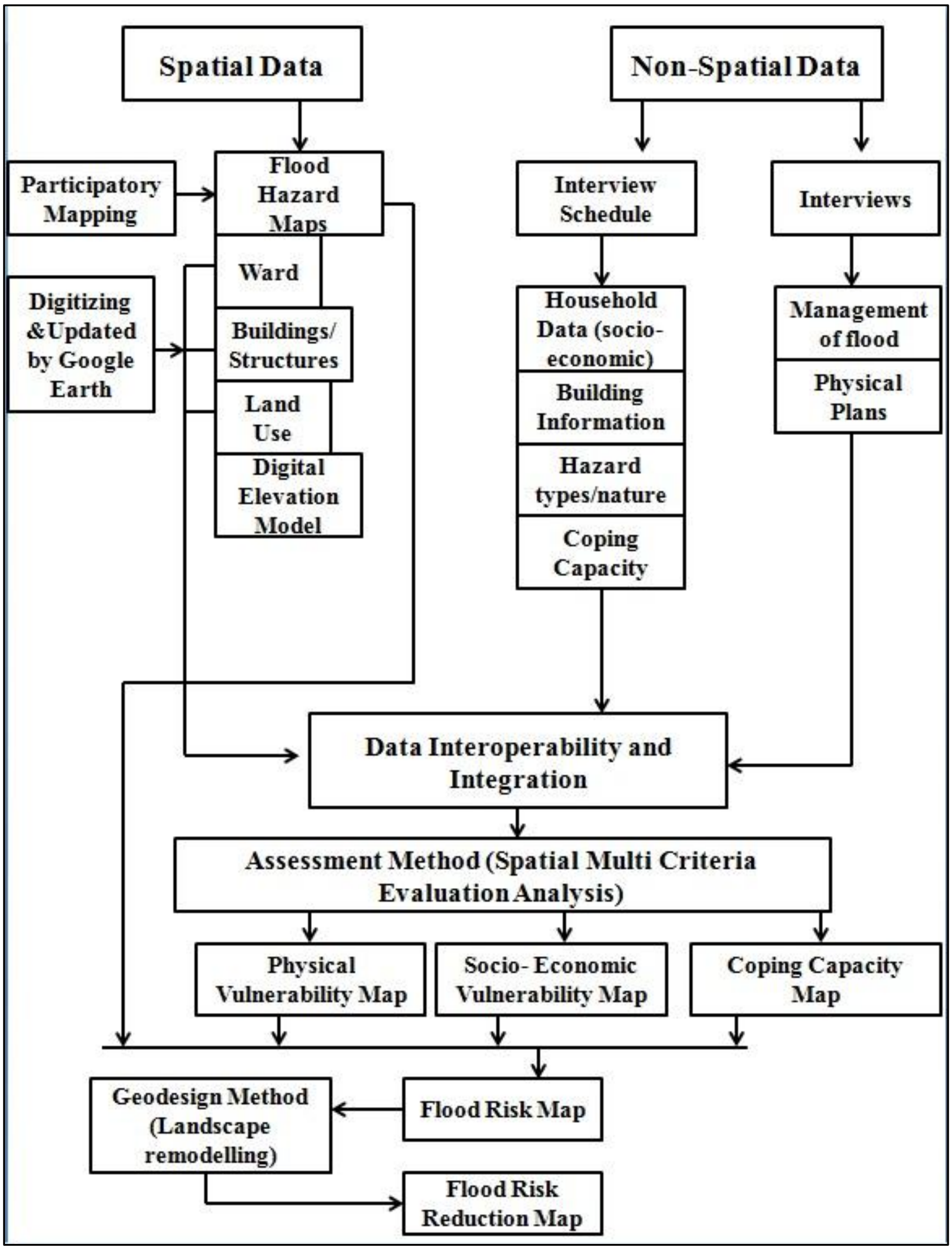
Source: Author's construct, 2014

Appendix E: Flow diagram for SMCE



Source: Author's construct, 2014

Appendix F: Workflow of the data collection, analysis and results



Source: Author's construct, 2014

Appendix G: Interview schedule

The main objective of this study is to assess risk to flood hazard within the Ankobra flood plain. This interview schedule is designed to elicit data regarding this research work. Data given will be used solely for academic purposes. You are also assured of full confidentiality, privacy and anonymity of any data you provide. You are kindly requested to answer the questions as frankly and openly as possible. Please make a tick [√] in the box against your response. Thanks for your co-operation.

Community: ....

Ward No: ....

SECTION 1: Background of respondents *(Please tick as appropriate)*

Respondent No:					
Sex	Male	Female			
Marital status	Single	Married	Divorced	Separated	Widowed
Number of persons in household	**Number of Children (-18) in the household**	**Number of Elderly (+60) in the household**	**Disable persons**	**Number of persons in the house during day**	**Number of persons in the house during night** ....
Native	**Migrant**				
Religion	Catholic	Protestant	Muslim	Traditionalist	....
Highest level of Education	Basic School	J.H.S	S.H.S	Tertiary	....

Main Occupation	Fisherman	Fishmonger	Farmer	Trader	....
Secondary Occupation	Fisherman	Fishmonger	Farmer	Trader	....
Monthly Income	....				

Section 2: Livelihood

Physical Assests

NO.	**TYPE OF ASSET**	**STATE/ FUNCTIONING**	
		GOOD	BAD
i	House		
i	Mobile Phone		
ii	Canoe		
iii	Electricity		
iv	Radio set		
v	Television		
vi	Car		
vii	Soften Chairs		
viii	Others		

Natural Assests

Landed Property	Yes	No	If Yes Use			
Natural Assets dependant on for livelihood	Land	Ankobra (River)	Sea	Mangrove Forest	Beach	....
Access to natural assets	Free	Restricted	If restricted how .... by whom:...			

Human Asset

Specialised skills /Training	Yes	No	If yes specify:..			
Registered member of the NHIS	Yes	No	If yes how long have you been a member................ If no why			
Health Facilities Accessed	Hospital	Clinic	Chemical store	Herbal center	Prayer camp	....
Where do you access health facility						
Distance to health facility						
Reason for choice of facility						

Other Facilities	**School** .... **Market** .... Where:............................... Where:..................................... **Pipe Water**.................... **Other Source of** **Water**...

Financial Assets

Other sources of income beside occupation	Pension allowances	Remittances	None	Other:....................................
Do you save	Yes	No	If yes with	
Access to credit facility	Yes	No	If yes which facility .... If no why..	
Access to reconstruction loans	Yes	No		
Is your house insured against flood	Yes	No		
How much do spend to recover from flood	....			

Social Assets

Member of any social group	Yes	No	(If yes) how many.. Type of group... Type of Assistance...
During floods do you receive any assistant from group	Yes	No	(If yes) Type of Assistance............................
After floods do you receive any assistant from group	Yes	No	(If yes) Type of Assistance..........................

Physical Characteristics of Building

Type of Building	**Age.............**	**No of Floors.......**	**No of exits...........**	**No of windows ....**
Foundation Material	Blocks	Concrete	Rafia	Other....................
Floor Material	Sand	Cement	Rafia	Other...................
Wall Material	Blocks	Rafia		
Roof Material	Zinc	Thatch	Asbestos	Plastic / Synthetic material
Height of Building	**Height of Foundation ....**	**Width of Building ....**	**Height of foundation from street ....**	

SECTION 3

Perception on flood

Types of flood experienced in the last 30 years..

....

....

Causes of Flood..

....

Frequency of occurrence flood type

i)..

ii)...

iii)..

Effects/ Measures

Effects pertain to the worst flood experienced in the last 30 years

Direct effects of flood on you ....

Indirect effects of floods on you ....

Positive effects of floods ....

Reasons for staying in flood prone zone ....

Measures to control damages and effects during

floods..

Measures to control damages and effects from next possible flood

....

Solution to solve the flood problem...

Appendix H : Observation check list

Observation check list of interviews with the District Assembly

Existence of Land use map

Existence of cadastral maps

Availability of building Codes and how will is it enforced

Availability of risk map

Availability of emergency plan

Flood situation within Ankobra estuary

Effects on the people and Assembly

Support by the Assembly to support flood victims

What percentage of Assembly resources is allocated to help flood victims

National support for flood victims within the area

International support for flood victims within the area

Flood awareness program and education for people

Availability of early warning systems

Measures to help solve flood

How will you rate your capacity to manage flood within the district

Population turn up during the last election

Observation check list for participatory mapping

Familiarization with the map

Mapping of important facilities

(Chief Palace, School, Market, Landing Sites, Cultural Heritages, Shops)

Which part of the land has the highest monetary and social value

Flood extent of the most devastating flood in the last 30 years

Flood depth of the most devastating flood in the last 30 years based on the wards

Severity of the flood (Damages, Effects)

Monetary Cost of Damages

Availability of emergency plan

Availability of early warning systems

Availability of flood risk management committee

Aid provided by District Assembly

Aid provided by NADMO

Aid provided by other people and agencies

Measures to help prevent such flood incidence

Solution to help solve flood problem within the community.