THE IMPACT OF FLOODING ON SOCIAL SERVICES IN THE TAMALE METROPOLIS OF GHANA

BY

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DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

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ABSTRACT

Floods do occur annually in the Tamale Metropolis flood prone zones. Floods occur when a body of water rises to overflow land which is normally not submerged. The Metropolis flood prone zones are a home to various communities namely Sogunayili, Gbalo, Jisonayili, Gumani and Fuo which were selected for this study. Flooding in the river basin affects life and property in many ways. The causes and socioeconomic impacts of flooding in the Metropolis flood prone zones have been investigated in this research. The cross-sectional research design was used in this study. Primary and secondary data were used. The purposive sampling method was used to choose a good sample to investigate the problem better. Related institutions were also contacted to give their own perspectives of the problem. It was found out that the causes of flooding in the Metropolis flood prone zones are both natural and artificial. Climate change has contributed to the natural cause of flooding through rise in average temperatures and increase in annual and seasonal rainfall at least, over the last twenty-seven years. Rise in temperature and increase in rainfall have led to increases in the discharge of the river with the excess overflowing to inundate the flood plain. The man-made causes of flooding in the Metropolis include poor land use, unplanned development of settlements and indiscriminate disposal of refuse into and on the banks of the river. The socioeconomic impacts of floods in the Metropolis include loss of life and property, disruption of the transport system as well as financial and health problems faced by inhabitants of the zoned areas. From the research, it was established that average temperatures and rainfall have generally been increasing over the last twenty-seven years and the indiscriminate disposal of refuse into and on the banks of the river have led to the annual floods in the Metropolis. Also, the actions and inactions of concerned institutions have encouraged the haphazard development of settlements in the zoned areas. The resettlement of communities in the

zoned areas and the enforcement of laws which protect the environment and its inhabitants as well as the proper disposal of refuse are recommended solutions to the problem.

TABLE OF CONTENTS

CHAPTER THREE: MATERIALS AND METHODS

CHAPTER FOUR: RESULTS AND DISCUSSION

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

Flooding is an old phenomenon, which can be traced back to the biblical history of Noah and the arc. Flooding is still an occurrence in this age and cannot be eliminated, as it is a natural phenomenon that leaves little to be influenced by human beings. Floods are natural phenomena, but they become a cause for serious concern when they exceed the coping capacities of affected communities, damaging lives and properties (Abhas *et al*., 2011). Globally, floods are frequently occurring destructive natural event, affecting both rural and urban settlements. Floods cause about one third of all deaths, one third of all injuries and one third of all damage from natural disasters (Askew, 1999).

Flooding has been defined in various ways. It is believed to be a natural and inevitable process which occurs when a river's channel cannot hold all the water supplied to it by its watershed (Geology Labs On-Line, 2008). An all-embracing definition is that given by Ayoade (1988) as: "A flood is said to occur when a body of water rises to overflow land which is normally not submerged". When a river floods its basin, water spills out over its channel onto the floodplain.

Floods usually result from a combination of meteorological and hydrological extremes, such as extreme precipitation and flows. However, it can also result from human created vulnerability which is an outcome of our interaction with the environment. Human activities such as designing and locating infrastructure, exploiting natural resources and concentrating population among others are some of the causes of flooding (Hualou, 2011). According to Action Aid (2006), flood hazards are natural phenomena, but damage and losses from floods are the consequence of human action. Flooding of property and land again can be a result of unplanned growth and development in floodplains, or from the breach of a dam or the overtopping of an embankment that fails to protect planned developments. Urbanization has become the major feature of the world's demographic growth, with the populations of cities, towns and villages engorged, particularly in developing countries. In many countries of the world, people moving from rural areas to cities, or within cities, often settle in areas that are highly exposed to flooding. A lack of flood defence mechanism can make them highly vulnerable. Land use changes like urban development that reduces the permeability of soils and increases surface runoff also increase the risk of flooding. In many cases this overloads drainage systems that were not designed to cope with augmented flows (Abhas *et al*., 2011).

Excess water in and of itself is not a problem, rather the impacts of flooding are felt when this water interacts with natural and human-made environments in a negative sense, causing damage, death and disruption (Abhas *et al*., 2011). The experience of flooding for an urban slum dweller will be very different to the rural farmer. To the rural farmer, floods are a natural force to be harnessed or endured for the long-term benefits it may bring, but for the urban dweller flooding is at best, a nuisance and at worst a disaster which destroys all possessions. As a result, floods are upsetting and overwhelming more urban areas, where unplanned development in floodplains, ageing drainage infrastructures, increased road surface and other impermeable surfaces, and a lack of flood risk reduction activities all contribute to the impacts experienced. These problems are compounded by the effects of changing climate (Abhas *et al*., 2011).

People resident or working in flood plains must be mindful of the fact that there is an ever present threat of floods. The probability may be high or low as in some area water courses. Yet the possibility is there always. Even those who live above the level of possible flood in a flood plain may find their access or services cut off by floods. Such people must acquire the knowledge that will help them to face floods with confidence and mitigate the attendant risks and discomfort (Abhas *et al*., 2011). The management of flood risk also requires knowledge of the types and causes of flooding. This understanding is essential in designing measures and solutions which can prevent or limit damage from specific types of flood. Equally important is the knowledge of where and how often flood events are likely to occur. This is a critical step in understanding the necessity or urgency and priority for flood risk mitigation.

1.2 Problem Statement

In many countries of the world, people moving from rural areas to cities, or within cities, often settle in areas that are highly exposed to flooding. Lack of flood defence mechanisms can make them highly vulnerable. Improper land use can also increase the risk of flooding, urban development that reduces the permeability of soils, increases surface runoff. In many cases this overloads drainage systems that were not designed to cope with augmented flows (Abhas *et al*., 2011). These are the key problems facing flood management in the world, and Tamale Metropolitan Area (TaMA) is not excluded. Ghana is not immune to the socio-economic and the negative developmental impacts of floods.

In 2007, the TaMA and other parts of northern regions witnessed prolonged dry spells followed by intense rainfall. The rainfall amount in August 2007 was more than 300 millimetres (WFP, 2010). This led to 56 deaths, over 54,000 homes destroyed and 325,000 people affected. In 2009, floods displaced over 121,000 people, destroyed about 5,104 houses, 13 schools collapsed and 30,000 acres of farm lands destroyed (Kunateh, 2009). In 2010, there were media reports about destroyed lives and properties by floods. For instance, Monday, 13 September, 2010 issue of the Daily Graphic reported of 17 deaths which were the result of the opening of the Bagri and Kampainga spillway and torrential rains in the northern regions of Ghana (Amenuveve, 2010; Indepth Africa, 2010). In this regard, there is the need to examine the impact of flooding on the social services in the Tamale Metropolitan Assembly of the Northern Region of Ghana and propose flood management measures necessary to tackle the predicament.

1.3 Objectives of Study

1.3.1 Main objective

The main objective of the study was to examine the impact of flooding on the social services in Tamale Metropolitan area of the Northern Region of Ghana

1.3.2 Specific Objectives of Study

- To assess the climate change induced causes of floods in the Tamale metropolis
- To assess the human induced causes of floods in the Tamale metropolis
- To assess the impact of floods on the social services delivery in the Tamale Metropolis
- To propose flood management measures necessary to minimise the impacts in the Tamale Metropolis

1.4 Research Questions

Questions the study seeks to answer are as follows:

- What are the climate changes induced causes of floods in the Tamale metropolis?
- What are the human induced causes of floods in the Tamale metropolis?
- What are the impacts of floods on the social services delivery in the Tamale Metropolis?
- What can be done to prevent or minimize the impacts of floods in the future in Tamale metropolis?

1.5 Propositions / Hypothesis

The following propositions / hypothesis guided the research:

- Social service constraints are the motivation of inhabitants' continual stay in flood prone areas.
- The main cause of flooding in the floodplains in the Tamale Metropolis is natural.
- Annual flooding of communities in the Tamale Metropolis along the floodplains is caused by unplanned human settlements.
- Local climatic change is responsible for intense rainfall that causes flooding along the floodplains in the Tamale Metropolis.

1.6 Justification for the Study

A lot of researches on flooding have been conducted in other parts of the country providing vast information for town and country planning. However, more research needs to be conducted particularly in the TaMA to bring to bear the causes and the impacts of flooding on the social service delivery of the people. This research is an applied urban geographic research that provides reliable information on the causes and impacts of flooding in urban areas. This would facilitate urban planning in the city of Tamale.

In recent years, talk of climate change has taken centre stage in a lot of global conferences. Scientists have warned against the extreme weather conditions that will accompany climate change with the resultant effect of the rise in global temperatures. A research of this nature will provide important awareness of the real challenges of flooding especially in cities, and the need to find lasting solutions instead of ad hoc measures to solve the problem particularly with the challenges of climate change looming. The Growth and Poverty Reduction Strategy II (GPRS

II) indicates the vital role that the natural and built environments play in achieving long-term growth and development. It draws attention to the need therefore for amenable, efficient, safe and healthy built environments for growth and development. Finding lasting solutions to the recurrent hazard of flooding is very necessary in achieving such an appropriate environment to ensure national growth and development. Information provided in this research could also serve as a basis for further research into the problem of flooding in Tamale and other parts of the country.

CHAPTER TWO: LITERATURE REVIEW

2.1 Types and causes of flooding

Over the years, flooding has become a major problem in the world. There is no doubt that globally, floods are on the ascendency. Over the past six or seven decades, the economic losses and the number of people who have been affected by floods have increased more rapidly (UNEP, 2007). Globally, about 200 million people were affected by floods in the 1990s with about US$ 63 billion lost in terms of market value of damaged properties (World Disaster Report, 2002). In terms of human life loss, between 1980 and 2000, floods caused about 180 deaths a day worldwide (Peduzzi and Ruiz, 2005). Currently, about 75% of the world's population live in areas at least once affected by these disasters (Peduzzi and Ruiz, 2005).

The physical, social and economic losses caused by these disasters are particularly harsh for developing countries since they have a long term effect on their development process (UNEP, 2007). Sustainable development and disaster reduction and prevention are therefore essential preconditions for each other. Effective disaster management can fully benefit humanity because it will impact on the environment, serve as a human intervention for sustainable development and improve food security (Pandey Okazaki 2005). Furthermore, current development studies prove that assistance in times of a disaster can serve as a tool for national development. This is exemplified in countries such as Botswana and Zambia in which emergency relief interventions became stepping stones for long term development projects (Buchanan-Smith and Maxwell, 1994)

The phenomenon of urban floods is increasingly becoming a great concern for both developed and developing nations due to the seeming increase in the occurrence. Fuelled by climate change and rapid urbanization it causes severe damage to housing and household assets, utility works, income losses in trade and industries, interruption to transport systems as well as disease outbreaks and even death. The damages caused by urban floods are on the increase and it is important to understand its causes and impacts as well as the influence different types of flooding have on urban areas. Urban floods usually occur as a result of a complex amalgam of causes. The presence of buildings in waterways coupled with the compacting of the soil surface reduces the rate of infiltration and further worsens the occurrence of floods in urban areas. Urban areas can be flooded by rivers, coastal floods, pluvial, groundwater floods and artificial system failures. In cities and towns, areas of open soil are very limited and all precipitation and other flows have to be carried away by surface runoff or through drainage systems, which are usually artificial and constrained by the competing demands on urban land. High intensity rainfall can cause flooding when drainage systems do not have the necessary capacity to cope with flows. Sometimes the water enters the sewage system in one place and resurfaces in others. This type of flood occurs fairly often in Europe, for instance the floods that affected parts of England in the summer of 2007 (Abhas *et al.,* 2011).

In many developing countries such as Ghana, urban floods are caused by the effects of deficient or improper land use planning. Many urban areas facing the challenges of increased urbanization coupled with increasing populations, and high demands for land do not properly enforce legislations aimed at militating against floods. While there are existing laws and regulations to control the construction of new infrastructure and the variety of building types, they are often not enforced properly owing to economic or political factors, or capacity or resource constraints. This leads to obstruction in the natural course of water, which results in floods. The key to reducing the effects of floods and in reducing the occurrence of floods is in awareness creation amongst residents and proper cooperation between decision makers, risk management authorities and the public in the process of flood risk management.

Understanding flood risk requires knowledge of the different types of floods, their probabilities of occurrence, how they can be modelled and mapped, what the required data are for producing hazard maps and the possible data sources for these. A detailed understanding of the flood hazard relevant to different localities is also crucial in implementing appropriate flood risk reduction measures such as development planning, forecasting, and early warning systems. As flood risk evolves over time it also becomes relevant to explore how these decisions will need to change in the light of predictable climate changes. Information about the existing models used to account for climate change at different scales and the uncertainties regarding those results are both important issues which need to be accommodated in any decision making process (Abhas *et al*., 2011).

Preventing and managing flood situations effectively ensuring sustainable regional development have been a source for major concern of academics, engineers, planners, decision-makers and different levels of government. In making plans and decisions about disaster prevention and management, more considerations ought to be paid to the spatial features of floods. Most natural hazards according to Curtis and Mills (2010) have patterns that leave spatial footprints and within these patterns are human places, cultures and interactions. There is a clear nexus between environmental degradation and floods in many regions of the world and those countries that suffer most from floods are the same ones in which environmental degradation is proceeding most rapidly (Kötter, 2003). In addition, it is the poor people that are more vulnerable to floods. Continuous and increasing occurrence of devastating flood events such as urban flooding often poses substantive danger to the achievement of both sustainable development and poverty-reduction initiatives (UN-ISDR, 2009). The issue of disaster reduction and risk management is rapidly being adopted into the policy agenda of affected governments as well as multilateral and bilateral agencies and NGOs. The International Strategy for Disaster Reduction (ISDR) through Resolution 54/219 of the UN General Assembly aim to mobilize Governments, UN agencies, regional bodies, private sector and civil society to unite efforts in building resilient societies by developing a culture of prevention and preparedness (Abhas *et al*., 2011).

Descriptions and categorizations of floods vary and are based on a combination of sources, causes and impacts. Based on such combinations, floods can be generally characterized into river (fluvial) floods, overland (pluvial) floods, coastal floods, groundwater floods or the failure of artificial water systems. Based on the speed of onset of flooding, floods are often described as flash floods, urban floods, semi-permanent floods and slow rise floods (Abhas *et al*., 2011). All these types can have severe impacts on urban areas and thus be categorized as urban floods. It is important to understand both the cause and speed of onset of each type to understand their possible effects on urban areas and how to mitigate their impacts as it is illustrated in Table 2.1.

Table 2.1: Types and causes of floods

Types of flooding	***Causes***		**Onset time**	**Duration**
	Naturally occurring	**Human induced**		

Pluvial and overland flood	Convective thunderstorms, severe rainfall, breakage of ice jam, glacial lake burst, earthquakes resulting in landslides	Land use changes, Urbanization. Increase in surface runoff	Varies	Varies depending upon prior conditions
Coastal (Tsunami, storm surge) flood	Earthquakes Submarine volcanic eruptions Subsidence, Coastal erosion	Development of coastal zones Destruction of Coastal natural flora (e.g., mangrove)	Varies but usually fairly rapid	Varies but usually fairly rapid
Groundwater flood	High water table level combined with heavy rainfall Embedded Effect	Development in low-lying areas; interference with natural aquifers	Usually slow	Longer duration
Flash flood	Can be caused by river, pluvial or coastal systems; convective thunderstorms; GLOFs	Catastrophic failure of water retaining structures Inadequate drainage infrastructure	Rapid	Usually short often just a few hours

Semi-permanent Flooding	Sea level rise, land subsidence	Drainage overload, failure of systems, inappropriate urban development, Poor groundwater Management	Usually slow	Long duration or permanent

Source; Abhas *et al*., (2011)

2.1.1 Pluvial or overland floods

Pluvial floods also known as overland floods are caused by rainfall or snowmelt that is not absorbed into the land and flows over land and through urban areas before it reaches drainage systems or watercourses. This kind of flooding often occurs in urban areas, is the lack of permeability of the land surface means that rainfall cannot be absorbed rapidly enough, flooding results. Pluvial floods are often caused by localized summer storms or by weather conditions related to unusually large low pressure areas (Abhas *et al*., 2011). Characteristically, the rain overwhelms the drainage systems, where they exist, and flows over land towards lower-lying areas. These types of floods can affect a large area for a prolonged period of time. The 2007 floods in the Hull area in the UK were the result of prolonged rainfall onto previously saturated terrain which overwhelmed the drainage system and caused overland flooding in areas of the city outside the fluvial floodplain. Pluvial floods may also occur regularly in some urban areas, particularly in tropical climates, draining away quickly but happening very frequently, even daily, during the rainy season (Abhas *et al*., 2011).

2.1.2 River or fluvial floods

River or fluvial floods occur when the surface water runoff exceeds the capacity of natural or artificial channels to accommodate the flow. The excess water overflows the banks of the watercourse and spills out into adjacent, low-lying floodplain areas. Typically, a river such as the

Mississippi in the United States or the Nile in North Africa floods some portion of its floodplains. It may inundate a larger area of its floodplains less frequently, for instance once in twenty years, and reaches a significant depth only once in one hundred years on average (Pittock and Xu 2011). The flow in the watercourse and the elevation it reaches depend on natural factors such as the amount and timing of rainfall, as well as human factors such as the presence of confining embankments (also known as levees or dikes). River floods can be slow, for example due to sustained rainfall, or fast, for instance as a result of rapid snowmelt. Floods can be caused by heavy rains from monsoons, hurricanes or tropical depressions. They can also be related to drainage obstructions due to landslides, ice or debris that can cause floods upstream from the obstruction (Pittock and Xu 2011).

2.1.3 Coastal floods

Coastal floods arise from incursion by the ocean or by sea water. They differ from cyclic high tides in that they result from an unexpected relative increase in sea level caused by storms or a tsunami (sometimes referred to as a tidal wave) caused by seismic activities. In the case of a storm or hurricane, a combination of strong winds that causes the surface water to pile up and the suction effects of low pressure inside the storm, creates a dome of water. If this approaches a coastal area, the dome may be forced towards the land, the increasing sea floor level typically found in inshore waters causes the body of water to rise, and creating a wave that inundates the coastal zones. The storm surge usually causes the sea level to rise for a relatively short period of time of four to eight hours, but in some areas it might take much longer to recede to pre-storm levels. Coastal floods caused by tsunamis are less frequent than storm surges, but can also cause huge losses in low-lying coastal areas. The 2004 Indian Ocean Tsunami was caused by one of the strongest earthquakes ever recorded and affected the coasts around the ocean rim, killing hundreds of thousands of people in fourteen countries (Abhas *et al*., 2011).

2.1.4 Groundwater floods

Water levels under the ground rise during the winter or rainy season and fall again during the summer or dry season. Groundwater flooding occurs when the water table level of the underlying aquifer in a particular zone rises until it reaches the surface level. This tends to occur after long periods of sustained high rainfall, when rising water levels may cause flooding in normally dry land, as well as reactivate flows in, which are streams that only flow for part of the year. This can become a problem, especially during the rainy season when these non-perennial streams join the perennial watercourses. This can result in an overwhelming quantity of water within an urban area. Groundwater flooding is more likely to occur in low lying areas underlain by permeable rocks where such an area has been developed, the effect of groundwater flooding can be very costly (Abhas *et al*., 2011).

Groundwater flooding can also occur when an aquifer previously used for water supply ceases to be used, if less water is being pumped out from beneath a developed area the water table will rise in response. An example of this occurred in Buenos Aires, when pollution of groundwater led to a cessation of pumping. Drinking water was imported instead. The resulting water table rise caused flooded basements and sewage surcharge, which is a greater volume of combined water and sewage than the system is designed to convey (Foster *et al* 2002). Since groundwater usually responds slowly compared to rivers, groundwater flooding might take weeks or months to dissipate. It is also more difficult to prevent than surface flooding, though in some areas water pumps can be installed to lower the water table. Flooding can also therefore occur in the event of the failure of pumping systems and may underlie the phenomenon of semi-permanent flooding. In many cases groundwater and surface flooding are difficult to distinguish. Increased infiltration and a rise in the water table may result in more water flowing into rivers which in turn are more likely to overtop their banks. A rise in the water table during periods of higher than normal rainfall may also mean that land drainage networks, such as storm sewers, cannot function properly if groundwater is able to flow into them underground. Surface water cannot then escape and this causes flooding (Abhas *et al*., 2011).

2.1.5 Flash Floods

"Flash flood**"** is a term widely used by flood experts and the general population. The US National Weather Service defines a flash flood as "A rapid and extreme flow of high water into a normally dry area, or a rapid rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam). However, the actual time threshold may vary in different parts of the country. On-going flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters". Flash floods are also characterized by a rapid rise in water, high velocities, and large amounts of debris. Major factors in flash flooding are the intensity and duration of rainfall and the steepness of watershed and stream gradients. Flash flooding occurs in countries, most commonly in steeply sloping valleys in mountainous areas, but can also occur along small waterways in urban environments. Dam failure, release of ice jams, and collapse of debris dams also can cause flash floods.

The damages caused by flash floods can be more severe than ordinary riverine floods because of the speed with which flooding occurs (possibly hindering evacuation or protection of property), the high velocity of water, and the debris load. Channel velocities of 2.74m/s, typically realized in flash floods, can move a 40.82 kg rock and major flash floods like the one that occurred in the Big Thompson Canyon in Colorado in 1976, where velocities exceeded 30 feet per second, moved boulders weighing 250 tons (Abhas *et al*., 2011). The density of water enables it to pack a destructive punch. Water moving at 10 miles per hour exerts the same pressure on a structure as wind gusts at 270 miles per hour (USA Today, 2005). Sudden destruction of structures and washout of access roads may result in loss of life. A high percentage of flood related deaths result from motorists underestimating the depth and velocity of flood waters and attempting to cross swollen streams.

2.1.6 Failure of artificial systems

Human-made systems which contain water have the potential to fail, and the resulting escape of water can cause flooding. Examples of this include burst water mains or drainage pipes, as well as failures of pumping systems, dams or breaches in flood defences. This type of flooding is not only confined to locations usually considered at risk of flooding, although low-lying areas and areas behind engineered defences are at greater risk. Often the onset will be rapid, as failure of a system will lead to an escape of water at high pressure and velocity. Dam failure for example, may be devastating as the volume and speed of water is typically large. Failure of embankments levees or dikes also has the potential to cause devastating floods, which may persist for a long time where the water has few escape routes. Between April and October of 1993 a large flood affected the US Midwest along the Mississippi and Missouri rivers and their tributaries. Many levees had been constructed along these rivers to protect residential areas and agricultural land, but many of these failed, contributing to widespread flooding. Fifty lives were lost and the economic damages were estimated to be US$15 billion (Larson 1993).

2.1.7 Semi-permanent flooding

Semi-permanent flooding may occur where settlements are in the vicinity of failed human-made structures awaiting repair. In New Orleans USA, for instance, following the failure of levees damaged by Hurricane Katrina, some residents remained in homes that were standing in water for over six weeks (Kates *et al*., 2006). Sea level rise and land subsidence have the potential to create many more such areas in the future. In some cases urban settlements are built on land which is flooded regularly and for long periods of time. Often these areas may lie below sea level or where the water table is close to the surface. This is usually the case where settlements are informal, unplanned and built on less expensive land due to rapid urban expansion and the poverty of the inhabitants. A typical scene of flooding is illustrated in Figure 2.1.

Figure 2.1: Stagnant water seven months after the 2010 floods in Baguida, Lome.
Source: (Abhas *et al*., 2011).

2.2 Probability of flooding

A sound understanding of the likelihood of occurrence of a flood hazard is a fundamental step in dealing with flood risk. Risk from flooding can be conceptualized into four stages as in Figure 2.2.

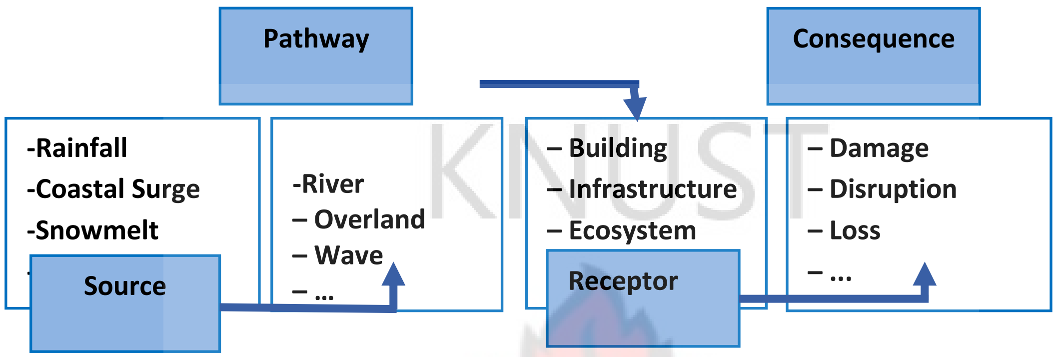

Figure 2.2 conceptualized stages of flood risk.

Source: (Abhas *et al*., 2011).

This model breaks down the process of flooding into the identification of a source of the flood water, the pathway which is taken by it, and the receptor of the flooding, which is the human settlement, building, field or other structure or environment that is exposed to the consequences. Flood hazard encompasses the first two of these steps, the source of flood water and the pathway by which it has the potential to damage any receptor in its path. To fully evaluate risk, the degree of exposure and the nature of exposed receptors and their potential to sustain or resist damage also need to be considered. This section deals only with the hazard, focusing on its nature, source and pathway, together with the probability of an event (Abhas *et al*., 2011).

Probability in itself can be a difficult concept to translate from the purely scientific generation of hydro-meteorological models into a description of hazard that lay people can comprehend and decision makers can use to evaluate their real options. This section explains different methods of calculating the probability of occurrence of flooding and clarifies some of the concepts of hazard and their communication. It is important to distinguish between the probabilities of occurrence of weather event and the probability of occurrence of a flood event. Flooding is primarily driven by weather events which are hard to predict due to what is termed their chaotic nature. In other words, despite the great advances in weather forecasting, it cannot be determined with certainty when and where rain will fall or storms will form. This means that it is impossible to know exactly when and where a flood will occur in the future, nor how high (either in water level or discharge) the next flood will be. Hazard predictions are commonly given in terms of probabilities, computed using historical data for the area of interest. This section now describes the use of frequency analysis and hydrological modelling in the estimation of flood probability, through to providing and communicating flood hazard forecasts (Abhas *et al*., 2011).

2.2.1 Probability and occurrence of floods

Flood forecasts for a natural drainage area or a city are usually obtained by analysing the past occurrence of flooding events, determining their recurrence intervals, and then using this information to extrapolate to future probabilities. This common approach is described below in simplified form for fluvial flooding. The probability of occurrence for pluvial, groundwater, flash, and semi-permanent floods is much more difficult to estimate, even if historical data is available. This is due to the fact that the causes of these types of floods are, as seen above, a combination of a meteorological event such as heavy rainfall and other factors such as insufficient drainage capacity, mismanagement of key infrastructure and other human factors. In the case of coastal floods caused by seismic activities, predicting their probability is as difficult as predicting the occurrence of an earthquake. For coastal floods caused by storms or hurricanes, their probability of occurrence can, in principle, be computed using historical data or numerical simulations of key variables such as wind speed, sea level, river flow and rainfall (Abhas *et al*., 2011).

2.2.2 Recurrence interval

The recurrence interval or return period is defined as the average time between events of a given magnitude assuming that different events are random. The recurrence interval or return period of floods of different heights varies from catchment to catchment, depending on various factors such as the climate of the region, the width of the floodplain and the size of the channel. In a dry climate the recurrence interval of a three meter high flood might be much longer than in a region that gets regular heavy rainfall. Therefore the recurrence interval is specific to a particular river catchment. Since only the annual maximum discharge is considered, the amount of data available to perform the return period calculation can be very limited in some cases (Abhas *et al*., 2011).

In Europe and Asia, partial records extending over centuries may be found as for instance in the case of sea floods in the Netherlands. In other places data may be scarce and records are rarely longer than for 50 years. This poses an important limitation to the calculation of recurrence intervals which must be taken into account when evaluating and communicating uncertainties in flood probability estimations. Once the recurrence intervals are determined based on the historical record, an assumption about the flood frequency distribution has to be made in order to extrapolate or interpolate the events that have not been recorded historically. To achieve this, an assumption about the distribution of flood frequency has to be made. In this way the recurrence interval for any discharge (and not just those present in the observational record) can be inferred (Abhas *et al*., 2011).

2.2.3 Flood probability

The recurrence interval, as discussed above, refers to the past occurrence of floods, whilst flood probability refers to the future likelihood events. The two concepts are related because the recurrence interval of past events is usually used to estimate the probability of occurrence of a future event. For any discharge, or alternatively, any recurrence period, the probability of occurrence (p) is the inverse of the return period (t),

$$P = \frac{1}{t} \qquad \text{Eqn 2.1}$$

Using the relationship between return period (t) and flood probability (P), it is clear that a flood discharge that has a 100 year recurrence interval has a 1 % chance of occurring (or being exceeded) in a given year. The term 'one hundred year flood' has often been used in relation to floods with a 100 year recurrence interval (Defra, 2010; Dinicola, 1996). This can be misunderstood, as a 100 year flood does not have a 100 % chance of occurring within a 100 year period. The probability of a 100 year flood not occurring in any of the next 100 years is 0.99.

2.3 Flood hazard assessment

The concept of hazard is the potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (UNISDR, 2004). Flood hazard maps are important tools for understanding the hazard situation in an area. Hazard maps are important for planning development activities in an area and can be used as supplementary decision making tools. They should therefore be easy to interpret: the aim should be the generation of simple hazard maps which can be read and understood by both technical and non-technical personalities. There is, therefore, a need to generate maps based on user specific requirements, whether for individual or institutional purposes. Flood hazard maps are characterized by type of flooding, depth, velocity and extent of water flow, and direction of flooding. They can be prepared based on specified flood frequencies or return periods, for example, 1:10 years, 1:25 years, 1:100 years, or to more extreme events such as the 1:1000 year return period for different scales (Abhas *et al.*, 2011).

2.4 Probability of flood into hazard estimation

Flood hazard is determined by the conjunction of climatic and non-climatic factors that can potentially cause a flood: the magnitude of a fluvial flood will depend on physical factors such as intensity, volume and timing of precipitation. The antecedent conditions of the river and its drainage basin (such as the presence of snow and ice, soil type and whether this is saturated or unsaturated) will also have an impact on the development of the event, as will human-made factors such as the existence of dykes, dams and reservoirs, or the loss of permeability caused by urban expansion into floodplains.

Flood hazard is usually estimated in terms of a rainfall event or 'design flood' such as the 100 year flood. The estimation of flood probability or hazard combines statistics, climatology, meteorology, hydrology, hydraulic engineering, and geography. The standard approach depends on the assumption that the flow data is sufficient to compute the design flood using statistical methods. In places where these data are not available because there are no gauges, or are of poor quality, other approaches are used. Data from a neighbouring watercourse may be interpolated to the site of interest, or, if precipitation data are available, a design rainfall event can be computed, and a rainfall runoff model used to estimate river flow. This is then fed into a hydraulic model that computes the depth and extent of the resulting flood. Finally, this information is combined with topographic, infrastructure, population and other geographic data in order to compute the flood hazard. Table 2.2 illustrates the range of model types used; the 'generation' denotes the level of sophistication inherent in the model, progressing from 'first generation' models including a number of simplified assumptions, through to the more advanced generations with fewer simplifying assumptions (Abhas *et al*., 2011).

Table 2.2 Types of flood models

Type of models	Useful in areas	Advantages	Disadvantages
First Generation with 2DH grid	Good for estimation of duration of flood, volume propagation, Useful in compact channels	Low to medium cost, simple calculation, low runtime (minutes to hours)	Does not give good results for vast areas or vast floodplains
Second generation 1D/2D and 2D and Finite element models	Good for broad scale modeling, urban inundation ,useful for compound channels	Medium to high cost, accuracy and run time (hours to days), , can get outputs like percolation and seepage other than depth, velocity and volume	Broad scale application requires coarse grid otherwise the computational time becomes immense, high data demand
Third generation models	Good for showing breaching in 3D and flood propagation in 2D, useful for local predictions	High cost, accuracy, computation time (days) , flow velocity and flood boundaries accurately simulated	High run time, high demand for data, high cost
Erosion models	Predicts final erosion profile based on wave height and storm surge water level	Can be used in coasts of different morphology	Does not include wave period
Sheach Model	Analytical more versatile	Estimation of cross shore transport rate in different shore zones	Demands high level of data, huge dataset

TIMOR3 and SWAN	Process based model, useful for short term	Detailed morph dynamic result	Not efficient to calculate initial response

Source: (Abhas *et al*., 2011).

2.5 How to prepare a flood hazard map (Riverine)

Production of hazard maps is the first step towards flood risk assessment. Their purpose is to better understand and communicate flood extent and flood characteristics such as water depths and velocity. Multiple stakeholders such as city managers, urban planners, emergency responders and the community at risk can use hazard maps in planning long term flood risk mitigation measures and the appropriate actions to be taken in an emergency.

For accurate estimation of flood hazard, selection of appropriate data, type of model, schematization, proper parameterization, calibration and validation of results are all important steps. A step by step process for achieving this is outlined below. This incorporates the factors to be considered at each stage.

2.5.1 Calculation of return period of flooding

The annual maximum flood series is the maximum volume flow rate passing a particular location (typically a gauging station) during a storm event. This can be measured in ft^3/sec, m^3/sec, or acre feet/hr and is calculated using the following formula:

$$Tr = (N + 1)/ M \qquad \text{Eqn 2.1}$$

Where Tr = Return Period of flooding; N= Peak annual discharge; and M = Rank, according to order of highest flow.

Where a number of tributaries exist within the catchment of interest, methods of gauging flows on each watercourse may be necessary. Output from the return period calculations will enable users to understand the ‘exceedance probability’ of given flood events. If actual annual maximum discharge data is unavailable then approximation will be needed. But it must be recognized that this may lead to uncertainties within the model and thus in the end product (Abhas *et al*., 2011).

2.5.2 Model result validation

Validation of results by means of surveying, also known as 'ground truthing' of the model, is extremely important to ascertain the quality of the model output. Additional validation, using actual event data, provides another way of testing how appropriately the hazard model has performed. Both the above checking processes are required in order to improve the precision of the model outputs and thereby the usefulness of the final map product.

2.5.3 Monitoring and regular updating of maps

Typically, for public access purposes, general maps with limited information are produced using GIS software, showing only the flood extent and perhaps protection measures where these exist. For use by local authorities for decision making more detailed information will be required, such as municipality level maps with real estate data. For professional bodies, maps with still more detailed supplementary data can be generated, going down to individual household plot level if required (Abhas *et al*., 2011).

Flood hazard maps must be updated regularly with both field information (for example, major building developments or road construction that significantly alter the terrain) as well as other relevant data, such as any changes in the peak recorded flows from gauging stations following extreme events. Monitoring of the hazard map's performance in use is also required (for example, where data from actual events following map production are found to exceed the modelled predictions). Known uncertainties in the model need to be incorporated into the decision making processes of the local authorities; revisions to the maps following any amendments to input data will also be required. A process to ensure that the superseded copies are taken out of use is further needed, such that future decisions are made on the basis of the updated information (Abhas *et al*., 2011).

2.6 Accounting for climate change and sea level rise

Climate change is likely to have implications for today's urban flood risk management decisions, but is one of many drivers that must be considered (e.g. urbanization, aging infrastructure, and population growth). Many decisions made today regarding flood risk management will have ramifications well into the future. Failure to adequately treat climate change in decision making today could lead to future unnecessary costs, wasted investments and risks to life. Decision makers therefore require long term projections of risk, as well as detailed hazard maps of current flood risk. The idea that climate change will cause huge changes in risk and therefore render current flood risk management practice obsolete in the future is widespread and justified in some cases. This makes it highly problematic for governments and individuals to make confident decisions and to critically assess their investments in risk management. Long-term infrastructure is an area where planning decisions are likely to be sensitive to assumptions about future climate conditions. This can lead to indecision, delay in investment and higher damages from flood events in the short term. It is, therefore, crucially important to explore the implications of climate change for future flood hazard and to look for ways to build those implications into decision making processes (Abhas *et al*., 2011).

There exists a broad consensus that flood risk is already changing at a significant rate, and that the rate of change might intensify in the future (Pall *et al.* 2011). A variety of climatic and non-climatic variables influence flood processes. Some of the climatic variables that flood magnitudes depend upon are; precipitation, intensity, timing, duration, phase (rain or snow) and spatial distribution. In the case of floods caused by sudden snowmelt, temperature and wind speed are also key factors. In this section we focus on the climatic drivers of floods and briefly discuss their observed and projected changes.

2.7 Potential impacts of climate change on cities

Around half of the world's population now lives in urban areas and this figure is projected to reach 60 % by 2030. Urban population and infrastructure is increasingly at risk to some of the possible negative impacts of climate change. There is potential for increased flood risk from:

- Increased precipitation
- Drought leading to land subsidence
- Rising sea levels
- Rapid snowmelt

Urban centres located predominantly in low-lying coastal areas are particularly vulnerable to sea level rise, storm surge and heat waves, all of which are likely to worsen due to climate change. In 2005, 13 out of the 20 most populated cities in the world were port cities (Nicholls *et al.*, 2007a).

Deltas are also widely recognized to be highly vulnerable to the impacts of climate change, particularly sea level rise and changes in runoff. Most deltas are undergoing natural subsidence that exacerbates the effects of sea level rise. This is compounded with some human actions, such as water extraction and diversion, as well as declining sediment input as a consequence of entrapment in dams. It is estimated that nearly 300 million people inhabit a sample of 40 deltas globally. The average population density is 500 people per square kilometer, with the largest population in the Ganges-Brahmaputra Delta and the highest density in the Nile Delta. Due to these high population densities, many people are exposed to the impacts of river floods, storm surges and erosion. Modeling studies indicate that much of the population of these 40 deltas will continue to be at risk primarily through coastal erosion and land loss, but also through accelerated rates of sea level rise (Nicholls, *et al.*, 2007b).

Estimation of impacts of sea level rise, increasing temperatures and changing rainfall patterns on cities, and the development of robust adaptation pathways, is complicated by a combination of the characteristics of the infrastructure to be protected and the uncertainty of local and regional climate projections. Adaptation measures have to take into account the fixed or long term life span of urban infrastructure already in place, and the long lead times for the planning of replacements. Although individual extreme weather events cannot be attributed to climate change, recent studies have shown that anthropogenic climate change can increase the chance of some of those events happening (Pall *et al,* 2011; Min *et al.*, 2011; Stott *et al.*, 2004). A recent IPCC special report on managing the risks of extreme weather events and disasters concludes the frequency of heavy precipitation, daily temperature extremes, intensity of tropical cyclones, droughts, and sea level will be increased (IPCC, 2011).

Analysis of specific extreme events can serve to illustrate their possible impacts where they become more frequent or intense in the future. One well-known example is that of Hurricane Katrina which made landfall in coastal Louisiana in August 2005. One result of the hurricane was the loss of 388 square kilometres of coastal wetlands, levees and islands that flank New Orleans in the Mississippi River delta plain. As these areas collectively act as the first natural defence against storm surge, this attribute was also lost. Over 1,800 people died and the economic losses totalled more than US$100 billion. Roughly 300,000 homes, and over 1,000 historical and cultural sites, were destroyed along the coasts of Louisiana and Mississippi, whilst the loss of oil production and refinery capacity helped to raise global oil prices in the short term (Nicholls *et al.,* 2007a).

2.8 Climate change and variability

2.8.1 Observed changes

At continental, regional, and ocean basin scales, some significant changes in the climate system have already been observed: The warming rate as demonstrated by global mean surface temperature over the last 50 years (0.13 ºC ± 0.03 ºC per decade) is almost double that over the 100 years from 1906 to 2005 (0.07 ºC ± 0.02 ºC per decade). Moreover, the 9 warmest years on record have all occurred since 1998 (Trenberth *et al*, 2007). At the end of the melt season in September 2010, the ice extent in the Arctic Sea was the third smallest on the satellite record after 2007 and 2009. Global mean sea level is rising faster than at any other time in the past 3,000 years, at approximately 3.4 millimetres per year in the period from 1993 to 2008 (WMO, 2009).

Precipitation over land generally increased during the 20th Century at higher latitudes, especially from 30ºN to 85ºN, but it has decreased in the past 30 to 40 years in the more southerly latitudes between 10º N and 30º N. There was an increase of precipitation in this zone from around 1900 until the 1950s, but this declined after about 1970. Global averaged precipitation does not show any significant trend in the period 1951-2005, with significant discrepancies between different data sets, and large decadal variability. Observed changes in weather extremes are all consistent with a warming climate. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (Solomon *et al.,* 2007) stated that increases in heavy precipitation over the mid-latitudes have been observed since 1950. This includes places where mean precipitation amounts are not increasing. Since 1970, large increases in the number and proportion of strong hurricanes globally have also been recorded, even though the total number of cyclone and cyclone days decreased slightly. The extent of regions affected by drought has also increased due to a marginal decrease of precipitation over land, with a simultaneous increase in evaporation due to higher temperatures. Increases in precipitation intensity and other observed climate changes during the last three decades, such as sea level rise, suggest that robust future projections for flood management systems cannot be based on the traditional assumption that past hydrological experience provides a comprehensive guide to future conditions (Bates *et al*, 2008). In the IPCC Summary for Policy Makers (IPCC, 2007), the conclusion drawn is that it is likely that the frequency of heavy precipitation events has increased over most areas during the late 20th Century, and that it is more likely than not that there has been a human contribution to this trend (Solomon *et al.* 2007). It is expected that global warming will affect both atmospheric and ocean circulation in such a way that many aspects of the global water cycle will change.

2.8.2 Projected changes

The IPCC has identified a range of possible futures for the planet, depending on the levels of greenhouse gas emissions that may be expected. These are defined in the Special Report on Emissions Scenarios (SRES) (IPCC, 2007). There are four groups of scenarios, termed 'families', which range from A1, covering the highest emissions envisaged, through A2 and B1, to the lowest emissions grouping, B2. Within each of the family groups, there are multiple scenarios depending upon the levels of individual variables chosen: for example, the A1 family encompasses scenarios 'A1T' and 'A1F1', amongst others. The range of global mean temperatures projected by several of these scenarios suggests marginally higher temperatures even if emissions were held at their 2000 values. This continued rise further suggests that even if emissions were drastically reduced now, at least in the short term the world will become warmer (IPCC, 2007) by about 0.5 degrees. The projection of temperature rise for the worst case scenario sees a potential six degree warming by 2100.

Projections of global mean temperature change and rainfall for the highest and the lowest emissions scenario overlap until the 2020s. For the 2020s, changes in global mean precipitation are masked by its natural variability in the short term. The picture is different for longer term projections, when the emissions path does matter (Solomon *et al.*, 2007). Changes in global mean precipitation become distinguishable from its natural variability, and some robust patterns emerge, such as an increase in the tropical precipitation maxima, a decrease in the subtropics and increases at high latitudes. However, due to larger uncertainties in the simulation of precipitation, the confidence in precipitation response to greenhouse gas increases is much lower than the confidence in simulated temperature response (Stone, 2008).

Clearly, regional changes can be larger or smaller than global averages and, in general, the smaller the scale the less consistent the picture when viewed across the ensemble of global climate model (GCM) projections, particularly for some climate variables. The Regional Climate Projections chapter of the IPCC's AR4 report (Christensen *et al.*, 2007), presents projections at continental scales, and then goes down to sub-continental scales in the form of so-called Giorgi regions: for example, Africa is subdivided into Western, Eastern, Southern and Sahara regions. One key feature of these regions is that they are typically greater than a thousand kilometres square and therefore much larger than the spatial scales relevant for most impact studies.

The greatest amount of warming is expected, and has been observed, over the land masses. In particular, it is expected that significant warming will occur at higher latitudes. In spite of the fact that these are regions with the largest uncertainties in their projections, and by the 2020s some GCMs project very small (or even slightly negative) temperature changes (Stone, 2008). Precipitation changes are less consistent than temperature changes, partly because precipitation is much more variable than temperature, and partly because it does not respond as directly to increases in concentrations of greenhouse gases' as temperature does. The changes in annual means projected for the 2020s indicate that the largest potential changes and simultaneously the largest uncertainties occur in areas where precipitation is low, such as deserts and Polar Regions. By the 2080s projections show even greater variability, but some patterns emerge, such as the fact that precipitation in the Polar Regions is projected to increase. This is related to the fact that models project a retreat of sea and lake ice, allowing surface waters to evaporate directly (Stone, 2008).

At the regional level, then, the seasonality of changes has to be considered, since clearly changes in annual averages do not uniquely determine the way in which the frequency or intensity of extreme weather events might change in the future. In Europe for example, where the annual mean temperature is likely to increase, it is likely that the greatest warming will occur in winter in Northern Europe and in summer in the Mediterranean area (Christensen *et al.*, 2007). Levels of confidence in projections of changes in frequency and intensity of extreme events (in particular regional statements concerning heat waves, heavy precipitation and drought) can be estimated using different sources of information, including observational data and model simulations. Extreme rainfall events, for example, are expected to be unrelated to changes in average rainfall. Average rainfall amount depends on the vertical temperature gradient of the atmosphere which, in turn, depends on how quickly the top of the atmosphere can radiate energy into space; this is expected to change only slightly with changes in carbon dioxide concentrations. On the other hand, extreme precipitation depends on how much water the air can hold, which increases exponentially with temperature. Thus it is reasonable to expect that in a warmer climate, short extreme rainfall events could become more intense and frequent, even in areas that become drier on average. Some studies have found that in regions that are relatively wet already, extreme precipitation will increase, while areas that are already dry are projected to become even drier, due to longer dry spells (Abhas *et al*., 2011).

Projections of extreme events in the tropics are uncertain, due in part to the difficulty in projecting the distribution of tropical cyclones using current climate models with too coarse a spatial resolution, but also due to the large uncertainties in observational cyclone datasets for the 20th Century. For instance, some studies suggest that the frequency of strong tropical cyclones has increased globally in recent decades in association with increases in sea surface temperatures. These results are consistent with the hypothesis that, as the oceans warm, there is more energy available to be converted to tropical cyclone wind. However, the reliability of estimating trends from observational data sets has been questioned based on the argument that improved satellite coverage, new analysis methods, and operational changes in the tropical cyclone warning centres have contributed to discontinuities in the data sets and more frequent identification of extreme tropical cyclones after 1990 (Füssel, 2009).

Global mean sea level has been rising; there is high confidence that the rate of rise has increased between the mid-19th and the mid-20th centuries. However, even though the average rate was 1.7 ± 0.5 millimetres per year for the 20th Century, the data shows large decadal and inter-decadal variability and the spatial distribution of changes is highly non-uniform. For instance, over the period 1993 to 2003, while the average rate of increase was 3.1 ± 0.7 millimetres per year, rates in some regions were larger while in some other regions sea levels fell (Solomon *et al.* 2007). Factors that contribute to long term sea level change are thermal expansion of the oceans, mass loss from glaciers and ice caps and mass loss from the Greenland and Antarctic ice sheets. The present understanding of some important effects driving sea level rise is too limited. Consequently the IPCC AR4 (Solomon *et al.* 2007) does not assess the likelihood, nor provide a best estimate or upper bound, for sea-level rise. Model based projections of global mean sea-level rise between the late 20th century (1980-1999) and the end of this century (2090-99) fall within a range of 0.18 to 0.59 meters, based on the spread of GCM results and different SRES scenarios. These projections do not, however, include the uncertainties noted above (Bates *et al.*, 2008). Sea level rise during the 21st Century is expected to have large geographical variations due to, for instance, possible changes in ocean circulation patterns. Even though it is expected that significant impacts in river deltas and low-lying islands might occur, the range of the plausible impacts are, therefore, yet to be specified.

2.9 Flood risk management

Flood hazard not only changes due to the natural and human induced variability of the climatic factors involved, but also due to the dynamics of societal factors. The contribution of the different drivers is largely unknown. In the short term, rapid economic, social, demographic, technological and political changes seem more important and immediate than climate change. Consequently, the effects of climate change on flood hazard should be considered in the context of other global changes that affect the vulnerability of flood-prone settlements Very importantly, flood risk management should be a constantly revised and updated process (Merz *et al.,* 2010).

Finally, flood risk is dynamic and the large uncertainties associated with the estimates of future risk make its management under climate change a process of decision-making under deep uncertainty. It is necessary to take a robust approach. Some risk management options that increase the robustness of urban flood risk management investments and decisions to climate change are so called 'no-regrets' measures that reduce the risk independently of the climate change scenario being realized (for example, measures that reduce current vulnerabilities to weather and climate, or other non-climatic drivers); options that incorporate flexibility into long-lived decisions; or options that have significant co-benefits with other areas, like ecosystems-based flood control (Ranger *et al.*, 2010).

2.10 Urbanization, urban expansion and urban poverty

In the short-term, and for urban settlements in developing countries in particular, the factors affecting exposure and vulnerability to flooding are increasing rapidly, as urbanization broadly defined as the transition from rural to largely urban societies puts more people and more assets at risk. Rapidly growing informal settlement areas, often termed slums, in central city and peripheral suburban or peri-urban locations, are particularly vulnerable to flood impacts.

2.10.1 Urbanization trends

In 2008 for the first time in human history, half of the world's population lived in urban areas (UN-HABITAT, 2008). It is estimated that by 2030, 60 % of the world's population will live in urban areas and by 2050 this will have risen to 70 % (UN-HABITAT, 2008; WDR, 2010). In the developing world, 95 % of urban population growth takes place in low quality, overcrowded housing or in informal settlements, with urbanization rates typically higher in small and medium sized cities, although this varies from continent to continent (WDR, 2010; WGCCD, 2009; Parnell *et al.,* 2007).

In East Asia, for example, most of the increase in urban population over the next 15 years is expected to be in towns and cities with fewer than one million inhabitants (Jha and Brecht, 2011). In addition, a significant percentage of urban growth will be in peripheral areas adjoining existing major cities. However, it is important to understand that urban areas are not necessarily cities: Satterthwaite (2011) points out: "Although it is common to see the comment that more than half the world's population lives in cities, this is not correct: they live in urban centers, a high proportion of which are small market towns or service centers that would not be considered to be cities".

2.10.2 Defining the 'urban'

Although the world is becoming more urban in nature, there is no commonly accepted definition of what is meant by the term 'urban'. Often, places with paved streets, street lighting, piped water, drainage and sanitation infrastructure, hospitals, schools, and other public institutions, are considered as urban areas. Urban centers, however, vary in size from a few thousand inhabitants to megacities with more than 10 million inhabitants. In addition, urban areas vary with regard to their spatial form, economic base, local resource availability, and local institutional structure. Typically, the conception of urban is now seen within the perspective of a rural-urban continuum spanning, in any given society, villages, small towns, secondary (or medium-sized) cities, metropolitan areas, and megacities. In addition, significant urbanized agglomerations are emerging, covering entire urban regions or urban corridors which encompass a range of urban centers of different sizes (Abhas *et al*., 2011).

There are also significant regional differences, a town of a few thousand people in Africa is often considered to be an urban centre, whilst in Asia urban areas tend to be agglomerations with far larger populations. There is even greater variation in the level and speed with which individual countries and individual cities within regions are expanding (Cohen, 2004). For example, Latin America is more urbanized than Africa or Asia, and matches Europe or North America with current urbanization levels of around 70 %. However, urbanization trends in Latin America are lower than in Asia and Africa, which are expected to experience relatively faster rates of urbanization over the coming decades. By 2030, Sub-Saharan Africa, which is the fastest urbanizing world region, will have crossed the threshold to be a principally urban region. In the 20 years that follow, Africa's urban population will rise to 1.3 billion people.

2.10.3 Implications of urbanization

Urban centers concentrate people, enterprises, infrastructures and public institutions, while at the same time relying on food, freshwater and other resources from areas outside of their boundaries (Satterthwaite, 2011). Furthermore, urban areas are often located in hazard prone locations such as low elevation coastal zones, which are at risk from sea level rise, or in other areas at risk from flooding and extreme weather events (OECD, 2009; WDR, 2010).

Urbanization is accompanied by increasingly larger scale urban spatial expansion as cities and towns swell and grow outwards in order to accommodate population increases. Urban expansion alters the natural landscape, land uses and land cover, for example by changing water flows and increasing impermeable areas, thereby adding to the flood hazard problem (Satterthwaite, 2011). High levels of urbanization in river flood plains and other areas of catchments might also change the frequency of occurrence of flooding. In the mid-1970s, when urbanization was just starting to accelerate, a study by Hollis (1975) showed that the occurrence of small floods might increase up to 10 times with rapid urbanization, whilst more severe floods, with return periods 100 years or over, might double in size if 30 % of roads were paved. The changes in land use associated with urbanization affect soil conditions and the nature of run-off in an area. Increased development of impermeable surfaces leads to enhanced overland flow and reduced infiltration. It also affects the natural storage of water and causes modification of run–off streams (Wheater and Evans, 2009).

Urban centers also change the local environment by reducing rainfall and increasing night-time temperatures. Urban micro-climates, especially urban heat islands caused by lack of vegetation, can modify the hydrology of an area. Heat islands create higher temperatures over cities: for example, during the summer heat wave of 2003 in the UK, differences of up to 10°C between city and rural temperatures were measured in the London area (Abhas *et al*., 2011).

2.10.4 The urban poor

The concentration of people in urban areas increases their vulnerability to natural hazards and climate change impacts. Vulnerability to flooding is particularly increased where inappropriate, or inadequately maintained infrastructure, low-quality shelters, and lower resilience of the urban poor intertwine (World Bank, 2008). The fact that rapid urban expansion typically takes place without following structured or agreed land use development plans and regulations makes conditions even more problematic. In addition, as the urban poor are often excluded from the formal economy, they lack access to adequate basic services and because they cannot afford housing through the market they are located in densely populated informal slum areas which may be vulnerable to flooding.

The houses of poor people in these most vulnerable informal settlement areas are typically constructed with materials and techniques that cannot resist extreme weather or natural disasters (Parry *et al*., 2009). Rapid urbanization in low-income and middle-income nations tends to take place in such relatively high-risk areas, thereby placing an increasing proportion of the economies and populations of those countries at risk (Bicknell *et al*., 2009).

2.10.5 Urban challenges

The economies of urban centers vary from simple, small market towns to more complex, large cities and metropolitan regions serving local, regional, national and global markets. Cities are usually major economic centers hosting enterprises and industries that create most of the Gross World Product (GWP) (Kamal-Chaoui and Robert, 2009; Bicknell *et al.,* 2009). However, the benefits associated with urban centers are not unalloyed. This is mainly because of the existence of negative externalities, including environmental costs such as high carbon intensities, as well as the high vulnerability to climate change and natural disasters (floods) (Corfee-Morlot *et al.*, 2009). In addition, urbanization is to an extent responsible for higher concentration of greenhouse gases (GHGs) in urban areas and cities, causing greater capital costs and environmental damage (Corfee-Morlot *et al.* 2009). Rapid urbanization also means that urban centers will need to invest in infrastructure services given the increase in the demand for these (Jha and Brecht, 2011).

Urbanization and consequent increases in urban populations, accompanied by urban expansion, can result in declines in average densities, as built-up areas spread outwards. This can compound flood risk and weaken urban resilience to flooding. Even though some of this increase is the natural consequence of urban population growth, urban expansion can also be associated with inefficient land use and planning policies (World Bank, 2008). However, the need for accommodating expanding urban populations does require the consumption of more land. Similarly, higher densities are not always or necessarily a panacea for alleviating urban flood risk, as they often are coupled to increases in non-permeable surfaces, the occupation of vulnerable terrains, and levels of congestion which can compromise or even overwhelm the operation of infrastructure services such as solid waste. Figure 2.3 illustrates the impact of flooding on an informal settlement.

Figure 2.3: Informal Settlement in Mexico City, Copyright: UN-HABITAT.

Source: World Bank (2008).

2.10.6 Opportunities

The unprecedented rate of global urbanization in cities and other urban areas implies that exposure and vulnerability is increasing, which will cause loss of life and property unless proactive measures are mainstreamed into urban planning processes (Jha and Brecht, 2011). Cities themselves are often blamed for social inequalities, the inadequacy of city governments, authorities and institutions, and environmental degradation (UN-HABITAT, 1996; Dodman, 2009). Nevertheless it should be recognized that cities can contribute towards more sustainable development, if they are adequately planned, governed and managed. Rapid urbanization presents the opportunity to do things right first time, by integrating flood risk management concerns into new settlements as they develop. As Dodman (2009) argues, many of the processes implicit in urbanization may have a beneficial effect on global environmental change, as economies of scale and proximity can provide cheaper infrastructure and services. In order for cities to take advantage of their potentials, however, good governance and urban planning are prerequisites.

The Working Group on Climate Change and Development (WGCCD, 2009) suggests that urban authorities in developing countries need to deal with both out-dated infrastructure and urban expansion if they want to increase resilience in the face of climate change. Moreover urbanization shifts the balance of prevention from individual measures to collective action (World Bank and United Nations, 2010). As a consequence, to address the flood risk that cities and urban areas in low and middle income countries face, a coherent, locally specific and integrated response to this environmental hazard and risk is needed.

2.11 Direct impacts on primary receptors

This section outlines the direct impacts of flooding on primary receptors including people, the urban built environment, infrastructure, and family assets. Risks to life and health caused directly or indirectly by flood water are discussed, with flood related injuries described in the pre-onset, onset and post-onset phases.

2.11.1 People

Floods worldwide pose a range of threats to human life, health and well-being. In 2010, reported flood disasters killed over 8,000 people directly. While economic losses rise, direct deaths from flooding may be declining over time as measures to prevent flooding are employed, particularly in developed countries (Abhas *et al*., 2011).

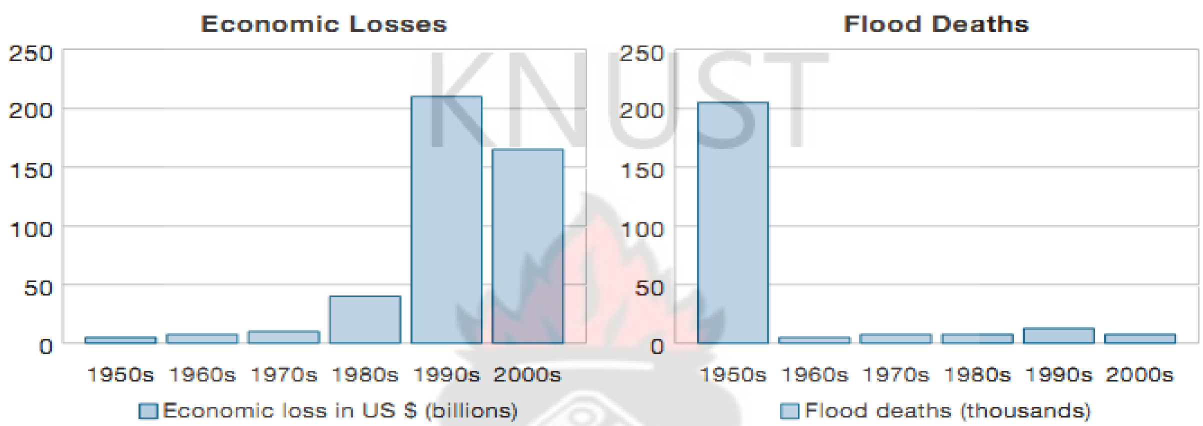

Figure 2.4: Reported economic losses and deaths.

Source: (Abhas *et al*., 2011).

Two-thirds of direct deaths from flood events are caused by drowning and one-third by physical trauma, heart attack, electrocution, carbon monoxide poisoning or fire (Jonkman and Kelman, 2005). Most deaths occur during a flash flooding event as against the slower riverine events (Du *et al.*, 2010). In developing countries such as Bangladesh, the majority of flood deaths have been found to be caused by diarrhoea and other water-borne diseases, or from drowning and snake bites. In Vietnam, electrocution is the biggest cause of death in the immediate aftermath of flooding, followed by respiratory diseases, pneumonia and exposure to cold. Diarrhoea-related deaths are primarily caused by a lack of pure drinking water, improper storage and handling of drinking water, poor hygiene practices and often total deterioration of sewage and sanitation facilities which lead to the contamination of drinking water in flood affected areas (Kunii *et al*., 2002; Ahern *et al.*, 2005). These deaths can occur during the period following the reported flood and, therefore, are not necessarily recorded in disaster databases.

The most commonly reported flood related injuries are sprains and strains, lacerations, contusions and abrasions. People may injure themselves as they attempt to escape, either by objects being carried by fast flowing water or by buildings or other structures collapsing (Du *et al.,* 2010). Flood related injuries can also happen in the pre-onset phase, as individuals attempt to remove themselves, their family or valued possessions from the approaching waters (Ahern *et al.,* 2005). Post-onset injuries are likely to occur when residents return to their homes and businesses to start the recovery and reconstruction process (WHO, 2002, Few *et al.,* 2004; Ahern and Kovats 2006). As these injuries are not monitored adequately, it is difficult to quantify the true burden of ill health due to flood events (Few *et al.,* 2004).

The mental trauma of flooding, caused by witnessing deaths, injuries and destruction of the home, can result in severe psychological effects in some individuals. Grief and material losses, as well as physical health problems, can lead to depression or anxiety. Three types of mental health issue have been noted: common mental health disorders, post-traumatic stress disorders (PTSD) and suicide (Ahern and Kovats 2006).

In the slums of Nairobi, coping responses to flooding include bailing out of houses to prevent damage to belongings; placing children on tables and later removing them to nearby unaffected dwellings; digging trenches around houses before and during floods; constructing temporary dykes or trenches to divert water away from the house; securing structures with waterproof recycled materials; relocating to the highest parts of the dwelling; or using sandbags to prevent the ingress of water. The most vulnerable members of the community can also be those worse affected: the poor, the elderly and the youngest members of the community will often require special help and assistance. Research has found that children and the elderly are more likely to die, particularly from drowning, than are adults (Bartlett, 2008).

2.11.2 Buildings and contents

Buildings and their contents can be directly and indirectly affected by flooding in a range of ways. In cities and towns, flooding in underground spaces, including subways, basement floors and utility facilities under the ground, is also typical. Direct impacts are the physical damage caused to buildings and their contents, whereas indirect effects include the loss of industrial or business processes. The impact of flooding on housing and households can be devastating. Fast-flowing flood waters are capable of washing away entire buildings and communities. Depending on their form of construction and characteristics of the flooding, many buildings may survive the flood but will be damaged quite extensively by the corrosive effect of salinity and damping, and be in need of substantial repairs and refurbishment (Abhas *et al*., 2011).

Flood events can have a variety of impacts on businesses, ranging from direct physical impacts to indirect effects (to supply chains, for example). Damage to premises, equipment and fittings; loss of stock; reduced customer visits and sales as well as disruption to business activities are among the common effects experienced by UK businesses (Ingirige and Wedawatta 2011). The characteristics of flood, including flood depth, duration and contaminants, will influence the extent of damage caused to a building. The speed of flooding can also determine the extent of the damage. Flash flooding, for example, can completely destroy properties or cause irreparable structural damage. In a slow rise flood, on the other hand, static floodwater can damage buildings in the following ways (Abhas *et al*., 2011):

- Water soaks into the fabric of the building elements causing them to deteriorate. Water can soak upwards through building materials through capillary action and in hot conditions can also cause damage through excess humidity in enclosed spaces.
- Water pressure of standing water causes building elements to fail or structures to collapse
- Water can travel underneath buildings and their foundations, thus lifting or partially lifting them causing them to float away or to crack. Water can also lift building contents and they may be damaged or cause damage within a building.
- Chemicals or contaminants in the water can react with building elements or contaminate them.
- Water can cause failure of electrical systems resulting in secondary damage.

In a flash flood or coastal flood, water which flows around buildings may damage them in the following additional ways:

- Water that is moving exerts a greater lateral pressure on building elements than static water. Changing pressure can increase the stress on building elements.
- Moving water will tend to cause scour or erosion, potentially undermining buildings and causing collapse.
- Debris is carried at higher velocity and can cause severe damage due to collision.

➢ Fires can be caused by the collision of fuel containers within buildings.

Generally speaking, the faster the velocity of the water the greater the damage, but the depth of floodwater is clearly another important factor in determining the scale of damage. It has been found that flood depths greater than 600 mm are more likely to result in structural damage to buildings (USACE, 1988). This relationship is normally demonstrated by a depth damage curve such as the example in Figure 2.4.

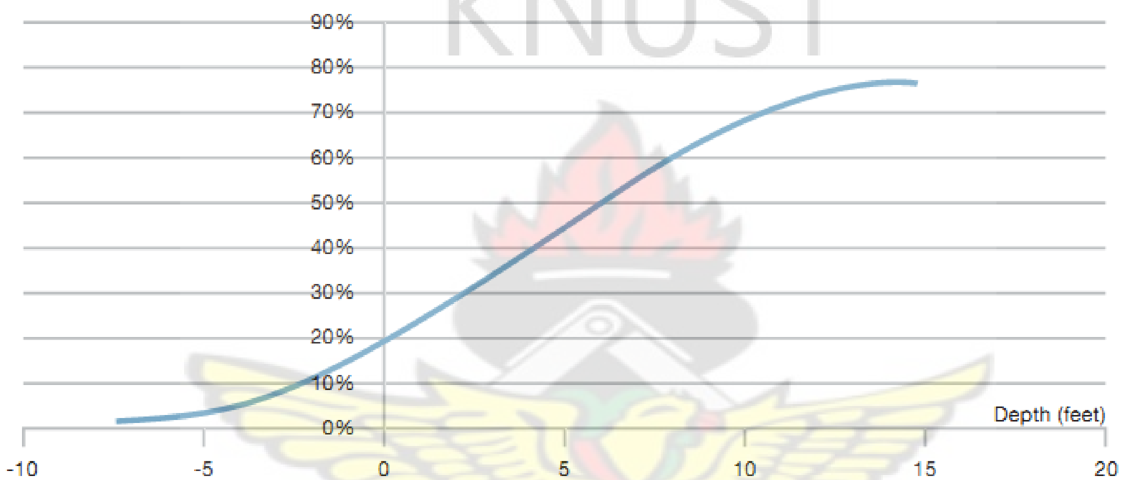

Figure 2.5: Example of a depth damage curve for one story residence with basement.

Source: USACE (1988)

Anticipated flood depth will tend to be a deciding point for the method of flood protection. Hydrostatic head caused by the weight of water being held above the pressure point will place stresses on walls and any other vertical elements and will also drive floodwater through walls. If the flood depth is predicted to be greater than 900 mm, flood proofing is unlikely to be feasible unless specially constructed methods are used. The consensus of opinion is that the cut-off depth for wet-proof construction should be 600 mm (USACE, 1988). Flow velocity is presumed to be an important factor in the causation of flood damage, although hazard models rarely quantify its impact and its influence is therefore rarely taken into account. Some recent studies which have examined both water depth and flow velocity have concluded that the latter has a significant influence on structural damage, for example on roads, but only a minor influence on monetary losses and business interruption (Kreibich *et al*., 2009). However, it has also been recommended that if the other impact factor, water depth, is less than two meters then flow velocity alone are not a suitable consideration for estimating monetary loss in flood damage modeling and assessment. The materials used for buildings, their drying characteristics and the condition of the building can also influence the extent of damage caused. Masonry construction, for example, is able to withstand the impact of flood waters up to a point but, being a porous material; it will absorb a large volume of water and take considerable time to dry out. Timber construction can be relatively waterproof but is often less robust. Adobe and soil based construction are more vulnerable to scour and erosion.

Building quality also has an impact on a structure's ability to withstand flooding. Flash floods within an urban environment present particularly high risks with respect to damage to buildings. As previously noted, many of the larger cities in the world which are at risk of flooding are characterized by high levels of density and congestion. For example, the city of Mumbai is extremely overcrowded which constantly threatens the city management system, leading to overburdens in sewage and wastewater, the dumping of household and commercial garbage in open landfills and direct discharges to water bodies. Safety standards are also overlooked to fulfil the demand for space and development of property. As a result of the already existing difficulties in management, a flood in such cities causes havoc. Flood waters carry with them the debris of waste but also the treasured belongings of a dense and overcrowded city. The materials from buildings damaged by floodwater are also swept along. In an overcrowded space this may lead to an avalanche of further damage. Existing buildings located in flood zones, therefore, represent a particular risk; in the light of climate change predictions, the adaptation of such buildings to future flood risk poses a considerable challenge for many countries. Regulations should also be designed to restrict or prevent new development, although it is possible that new buildings can be designed to withstand the effects of flooding by appropriate use of materials and flood resilient measures (Satterthwaite *et al.,* 2007).

Damage caused to public buildings such as hospitals, clinics, educational buildings, and significant cultural sites such as churches can lead to further indirect impacts: for example, the disruption to education, which over a long term period can lead to children suffering academically; similarly, there is likely to be a reduction in the capacity for providing both immediate and longer term health care and support. Release of contaminants poses serious public health risks for survivors of floods. Flood waters can mix with raw sewage and thus dramatically increase the incidence of water borne diseases. Although the release of toxic chemicals is diluted by flood water (causing toxicity levels to decline) the uncontrolled release of various chemicals some of which may interact with each other poses a considerable risk to public health infrastructure (Abhas *et al*., 2011).

The UK based Centre for the Protection of National Infrastructure (CPNI) defines national infrastructure as "those facilities, systems, sites and networks necessary for the functioning of the country and the delivery of the essential services upon which daily life depends" (CPNI, 2010). These sectors include finance, food, government, emergency services and health. Particularly at risk from flooding are: communications; transport (roads and bridges, rail, waterborne navigation, both inland and sea, air), telecommunications; energy (power generation and distribution, petrol, gas, diesel and firewood storage and distribution); water supplies, and waste water collection networks and treatment facilities.

Critical infrastructure is also defined by the CPNI as those elements of national infrastructure, of which "The loss or compromise would have a major impact on the availability or integrity of essential services leading to severe economic or social consequences or to loss of life." Flood damage to infrastructure represents a considerable concern as it affects the ability of communities to respond during a flood and to recover after an event. Damage to critical infrastructure can represent a danger to life: damage to the road network, for instance, can prevent temporary flood defences from being erected, as well as leading to major disruptions in the lives of people and businesses. Flooding of airports and railways can similarly create chaos for major national and international transportation hubs. Impacts on power generation can lead to temporary and permanent power losses leading to loss of electricity, heating and lighting in some locations. Table 2.3 show the damage to the electricity sector in Yemen by flooding in 2008.

Table 2.3 Damages to electricity services in flood-affected areas of Yemen (million YR).

Damage items	Hadramout-wadi		Hadramout-sahel		Mahara		Total Damage
	Urban	Rural	Urban	Rural	Urban	Rural	
(a) Power Plant							
Diesel Power Generator	0	50	200	90	220	40	600
Others	10		10		4		24
(b) Transmission and distribution systems							
Transmission lines	880	300	220	40	140	20	1600
Distribution lines	300	150	200	20	120	20	810
Transformers	120	30	70	100	40	40	400
(c) Transmission and distribution grids	150	50	100	20	20	10	350
Others	40	10	150	20	10	2	232
Total	150	590	950	290	554	130	4016

Source: (GOY, 2009).

Water supplies can become disrupted and contaminated leading to health concerns. Waste water collection and treatment facilities can become overwhelmed leading to pollution and contamination of drinking water supplies. Damage to urban water systems can be much more severe than in the rural areas as shown in Table 2.4 from the earlier 2008 floods in Yemen. Urban damages again exceed rural ones.

Table 2.4: Damages and Losses in the water supply and sanitation sector

Sector	Damage	Loss	Total	Total
	Riyal Millions	Riyal Millions	Riyal Millions	US$m
Rural	1,059	66	1125	5.63
Urban water	3559	612	4171	20.86
Urban wastewater	1414	43	1457	7.29
Total	6032	721	6753	33.78

Source; GOY (2009)

Drainage systems can also become overwhelmed as a consequence of intense rainfall; they may also have inadequate capacity to cope with the rate of rain water runoff, leading to surface water flooding. The interconnected nature of modern infrastructure systems often means that failure of one system caused by floodwater can have a cascading impact on other systems which may or may not have been damaged by the flood. Loss of power, for example, may have impacts on many other systems such as water supply and communications. In particular the high dependence of most modern systems on information and communications technologies makes them extremely vulnerable to loss of connectivity (Abhas *et al*., 2011).

2.11.3 Animals and crops

Within urban and peri-urban environments the impact of floods are likely to be on domestic pets and individual animals kept for personal food supply, such as poultry. Such animals can be regarded as part of the family and their rescue, or concern for their whereabouts, can delay or prevent evacuation. Floods also cause deaths and injuries to livestock and fish stocks and damages crops, although for urban populations this may represent an indirect impact, as they are less likely to be involved in agriculture than the rural population. Loss of agricultural production will, however, affect the food supply chain on which the populations of urban areas are highly dependent (Weir, 2009). Large scale disasters like flooding can reduce food availability in cities, but such urban food insecurity is, for the most part, considered to be a food access problem, rather than a food availability problem. Food shortages lead to rising prices, so that the poor cannot afford to buy it as incomes decrease due to lack of work; this results in economic and financial hardship (IFRC, 2010).

2.11.4 Cascading impacts

Flood events can be a catalyst for other disasters both natural and human-made, or can be part of a chain of cascading events mentioned above. A dramatic recent example of this phenomenon is the damage to the Fukushima nuclear power generator in Japan after the 2011 tsunami: a massive-scale disaster arose at the end of a chain initiated by an earthquake. A common secondary effect of flooding is large mudflows and landslides, as was observed in Korea in 2011. Catastrophic failure of interconnected infrastructure can also cause a man-made disaster if, for example, dam controls fail due to loss of power or flood damage. Chemical or sewage related pollution of water supply can result from damage to factories or treatment plants. In considering the impact of floods, and the benefits of prevention, the potential for cascading impacts should not be overlooked (Abhas *et al*., 2011).

2.11.5 Post-disaster damage assessment

In the aftermath of major disasters such as floods, governments with the help of organizations such as the World Bank and the United Nations, undertake damage, loss and needs assessment, widely known as Post Disaster Needs Assessment (PDNA), in order to better plan recovery actions. Many use the Damage and Loss Assessment (DaLa) methodology, which was developed by the UN Economic Commission for Latin America and the Caribbean (UN-ECLAC) in the early 1970s. In the 2010 Pakistan floods, which have been described as the worst in the last 80 years, the assessed damage and loss estimated by the PDNA was PKR 855 billion or US $10.1 billion, which is equivalent to 5.8% of GDP (GFDRR, 2010).

Flood loss assessment can be carried out at various points within the event cycle: during the flood itself (thus informing the emergency response and relief coordination); in the immediate aftermath of a flood event (around one to three weeks after the flood peak); or three to six months after the event (to provide a more in-depth assessment of the full economic impact). Often the best time to conduct an in-depth assessment of flood losses is after six months, as most losses, including indirect and intangible losses, can then be assessed with sufficient reliability. There needs to be a standard approach to loss assessments, primarily to ensure that works undertaken to provide mitigation or warning systems produce a sound return on the investment; to have a common measuring tool for assessing alternative mitigation plans; and to assist with post-disaster recovery planning and management. Loss assessments should be transparent, so assessment procedures can be easily followed; consistent and standardized, to allow meaningful comparisons; replicable, to enable the assessments to be checked; and based on economic principles, so that assessed losses accurately represent the real losses to the economy.

2.12 Indirect and other effects of flooding

In addition to the direct impacts of floods outlined above, there are indirect impacts caused by the complex interactions within the natural environment and the human use of resources in cities and towns. Such indirect impacts can be hard to immediately identify and harder still to quantify and value. Indeed, some will not become fully apparent until well after the flooding subsides. These indirect impacts can be subdivided into four major groups and are outlined below.

2.12.1 Natural environment

High rainfall can cause erosion and landslides, often on a large scale in areas of steep topography. These in turn can damage infrastructure, especially roads, which are often the only way of accessing communities affected by flooding. The erosion causes high concentrations of sediment and debris which are then deposited when the flooding subsides. Removal of the sediment and debris is costly and time consuming. In some extreme cases, buildings and whole parts of towns may well have to be abandoned. Relocation may be the only solution, which will involve revised land use zoning.

The smothering of agricultural land by sediment can also be a problem for high value vegetable production in peri-urban zones, as a lot of such sediment is low in organic matter. Yields may never return to their previous level with resulting impacts on human livelihoods and nutrition Heavy rainfall can also cause damage to vegetation (whether natural or planted), and results in the reduction in the ability of vegetation to dissipate the energy of heavy rain. Primary forest cover with a high closed canopy is very efficient at dissipating rainfall energy whereas secondary regrowth or trees planted for economic reasons are less likely to have closed canopies and are less efficient in diffusing rainfall energy. This can result in less infiltration to the soil and higher levels of rainfall runoff which also further increases the risk of soil erosion and gullying (Abhas *et al*., 2011).

Coastal flooding in tropical areas as a result of tsunamis triggered by seismic action, or cyclones, causes damage or destruction to coral reefs which then reduces their ability to dissipate wave energy. When coupled with the fact that sea level rise in many such locations is now faster than the rate of coral growth, the risk of more severe flood events is increased. The damage to coral often increases the risk of coastal erosion. Flooding of coastal areas with saline sea water as a result of cyclones and that more girls and young women were killed than boys in south east Asia, for example. The boys were often able to climb trees, whereas the girls did not, partly because of social taboos. Some years later, there was an increase in the birth rate, which was seen to be a response to 'replace' children who had perished. This created a very unbalanced age structure and, in particular, put a greater burden on women, which is often exacerbated by rising levels of post-flood gender-based violence and the negative impact of floods on women's assets, such as dowries, which often do not feature in post-disaster impact assessments. In the case of Bangladesh, as elsewhere, these changes in demography varied greatly across the affected area, reflecting highly localized flood risk situations (Abhas *et al*., 2011).

2.12.2 Health impacts

The impacts on human health as a result of flooding can be very serious indeed, and there is evidence that in some flood events more fatalities have occurred due to waterborne and water related disease or injuries, rather than by drowning. During the 2007 monsoon floods in Bangladesh, snake bites were estimated to be the second most significant cause of death after drowning and contributed to more deaths than even diarrhoeal and respiratory diseases (Alirol *et al.*, 2010). Post-disaster human health is also closely associated with changes in the balance of the natural environment. For example, flooding caused by over flow of river banks, or by storm surges, alters the balance of the natural environment and ecology, allowing vectors of disease and bacteria to flourish. Outbreaks of cholera and a higher incidence of malaria can result from such alterations. Noji (2005) maintains that an increase in disease transmission and the risk of epidemics in the post-flood period depends on population density and displacement, and the extent to which the natural environment has been altered or disrupted. In 2009, weeks after back-to-back cyclones left nearly 1,000 people dead, the Philippines was grappling with an outbreak of Leptospirosis (a fatal flood-borne disease); this infected survivors from areas where dirty water had yet to subside. In a report to emergency relief agencies, Health Secretary Francisco Duque said that as of 26 October that year, there were 2,158 confirmed cases of this particular infection, with 167 deaths reported by the National Epidemiology Center (IRIN, 2009).

The provision of adequate non-contaminated water supplies during and after a flood event is critical. There are often problems due to a lack of fuel to boil water for drinking. The main risks are diarrhoeal diseases including cholera, dysentery and typhoid along with malaria, dengue (although mosquito carriers require relatively clean water habitats), Leischmeniasis (also known as kalaazar) and Leptospirosis, spread by contact with water contaminated by infected animal urine. Another significant issue is the psychological impact on survivors, including delayed trauma. Many survivors, including children, will be severely traumatized. Great care is needed when dealing with this. A number of studies have shown a range of symptoms resulting from exposure to natural disasters such as flooding. Among these consequences, individuals may experience symptoms of post-traumatic stress disorder (PTSD), depression, and anxiety (Mason *et al.*, 2010).

Miller (2005) suggests that alcohol consumption, substance abuse, and antisocial behaviour increased among men in the aftermath of the 2004 Indian Ocean Tsunami in India and Sri Lanka. Given the range and severity of health implications following disasters, the health profession has developed new approaches and new mechanisms referred to as 'disaster medicine' or 'disaster health management' (Andjelkovic, 2001).

2.12.3 Human development impacts

The impact on long-term health and development of populations may be difficult to quantify but some research shows that severe floods can affect nutrition to the extent that children affected never catch up and are permanently disadvantaged (Bartlett 2008). Births in the immediate aftermath of disasters are likely to result in higher mortality and birth defects. After a major event, displacement or break up of families due to the death of one or both parents can have disastrous long-term effects on the families themselves and the wider community. Education can also suffer due to malnutrition effects, displacement or schools being closed. Although in wealthy areas a flood event is usually a temporary interruption which can be coped with, in poorer areas floods typically worsen poverty.

2.12.4 Economic and financial impacts

The direct impacts of flooding as indicated earlier will have knock on economic implications aside from the cost of replacing damaged or destroyed items. For example, a recent report stated that flooding is one of the major factors that prevents Africa's growing population of city dwellers from escaping poverty, thereby standing in the way of the UN 2020 goal of achieving 'significant improvement' in the lives of urban slum dwellers (Action Aid, 2006).

2.12.5 Impact on long-term economic growth

In assessing the economic impacts of flooding, care must be taken to adopt both local and national perspectives. Disasters have a large impact on those directly affected but a much smaller effect on the national economy. Some local impacts, such as the effect on the tourist trade, may be balanced by growth in trade elsewhere in the country. Typically, small to medium scale disasters may have no impact on the national balance sheet. At a national level, studies have found a variety of relationships between disasters and economic growth. There is some evidence to suggest that frequent natural disasters can have a positive impact on national economies (Kim 2010). The process has been labelled 'creative destruction', based on the assumption that reconstruction activities result in increased employment and renewal of facilities. An article by Skidmore and Toya (2002) into natural disasters in 89 countries concluded that the frequency of climatic disasters is positively correlated with human capital accumulation, growth in total factor productivity and per capita gross domestic product (GDP). Noy (2009) found that a nation's ability to mobilize resources for reconstruction influences the relationship between disasters and economics. Developing countries are therefore unlikely to benefit in the long term from disasters. Other studies have contradicted these findings, but Kim (2010) found a difference between climate related and geological disasters, in that the former had a positive effect on the long term economy. Loayza *et al.*, (2009) found that median level flood events had a significantly positive impact on economic growth, while larger scale floods had little effect.

2.12.6 Impact on development goals

As a result of the lack of insurance cover, most low income countries divert funds from other development goals to flood recovery operations. Governments may face liquidity problems in the face of massive natural disasters and have to rely on international aid, development funds or insurance to reinforce national tax revenue. Gurenko and Lester (2004) estimate that, on average, the direct cumulative costs of natural disasters in India account for up to 12 % of central government revenues. This can have significant impact on the national economy, resulting in important infrastructure spending being delayed or cancelled. In addition, there will be a need to arrange a system of financing for replacement infrastructure provision, both private and public. It is likely that funding for this will be at the expense of existing on-going development work. Economic priorities have to be set against a background of widespread need and the economic implications will, therefore, spread through a much wider part of the society than those directly impacted by flooding. The challenge is for governments and the private sector to work together to set the priorities for reconstruction. Another post-flood impact, which directly or indirectly affects already suffering people, is the burden of debt for restoration of the economy. This puts extra pressure on people and reduces their financial ability to cope with the changed situation, making them in turn more vulnerable (Abhas *et al*., 2011).

2.12.7 Impact on livelihoods

At the household level, livelihoods are likely to be severely undermined. The severity of this is a function of the impact of the flood on employment availability, specifically whether any members of the household have been killed or injured and the degree to which they contributed to the social and economic functioning of the household. Single-headed households, notably by women, are particularly vulnerable to the loss of livelihoods. At the wider community level, skills which will suddenly be in demand (for instance, those needed for building replacement infrastructure) could well be beyond those available within the surviving population (Abhas *et al*., 2011).

2.12.8 Business interruption

Businesses often fail in the aftermath of disasters due to direct damage, or to indirect impacts such as business interruption. Business may be closed down due to lack of access or failure of basic services, such as water supply, waste water collection and treatment, electricity, roads and telecommunications. This, in turn, is likely to have significant economic implications for areas much wider than the immediate flooded area. The replacement of such services can be complex (for example, starting up a damaged power station when you need power in order to do so), will take time and money, and will cause serious economic losses. The 2011 tsunami in Japan put a serious strain on the national economy and also had global impacts: as an example, the supply of Japanese made vehicle parts to automobile assembly plants around the world was severely disrupted. Businesses which can continue to operate may take months to recover and to return to normal trading. The recovery process may be hampered by the loss of documentation in the flooding, leading to delays in tracing orders, completing insurance claims and issuing invoices (Abhas *et al.,* 2011). Other indirect effects may include increased expenses; lack of demand; the short term loss of market share; loss of key personnel; lack of availability of staff due to injury, travel difficulties or involvement in recovery operations; loss of production efficiency; loss of supplies; withdrawal of licenses; and loss of quality accreditation or approved standards. For many businesses these impacts can be catastrophic: one report suggests that 43 % of companies experiencing a disaster never reopen and 29 % of the remainder close within two years (Wenk 2004).

2.12.9 Political and institutional issues

A severe flooding occurrence is likely to place a serious strain on the institutional structures and capabilities that, in less developed countries, may already be weak. There will be a pressing need to clearly identify the roles and remits of both government and non-government organizations. The lack of or poor performance by government organizations can seriously undermine faith in government institutions; this happened after Hurricane Katrina in New Orleans in 2005 (Abhas *et al.,* 2011). In some cases, political bias in allocation of funds is detectable, which may result in donors reducing the level of future disaster aid. Another major factor can be maintaining the security of assets that displaced people have been forced to leave behind. The less well-off sections of society will be those least able to help themselves, but conversely they have fewer assets to lose. This may also have ethnic or gender dimensions, which can divide communities and lead to political instability (Abhas *et al*., 2011).

2.13 Vulnerability and risk mapping

Given the seriousness and implications of the flood impacts detailed above, techniques are required for the estimation and assessment of risk. According to the United Nations Department of Humanitarian Affairs (UNDHA) the concept of risk assessment involves the survey of a real or potential disaster in order to estimate the actual or expected damage for making recommendations for prevention, preparedness and response (UNDHA, 1992). This essentially consists of evaluation of risk in terms of expected loss of lives, people injured, property damaged and businesses disrupted. Based on the existing definitions, risk is the product of hazard and vulnerability and can be mathematically expressed for a given event in a particular area and reference time period.

Assessments are mainly based on the depth of flood water and they are further used for risk analysis and evaluating the cost of damage. The main philosophy behind evaluation of risk is to provide a sound basis for the planning and allocation of funds and other resources. The framework of risk assessment illustrated by WMO (1999) indicates that evaluation of hazards and vulnerability assessment should proceed as parallel activities, in a consistent manner, so that results may be combined and comparable. For example, two cities may be equally vulnerable, but could have very different exposure to the hazard, depending on their elevation. The main problem in doing so is the availability of organized data, especially in developing countries and the cost and effort needed to acquire data. The basic steps involved in a risk assessment process are:

- Hazard estimation with reference to location, level of severity and the frequency of event occurrence
- Estimation of exposure of elements at risk
- Estimation of vulnerability
- Estimation of risk by integrating hazard, exposure and vulnerability.

As indicated earlier, in most cases risk assessments are performed based on direct damages. Indirect damages, also known as 'second order' effects, are often ignored leading to underestimation of the total cost of flood damage. It can be difficult to get appropriate data for indirect damage assessment, the main problems being measuring accurately the ripple effects on the economy and impacts on infrastructure and communication disruption. In addition, historical data do not disaggregate the total loss into direct and indirect losses; discrepancies in data can arise when gathered on a survey basis and there may be non-cooperation in disclosure of financial losses by affected people and companies. The assessment of second order risks is, however, achievable if appropriate data is available. In order to perform a comprehensive risk assessment, thus reducing the difference between actual and estimated damage assessment, integration of primary and secondary sources of damage assessment and risk evaluation is necessary. In areas of multiple hazards the risk is sometimes cascading in nature. It might not be generated by natural sources, but accompanies an event or follows immediately afterwards. Flooding leaves a large amount of debris in its way, disrupting normal drainage and transportation systems. It may also cause fires and electrical short circuits, leading to more damage and destruction. Salt water contamination in coastal regions can also affect water supply lines, as well as contributing to the rate of deterioration of property and other assets (Abhas *et al*., 2011).

In addition to raw sewage spills and debris, flood water may also contain toxic materials, leading to pollution of the local environment. There are occasions when a landslide or earthquake causes flooding: this is particularly true in multi hazard areas where one disaster leads to another, resulting in a much greater incidence of damage and destruction.

As discussed above, the impact of floods on the urban environment is caused by the action of hazard on exposed and vulnerable receptors. Changes in impacts from flooding can, therefore, result from changes in the hazard; changes in the exposure of populations and their assets; or changes in the vulnerability of the exposed populations and assets. To understand the potential impact on a community and the appropriate response, flood risk maps are an invaluable tool: they provide the foundation upon which a well-planned risk management strategy can be built. They assist decision makers to make cost benefit assessments, to prioritize spending, to direct emergency assistance and to design and implement mitigation activities of all kinds. Risk maps are also necessary for financial planning and insurance purposes (Abhas *et al*., 2011).

Flood risk maps are built upon the flood hazard maps which were discussed in Chapter 1 and on the understanding of the impact of different flood events on the exposed population and assets. In this chapter the impacts which lead to damage and loss have already been outlined. In order to quantify flood risk completely, it is necessary to estimate the expected losses from potential future flood events, based on the best understanding of impacts. Most risk assessments will start with an assessment of losses due to physical direct damage using a stage damage function and asset database. Extension of risk analysis to incorporate indirect and intangible losses is rarer. Such damage calculations include other sources of uncertainty such as the valuation of non-market goods and affected services (like ecosystems and biodiversity) and the choice of discount rate or any other means of dealing with time preference (Hall *et al*., 2008; Merz *et al*., 2010).

2.13.1 Assessing vulnerability

Vulnerability is the degree to which a system (in this case, people or assets) is susceptible to or unable to cope with the adverse effects of natural disasters. It is a function of the character, magnitude and rate of hazard to which a system is exposed, its sensitivity (the degree to which a system is affected, adversely or beneficially) and its adaptive capacity (the ability of a system to adjust to changes, moderate potential damages, take advantage of opportunities or cope with the consequences). The different types of vulnerability and the factors affecting their rate of exposure are shown in Table 2.5 below.

Table 2.5: Different types of vulnerability and the factors affecting their rate of exposure

Types of Vulnerability	Exposure factors
Individual or household vulnerability	Education, age, gender, race, income, past disaster experience
Social vulnerability	Poverty, race, isolation, lack of social security services
Institutional Vulnerability	Ineffective policies, unorganized and non-committed public and private institutions

Economic Vulnerability	Financial insecurity, GDP, sources of national income and funds for disaster prevention and mitigation
Physical Vulnerability	Location of settlement, material of building, maintenance, forecasting and warning system
Environmental Vulnerability	Poor environmental practices, unprecedented population growth and migration
System vulnerability	Utility service for the community, health services, resilient system
Place Vulnerability	Mitigation and social fabric

Source: Abhas *et al.,* (2011).

To measure vulnerability at different scales, hazard researchers have used numerous strongly correlated variables, such as the physical, social, economic, and political condition of the area of occurrence. Some of the major factors which increase vulnerability to urban flooding, especially in developing countries, are: poverty, poor housing and living conditions, lack of preparedness and management of flood defences, increasing population, development of squatter settlements in hazard prone regions, poor maintenance of drainage structures, lack of awareness among the general population and limitations in early warning systems.

Vulnerability assessment is carried out in order to identify the most vulnerable sections of the society and thus prioritize the assistance by channelling resources. Undertaking a vulnerability assessment therefore requires consideration of: the location of the area, resources under threat (both population and physical elements), level of technology available, lead time for warning and the perceptions of residents regarding hazard awareness (ADPC and UNDP, 2005). Mapping vulnerability can help the policy makers and managers to identify the areas of highest susceptibility and impact, in order to reduce vulnerability and enhance capacity building, by concentrating efforts in those locations.

2.15 Summary of Literature Review

From the reviewed literature, it is quite clear from the numerous studies, articles and peer reviewed journals that floods are really issues of public concern. The literature identified among many other things, the causes, impacts, vulnerability, mitigation and preventive responses to floods. This study will be of relevance to national and international discourse on flood management as findings on the causes of flood in the study areas will help reinforce what is already known or yet to be known. The identified impact of flood disasters on the livelihood of the people is necessary to formulate pragmatic policies to help the most vulnerable and socially disadvantaged individuals to adapt to the situation. This is because they are at the centre of discourses on sustainable development. Doing this will not only require adaptation but also long term mitigation and preventive responses to flood. This means a seasonal and ad hoc response to flood management may not be an adequate preventive measure. Local participation in flood management is an acclaimed strategy in current development discourse. NADMO"s performance in this regard will help determine the extent to which the country is well prepared for flood disasters. An analytical comparison between flood disasters and rural urban migration will assist development actors to take a second look at the environmental implications of flood disasters.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location and the People

Tamale Metropolitan Assembly (TaMA) is one of the six Metropolitan Assemblies in the country and the only Metropolis in the three northern regions of Ghana. TaMA has 3 sub metros comprising Tamale Central, North and South, and Sagnarigu District within the metro with a total population of 418,608 (Ghana Statistical Service, 2010). The TaMA is one of the 26 districts located in the centre of the Northern Region and shares boundaries with six other districts namely the Savelugu/Nanton to the north, Yendi Municipal Assembly to the east, Tolon/Kumbungu to the west, Central Gonja to the south west and East Gonja to the south. The Metropolis has a total estimated land size of 750 km sq which is about 13% of the total land area of the Northern Region. Geographically, the Metropolis lies between latitude 9º 16^1 and 9º 34^1 North and longitudes 0º 36^1 and 0º 57^1 West. There are a total of 197 communities in the Metropolis of which 33 are urban communities. The Metropolis is located about 180 metres above sea level. The topography is generally rolling with some shallow valleys and some isolated hills, which do not inhibit physical development (Ghana Statistical Service, 2010).

The Metropolis is a Cosmopolitan area with Dagombas as the majority ethnic group. Other minority ethnic groupings are Gonjas, Mampurusis, Akan, Dagarbas, and tribes from the Upper East region including Gruni, Kasena and Kusasi. The area has deep rooted cultural practices such as festivals, naming and marriage ceremonies. Important traditional festivals celebrated in the area include the Bugum (fire) and Damba festivals. Important religious festivals celebrated by Muslims who are the majority are Eid-ul-Fitr and Eid-ulAdha. History traces the origin of the Dagomba Kingdom to Tohazie (the Red Hunter) through Naa Gbewaa to the present traditional system of administration. The map below shows boundary of TaMA with Sagnerigu District.

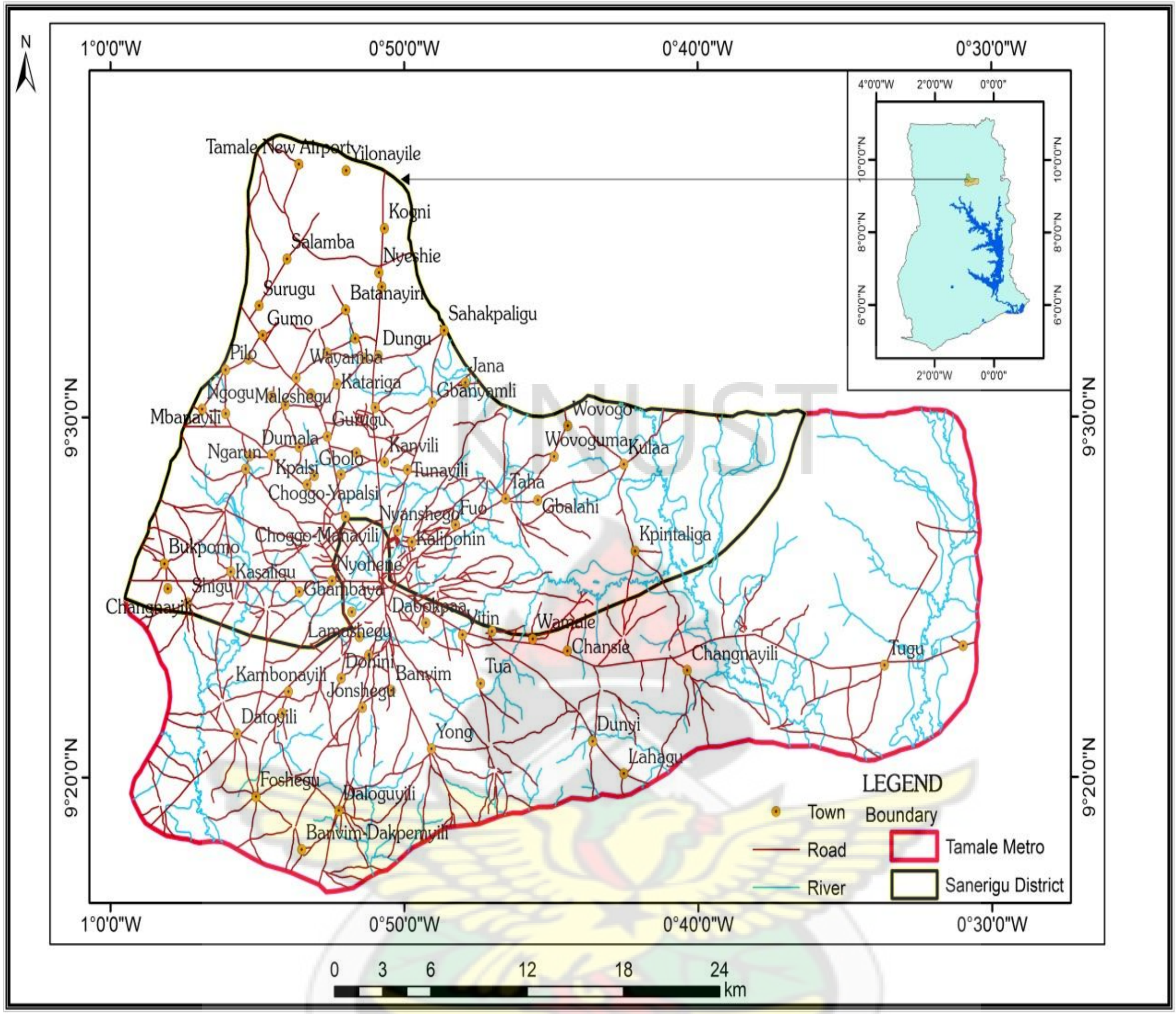

Figure 3.1: Map showing boundary of TaMA with Sagnerigu District.
Source: Town and Country Planning, Tamale (2014).

The five communities along the zoned area chosen for the purpose of this study are located in Sagnerigu District within the Metropolis. These can be located in Figure 3.2, which shows the selected communities all located along the river in the district within the metropolis.

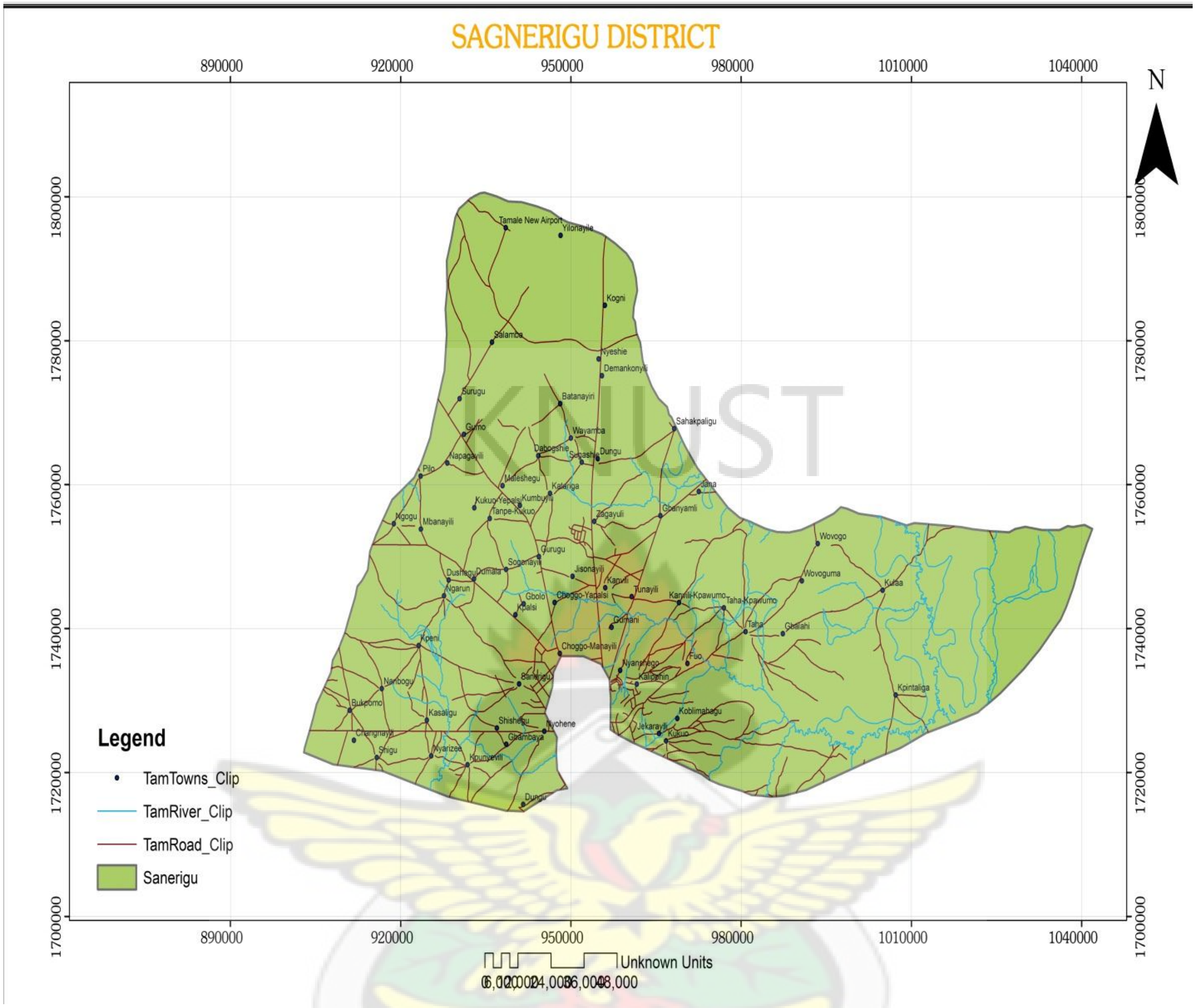

Figure 3.2: Map showing selected communities in Sagnerigu District.

Source: Town and Country Planning, Tamale (2014).

3.1.2 Climate

The climate of the study area is tropical and semi-arid. Annual precipitation averages just over 1050 mm, while potential evapotranspiration is about 1770 mm (Pelig-Ba, 2000). There are only about 4–6 months of rainfall during the year, from May to October, the rest, from November to May, is relatively dry and hot. After the raining period, the northeast trade winds, locally termed the harmattan, prevails up to February/March. During the period, the weather becomes very dry and hot during the day, with temperature up to 40°C but cools to less than 20°C in the night (Ghana districts.com, 2006). The harsh climatic conditions during the warm season usually have considerable effect on temperatures and make the area mostly endemic to cerebrospinal meningitis popularly now as csm (Ghana Statistical Service, 2005). Positively, this climatic feature is also a potential for the preservation industry that could use the sunshine as a natural preservative.

3.1.3 Soils

The main soil types in the Metropolis are derived from sandstone, gravel, mudstone and shale that have weathered into different soil grades. Due to seasonal erosion, soil types emanating from this phenomenon are sand, clay and laterite ochrosols. The availability of these soil types has contributed to rapid real estate development in the area where estate developers have resorted to the use of local building materials such as river sand, gravel and clay (TaMA, 2012).

3.1.4 Drainage

The Metropolis is poorly endowed with water bodies. This is attributed to the low underground water table. The only natural water systems are a few ephemeral streams which have water during the rainy season and dry up during the long dry season. The streams have their headway from Tamale which is situated on a higher ground and the few ephemeral streams whose drainage basin forms part of the study area of this research. Unfortunately, these water bodies are quickly becoming extinct due mainly to the influence of human activities such as estate development, encroachment and indiscriminate waste disposal activities. This is a very serious problem and contributed to the choice of the research problem being investigated.

Aside this, some artificial dams and dugouts have been constructed either by the metropolitan assembly, individual community members or by Non-Governmental Organisations in the Metropolis. Two such dams include the Builpela and Lamashegu dams. These dams/dugouts serve as watering sources for animals as well as for domestic purposes. Despite this poor drainage situation, the Metropolis still has the potential for irrigation schemes. For instance the Pagazaa stream, is the main drainage basin, has a potential for agricultural production if it is dammed for irrigation purposes (TaMA, 2012). Figures 3.3, 3.4 and 3.5 show drainage basin in TaMA

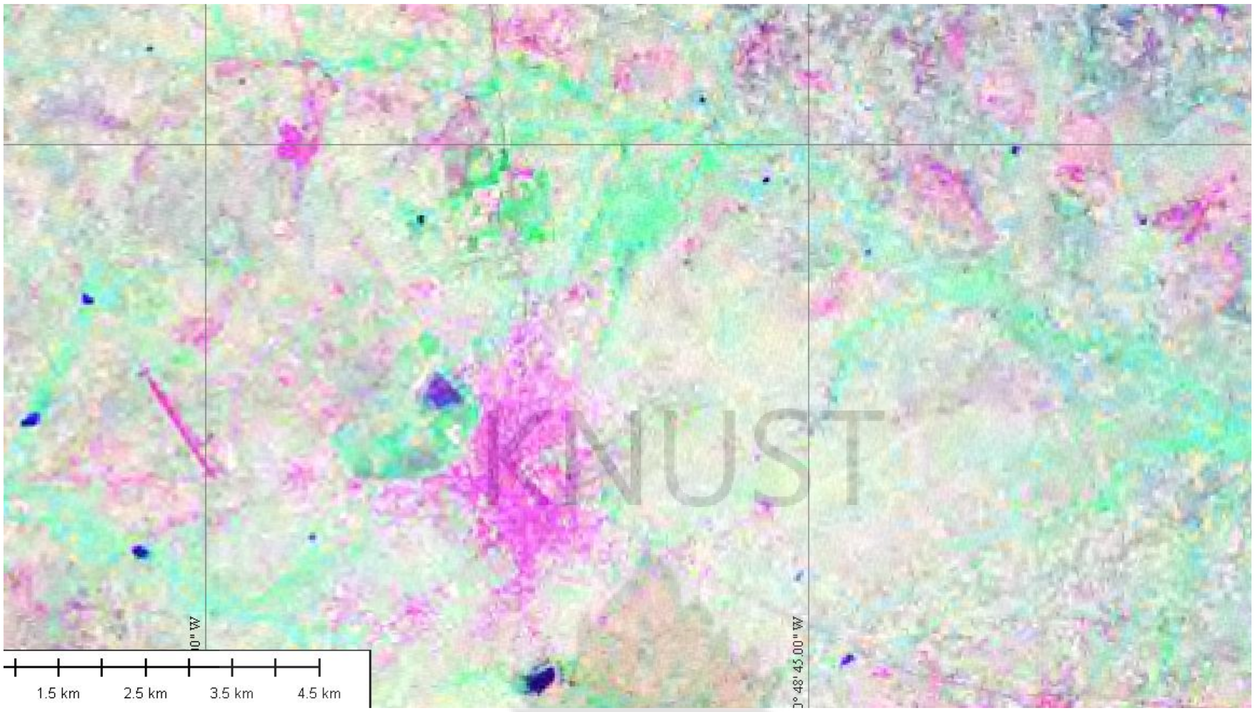

Figure 3.3 Map showing drainage basin in TaMA

Source: Field work, 2014.

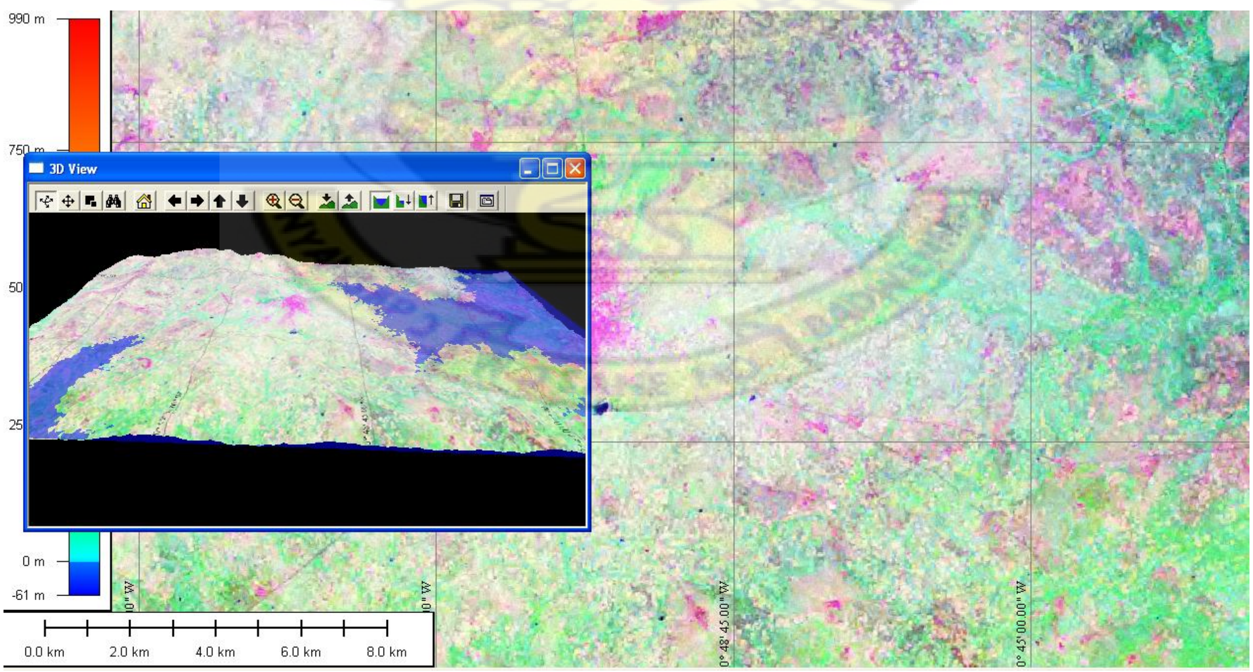

Figure 3.4 Map showing drainage basin and 3D in TaMA

Source: Field work, 2014.

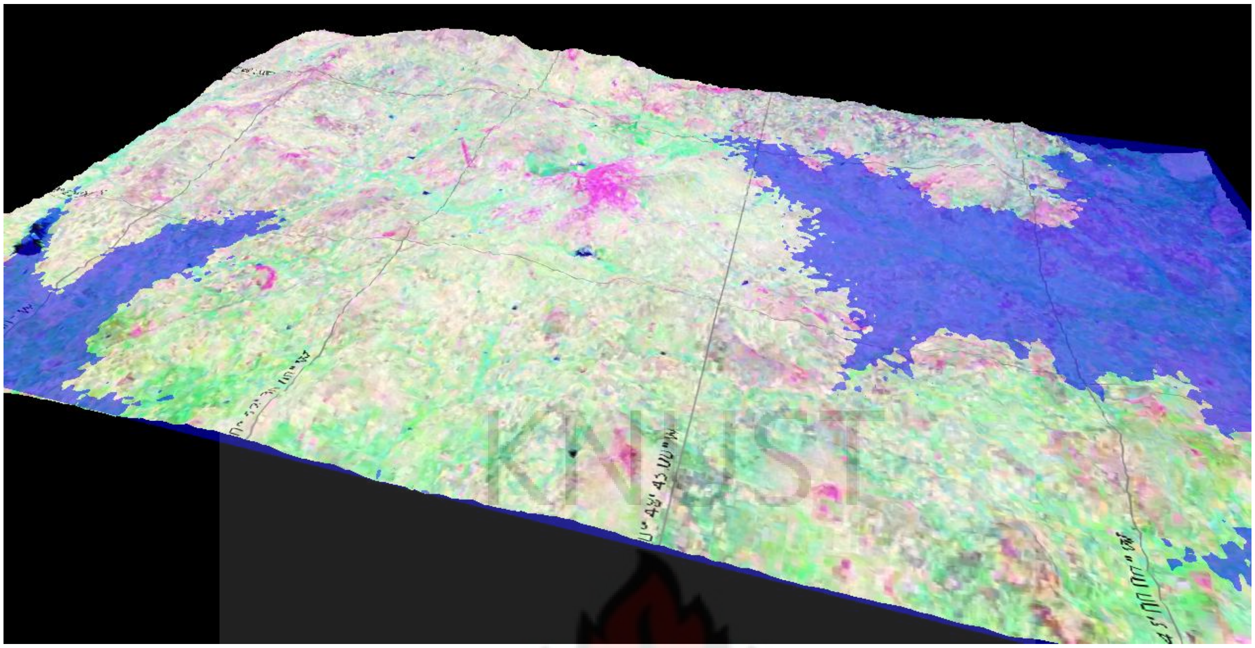

Figure 3.5 Map showing 3D drainage basin in TaMA
Source: Field work, 2014.

3.1.5 Development Indicators

Literacy rate: Less than one-quarter (22.6 %) of adults (15 years and older) in the Northern Region are literate compared to the national average of 53.4 %. The adult literacy rate for males (32.2 %) is about two and a half times that of females (12.9 %). At the district level, Gushiegu/Karaga records the lowest rate (9.3 %) while Tamale has the highest (46.4 %). Apart from Tamale Metro, all the other districts register adult literacy rates below 30 %. In all the districts, adult literacy rates for males are substantially higher than females, with rates more than twice those of females except for Tamale which is one and a half times. Gushiegu/Karaga records the lowest rates for both females (3.2 %) and males (16.1 %) (CWIQ, 2003)

The youth literacy rate for the region were 35.7 % which is slightly over half of the national average (68.7 %), with Tamale having the highest rate (62.9 %) while Gushiegu/Karaga (18.9 %) has the lowest. The rates for males exceed those of females in all the districts, still by wide margins, and Gushiegu/Karaga records the lowest youth literacy rates for both females (9.6 %) and males (25.7 %) (CWIQ, 2003)

Poverty rate: The proportion of persons aged 15 years and older who are unemployed in the region is 2.0 % compared to the national average of 5.4 %. The proportion for females (2.3 %) is slightly higher than that of males (1.7 %), and they are generally low for both males and females in all the districts including Tamale Metro. However, the level of unemployment is higher for females than for males in all districts except in Savelugu/Nanton, Nanumba, East Mamprusi and Tolon/Kumbungu, where the levels for males are either higher or about equal to the levels for females. The underemployment rate (6.75 %) in the region is about half the national rate (13.6 %). The lowest underemployment rate is reported in West Gonja (0.5 %) followed by West Mamprusi (2.3%), but is as high as (14.8 %) in Nanumba (CWIQ, 2003).

3.2 Study methods

The study will essentially focus on the human induced causes of flooding while examining the roles professional bodies play as well, particularly the Hydrological Department, Town and Country Planning Department as well as TaMA. It also looks at how the floods have affected the lives of the people as well as the efforts that can be made to avoid or minimize the impacts of a similar future disaster.

3.3 Conceptual Frameworks

The contextual framework can be represented by the organogram below where the cause of the floods are seen as the activities of the people within the communities as well as the lack of relevant professional bodies such as planners or the neglect of their responsibilities. With the building of the capacity of the professionals and social capital through education, an informed population will be achieved and will be more proactive in dealing with issues concerning floods so as to achieve a safer environment.

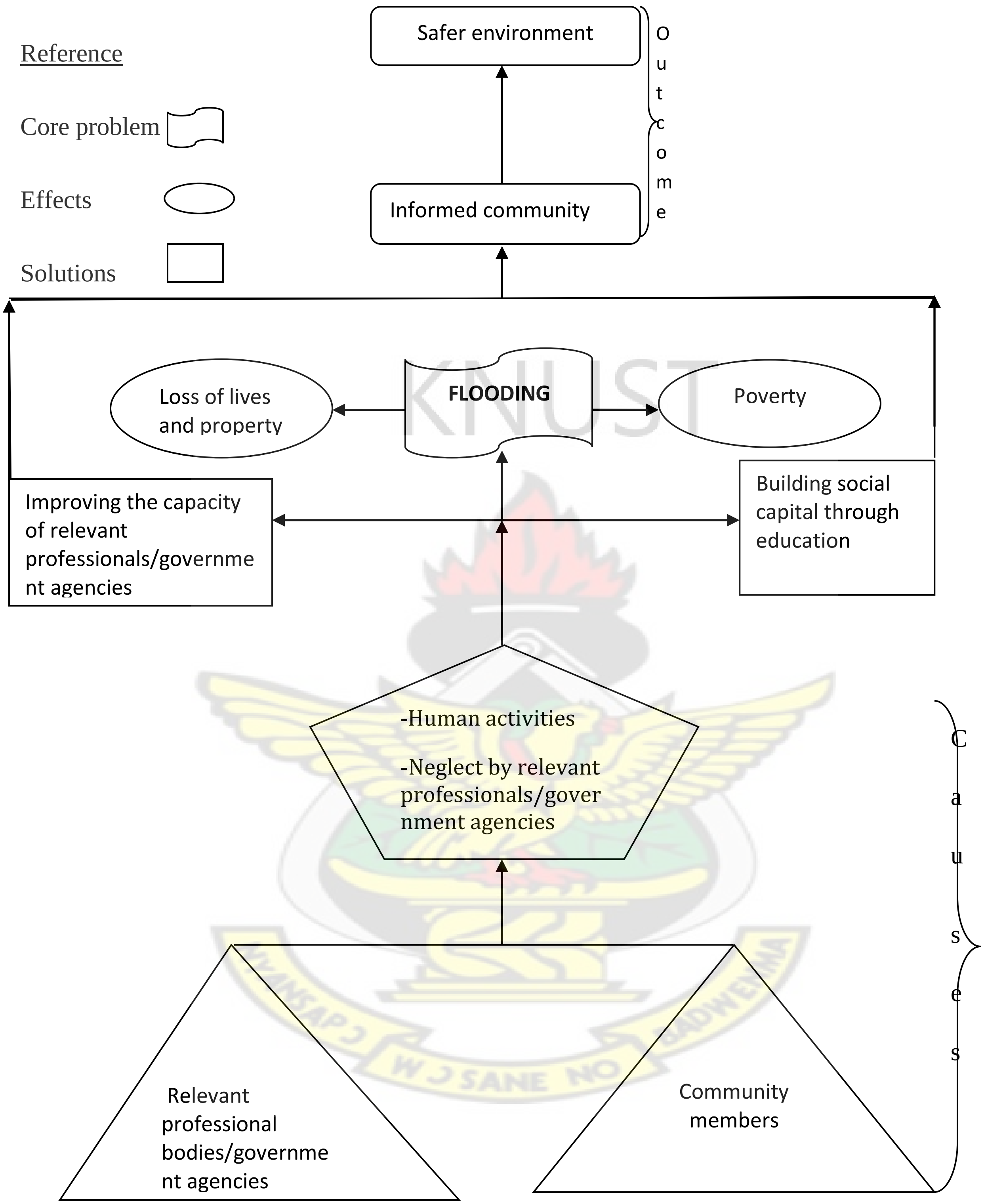

Figure 3.6: Conceptual Framework diagram.

Source: Author's concept based on field visit (2014)

3.4 Tools and techniques for collecting and analysing data

This study uses a qualitative and quantitative research strategy as the methodological approach to find answers to the research questions raised. This choice is influenced by the researcher's quest to "see through the eyes of the people being studied" and assess their local knowledge on the causes, impacts, vulnerability and mitigation response to flooding in Tamale Metropolis. Both primary and secondary data sources where collected over a two-month period, June 2013 to August 2013, from five key communities, namely Sogunayili, Gbalo, Jisonayili, Gumani and Fuo all in Tamale Metropolis. Semi-structured interviews, Focus Group Discussions (FGDs), participant observations and text and document analysis where used as qualitative tools to collect data.

3.5 Scope of the study

The research considered the case of flooding as it occurs in communities along the river basin in Tamale Metropolis. The communities chosen were Sogunayili, Gbalo, Jisonayili, Gumani and Fuo in the Tamale Metropolis. These communities were chosen because after visits to them and enquiries from related authorities and departments, it was discovered that they are the most affected whenever the Metropolis river basin exceeds its carrying capacity, overflows its banks and floods its basin.

The research was designed to carefully identify the causes, impacts, prevention and management techniques of flooding in the selected communities. It is important to note that the causes as well as impacts of flooding in these areas may not be only natural but also man-made. The study identified both the natural and man-made causes and impacts of flooding in the selected communities. The proper management of flooding by both authorities and the affected members of the communities was also investigated and recommendations made where necessary.

Through observation and analysis of responses from affected members of the communities, the impacts of floods were identified. Reasons were sought as to why the households continued to endure the losses which sometimes could be as priceless as the loss of life by still living in this 'danger' zone. Prevention they say is better than cure. The study demanded answers from concerned authorities including the metropolitan assembly and the respective assemblies and leaders in the communities in a bid to understand what methods had so far been adopted to at least reduce the impact of flooding on family members and the successes and failures of these methods. Coping strategies adopted by affected communities were thus identified and discussed in this study.

3.6 Limitations

The researcher was faced with quite a number of limitations including constraints which were mainly financial and logistical in nature. The researcher was also constrained by time since specified time periods have been set by the University Completion and submission of theses.

3.7 Methodology

Research methodology is crucial for the success of any research and more especially, academic research. The methodology helps to put the study in proper perspective by presenting the underlying rules and principles for a particular research. A successful research is thus based on an appropriate choice of design and control in order to efficiently achieve the objectives of the study.

3.7.1 Research design

The research design was basically a systematic plan or strategy of investigation using the most efficient methods. Qualitative and quantitative design methods featured prominently in this research. A cross-sectional design was adopted in this research because only a cross-section of the problem could be studied given the constraint of time. It followed a logical sequence from the collection of data to its analysis after which appropriate recommendations were made.

3.7.2 Types and sources of data collected

Primary data used included information from selected residents and other business owners about the causes of flooding and its impacts on their social service deliveries. Secondary data was collected from selected institutions in Tamale. Information sought included the government institutions' primary functions and specific roles in flood prevention and management as well as their views as to the causes and possible preventive measures needed to deal with floods in Tamale. These institutions included:

Ghana Meteorological Agency, Tamale

Town and Country Planning, Tamale

Ghana Statistical Service (GSS), Tamale

Ghana Hydrological Service (GHS)

Waste Management Department of the Tamale Metropolitan Assembly

National Disaster Management Organisation (NADMO), Tamale

Other forms of data including maps, population figures, rainfall figures and city plans were also sourced from the relevant institutions mentioned above. Secondary data was carefully studied and reviewed to come out with information relevant to the better understanding and execution of the research study. Tertiary sources of data in the form of text books about flooding were also consulted.

3.7.3 Methods of data collection

Primary data was used in this study. Questionnaires were administered to 376 respondents and five relevant institutions in the field to gather primary data relevant to the study. The interview technique was used to gather qualitative primary data in the study area. Furthermore, the structured type of interviews was conducted using an interview schedule with the households and relevant institutions as key informants to the research problem. Observation was one of the methods used in data collection. Through this, the impacts of flooding on various physical structures were observed and noted and some pictures were taken. The levels of flood water in and around such structures in times of floods were also identified and measured. Relevant information from secondary data was also used to help in the better understanding and execution of the research study.

3.8 Sampling design and technique

The researcher was faced with a very large sample size. The total population of the Sogunayili, Gbalo, Jisonayili, Gumani and Fuo communities lying within the Metropolis flood prone zone is 38213 people (GSS, 2000).

Table 3.1: Flood prone areas and population at risk in the Metropolis

Area	Total population	Number of Households	Sample Size
Sognayili	869	119	7
Gbalo	346	56	3
Jisonayili	2802	374	22
Gumani	33345	5829	337
Fuo	851	110	6
Total	38213	6488	376

Source: Ghana Statistical Service, (2000).

The population from which the sample was drawn consisted of all the households within 100 to 200 meters of the zoned areas in the respective communities. The purposive sampling method was used in choosing households because there was the need to interview those situated close to the river that had experienced flooding. The stratified sampling method was used to calculate the number of households per community, the total of which made up the sample frame. The household head or any adult in charge was interviewed.

Table 3.1 shows the respective sample sizes of the communities within the catchment area indicated in the study. The calculation of these can be found in appendix 1. Officials of the Town and Country Planning Department, the Waste Management Department and the Ghana Meteorological Service in the Tamale Metropolis were interviewed. Attempts were also made to interview the Hydro Engineer of the Hydrological Services Department and personnel from the National Disaster Management Organisation in Tamale. All these institutions are related in one way or the other to the problem under investigation as key informants.

3.9 Data analysis

The data collected was summarised and analysed using both qualitative and quantitative method. Responses from households and other institutions were coded and entered into a database to generate tables and cross tabulation where necessary to facilitate the analyses of the quantitative data. This was necessary to help establish relationships between variables. All these were done with the aid of the Microsoft Office Excel and Statistical Package for Social Sciences (SPSS). The specific tools of the package utilised include cross tabulations, regression, correlation, percentages, pie charts and bar graphs. Maps of the drainage basin of the Metropolis and the selected communities especially in low lying areas were also analysed to show the areas around the zoned areas which are most liable to flooding. Various types of tables, charts and graphs have been used in descriptive analysis of both qualitative and quantitative data gathered.

3.10 Presentation of results

Efforts were made to present results in a clear and comprehensive manner. Responses obtained from questionnaires were coded and entered into a database with the help of the SPSS for analyses. Results were represented mainly using tables, maps, graphs and charts.

3.11 Organisation of the study

The study has been organised into five chapters. The first chapter gives a general orientation of the study. This contains the introduction, problem statement, objectives, method of study as well as the rationale for the whole exercise.

Chapter two is an in depth review of literature and the conceptual framework on the problem of flooding. It considered and examined other works done on the problem identifying gaps that needed to be filled where necessary.

Chapter three is a discussion of the profile of the study area while chapter four deals with the analysis, presentation and discussion of data collected on the field. It involves the organisation of field data for analysis, discussion using specific tools of data analysis and presents a discussion based on the institutional perspective of the problem. Finally, chapter five which is the last chapter presents a summary of the findings of the study. Conclusions are then drawn with recommended solutions for solving the problem.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

Sogunayili, Gbalo, Jisonayili, Gumani and Fuo are part of the communities in the Metropolis forming the study area, which are all flood zones and flooded annually. People living in these communities face various problems due to this annual phenomenon. The data obtained from the field has been critically considered and analysed and the results from this have been elaborately discussed in this chapter.

4.2 Bio- data of respondents

To understand the issues arising from the problem and the appropriate primary data, it was important to obtain the bio data of the respondents to put their concerns into proper perspective. Because of the serious nature of the problem under investigation, it was important to identify respondents in the study area who were old enough to understand the issues and give meaningful responses which will help in giving an appropriate policy direction to correct the problem. Only 17.6 % of respondents were below 25 of age and 82.4 % of them aged from 26 years to above 50 years old. Thus, information given by respondents is clear and relevant since they clearly understood the problem under investigation. The Majority of respondents interviewed were male 54 % with females being in the minority of (46 %). Dependants of the heads of households who were aged below 25 years are 9.8 %.

The population and ethnicity forming the study area varies from one to another predominantly made up of Dagombas and other groups from other parts of Ghana. However, more than half of the respondents interviewed are Dagombas, less than quarter of them are tribes from Upper East and the rest are other tribes from the country. There is a clear sign that the communities under the study area are made up of different ethnic groups co-existing peacefully. Respondents were mainly traders, students, artisans, wood workers and public servants. Respondents are mostly self-employed with only 9.2 % working in the public service, with 11.7 % of respondents unemployed. Respondents are mostly of the middle and lower class income levels. Accommodation in the area is mostly for the middle and lower class income earners. This assertion also reflected in the educational levels of respondents: 32.4 % of respondents had attained primary school education, 46.9 % of respondents are senior secondary school graduates, 11.9 % are obtained tertiary education and 11.0 % have no formal education. Over sixty seven percent (67.4 %) of respondents are owners of the houses they lived in, 24.1 % are tenants and 8.5 % being free occupants.

4.3 Reasons for continuous stay in flood prone area

One of the objectives of this study is to ascertain the reasons why people who are affected by flooding keep on living in the flood prone areas. It is a very important objective since one nagging question the researcher could not quite answer was if one has to go through such a dangerous hazard every year, why not move away to stay in a safer and more conducive place. Respondents were asked if they had experienced flooding before and almost all of them had: 97.9 % of respondents had experienced flooding and only 2.1 % said they did not. This led to the attempt to understand why people continued to live in the area although they endure the phenomenon of flooding each year.

Table 4.1: Reasons for Continuous Stay

Reasons	Frequency	Percentage
Affordability	226	60.1
Others	74	19.7
Proximity to work	38	10.1
Not applicable	30	8.0
Did not face problem	8	2.1
Total	376	100.00

Source: Field survey, 2014.

Table 4.1 indicates a summary of the varied reasons why respondents continued to stay in the flood prone area of study. It is clear that most people lived in these areas because of affordability of housing or accommodation: 60.1 % of the respondents are still living in the study area because they could not afford the cost of renting or putting up a building at safer places. Over nineteen percent (19.7 %) continue to stay in the area because of other reasons as living in family houses or having lived there throughout their lives, others because of friends, just to mention a few.

Nearly ten percent (10.1 %) continued to stay in the area because of proximity to their places of work or because it makes life a little easier for them especially with regard to earning a livelihood. Some residents had their businesses right there in their various houses where they also lived. Most of them were traders and artisans such as carpenters and they operated these businesses in the study area. About 2 % of respondents claimed that their reason for staying in the area was because they did not face any problem before. That does not debunk the fact that they are not facing the problem since most of them admitted that currently, the issue of flooding was becoming a problem for them. All these go to validate the proposition that 'Socioeconomic constraints are the motivation of inhabitants' continual stay in flood prone areas'. While some residents could not afford to move out of their communities, others continued to stay because of social ties such as the need to stay in a family house to take care of it and not pay any rent.

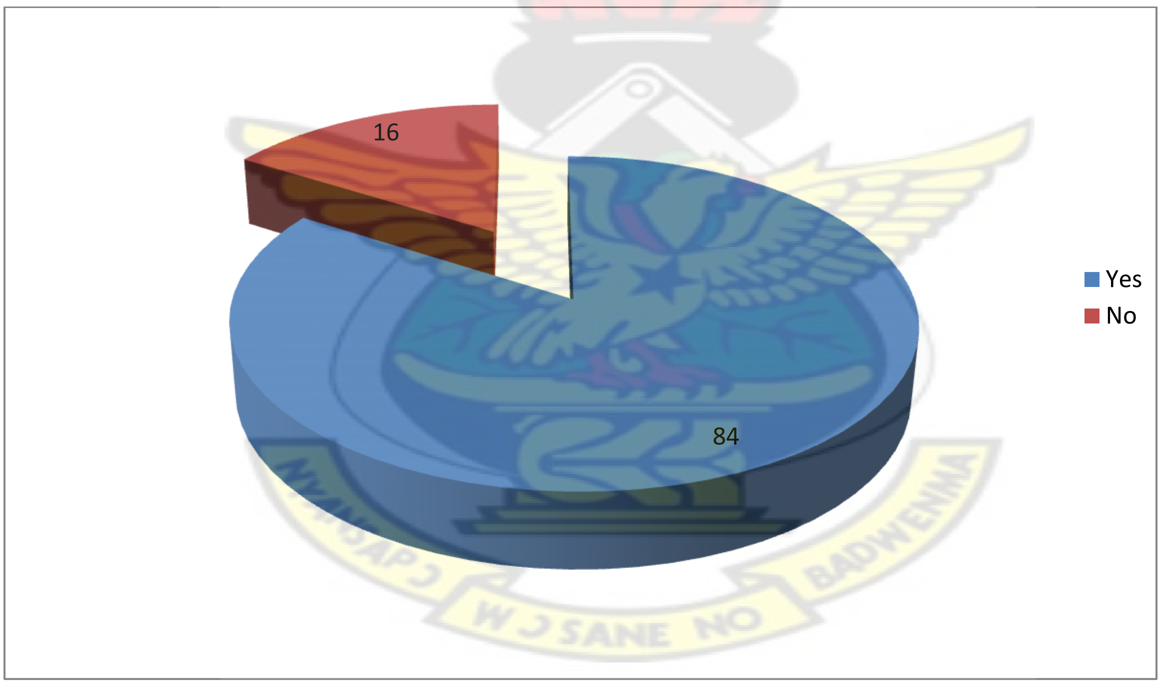

Figure 4.1: Desire to move out.

Source: Field survey, 2014.

Almost 82 % of the respondents were willing to move out of their communities in the study area if they could. Nineteen percent (19 %) were however unwilling to move out because of some socioeconomic reasons previously discussed.

4.4 Causes of flooding in the Tamale Metropolis

The specific objectives of the study were to find out the natural and artificial causes of floods in the Tamale Metropolis. This was essential because the causes revealed would be of immense help to policy makers and other stake holders in the attempt to plan and mitigate current situations and to prevent future occurrences.

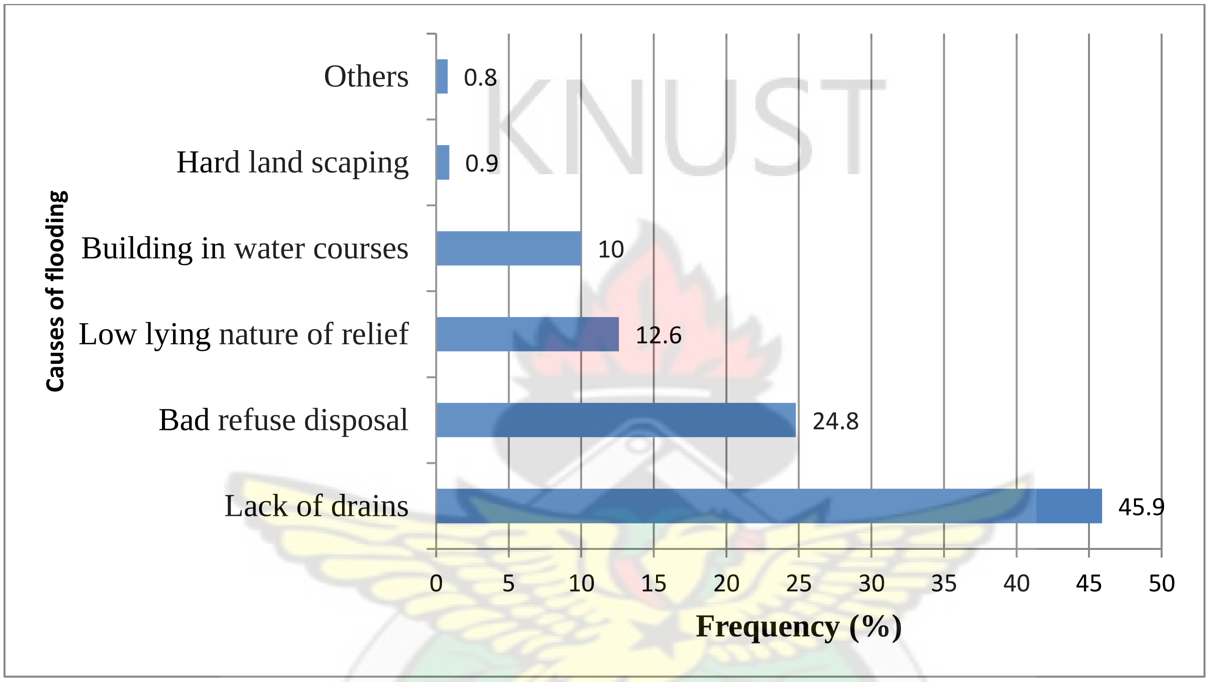

Figure 4.2: Causes of flooding.

Source: Field survey, 2014.

Figure 4.2 gives an exciting vision into the causes of flooding according to the respondents in the area. The most important root of flooding according to 45.9 % of the respondents is lack of drains in the area. This was true because observations made in the field showed that in most areas, proper drainage systems were absent. Where such drains existed, they were poorly constructed. Another cause of flooding, according to the respondents, is improper refuse disposal in the area: 24.8 % of the respondents indicated that the method of refuse disposal was an issue and they believed that it was one of the major causes of the problem since natural drains were choked with refuse. Over twelve percent (12.6 %) assign the cause of flooding to the low lying nature of relief. This assertion was made mostly by those staying in the valley, and bear the brunt of the floods. Building in water courses accounted for 10.0 % and building design 5.0 %. Only

0.9 % out of the sample size of 376 believed that hard landscaping was a cause to flooding while 0.8 % attributed the floods to other causes. Hard landscaping according to respondents was not an issue for flooding. They however assigned other causes such as poor drainage design and poor building designs to flooding in the study area.

4.4.1 Waste disposal

Field observations show waste disposal practiced in the area of study, was not environmentally friendly at all. Respondents also specified that this was one of the major causes of flooding in the area. Over 81 % of respondents dumped their waste in the natural drains or the banks of the water ways. Only 9.1 % used public waste disposal dumps for waste disposal. This gives a clear indication of the fact that human activities is one of the important causes of flooding in the communities of the study area, since the natural drains get choked. Table 4.2 is a summary of respondents' views on the issue of waste disposal.

Table 4.2: Methods of waste disposal by respondents

Waste disposal method	Frequency	Percentage
Public dump	34	9.10
Dumping of refuse in the water way	194	51.60
Dumping of refuse at the banks of the water way	114	30.20
Burning of refuse	24	6.30
Others	10	2.70
Total	376	100.00

Source: Field survey, 2014.

Only less than 2.7 % of respondents paid for their waste to be collected and disposed of properly. Unfortunately, they constitute the minority.

4.4.2 Land use

With regard to the respondents' views about the causes of floods in the field, one could wonder if there were any rules, regulations and plans governing land use in the flood prone zones. Majority of respondents believed that land use planning was not followed at all. Buildings were erected anywhere and anyhow without permits. About 56.1 % of respondents believed that rules were not followed and land use was an issue to be dealt with in solving the flooding problem.

Table 4.3: Land use plan implementation according to respondents

Land use	Frequency	Percentage
Yes	165	43.9
No	211	56.1
Total	376	100

Source: Field survey, 2014.

4.5 Frequencies of flooding in the study area

Respondents' views confirmed that flooding was a frequent phenomenon in the area. Almost 100 % quantified that floods occurred several times annually. Less than 1% out of the 376 respondents claimed that floods occurred only twice a year. Majority of the respondents (61.3 %) confirmed that floods usually occurred during the months of August and September and 38.7 % of the respondents found it difficult to specify the particular months in which the floods usually occurred. They clarified that the flood results whenever there was heavy rainfall or a long period of heavy rainfall or storms. Figure 4.3 shows the flood periods and frequency in the study area: floods occurred mostly in the month of August and September and least in the month of October. These follow the national rainfall distribution patterns.

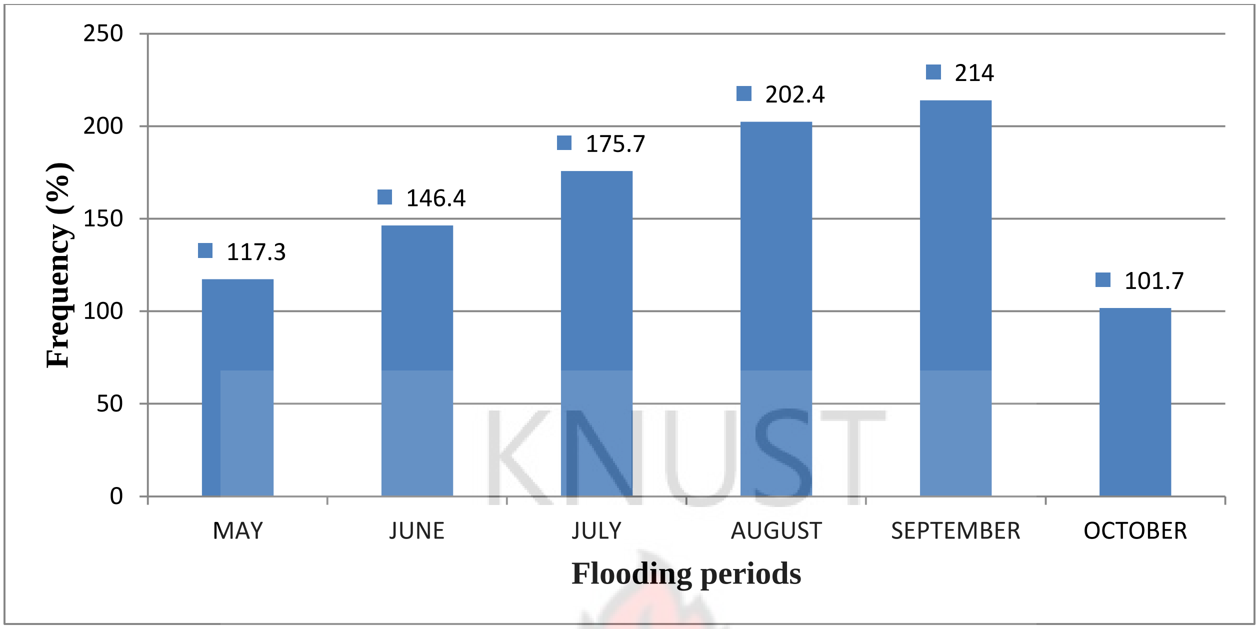

Figure 4.3: Periods of Annual Floods.

Source: Field survey, 2014.

It was important to find out the duration of floods, for detailed understanding of the problem and its solution. Investigations were made from respondents of which minority (2.7 %) specified that flood water and its after-effects usually lasted for as long as 1 to 2 days. That is to say the flood waters took that long to recede. Majority (97.3 %) of the respondents indicated that flood water lasted for less than a day. However, it was observed that those who made this claim were not living very close to the bottom of the valley floor. Those who claimed floods could last for days, however, were those who reside in the valley.

Table 4.4: Duration of floods

Flood duration		
Less than a day	366	97.3
1-2 day	10	2.7
Total	376	100

Source: Field survey, 2014

4.6 Natural causes of flooding

Information obtained from the field was compared with secondary data obtained from the Ghana Meteorological Agency in Tamale. This was to prove that climate variability and change could be the cause of flooding. The rainfall and temperature figures obtained from the agency spanned over a period of 27 years. These were analysed and used to draw graphs which show deviations from average rainfall and temperature respectively over the 27 year period. The calculations for the standard deviations of both rainfall and temperature can be found in appendices 2 and 4 respectively.

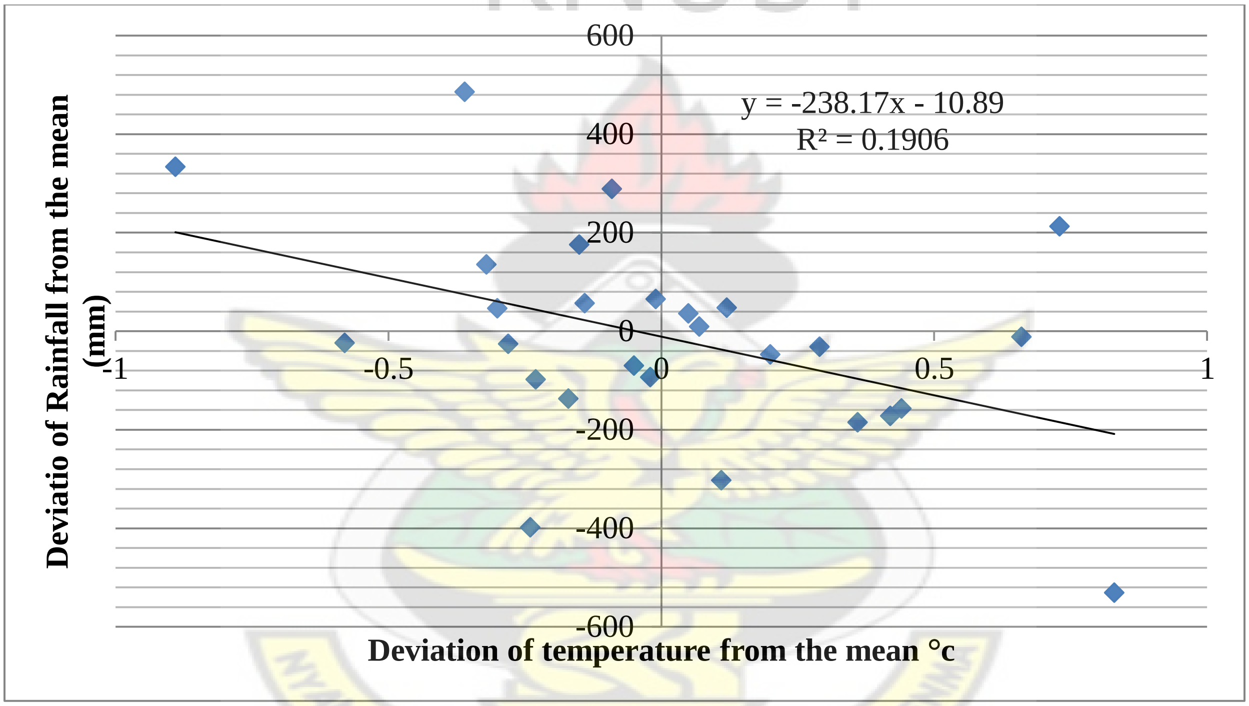

Figure 4.4: Scatter plot between rainfall deviations (mm) and temperature deviations (^{0}C). Source: Field work, 2014.

According to the Meteorological Agency Tamale (2014), figure 4.4 clearly shows the relationship between the deviation of rainfall from the mean (mm) and deviation of temperature from the mean (°c). The basis of this graph is to test the hypothesis that "local climatic change is responsible for intense rainfall that causes flooding along the zoned areas". From the graph, it is clear that there is a relatively weak relationship between the two as of now. The relationship is negative meaning that temperature has no influence on rainfall; it is relatively weak and indicates that climate change is not yet a major issue so far as flooding is concerned in the zoned areas. Table 14 and figure 8 in appendix 3 show an interesting trend of increasing rainfall over the last 27 years. The average rainfall over the 27 years was 1094.16 mm. Thus, the origins in the graphs represent the mean annual rainfall figure of 1094.16 mm. There are however deviations from this average which peaked in the year 1991 at 485.6 mm. This is not surprising and could account for the many floods which occurred in the year 1991. From table 14 and figure 8, it is clear that rainfall patterns have been changing over time. In 1991 and 2002, rainfall values changed form 1579.8 mm to 563.3 mm respectively. This was far below the average rainfall over the 27 years. This is attributable to the period of drought the country experienced in the year 2002. It can be observed however from the trends in Table 14 and Figure 8 that the occurrence of above-average rainfall was gradually increasing over time. With more rainfall into the study area, the incidence of flooding also increases since excess discharge in channel naturally overflow and inundate the adjacent lands. This is one of the reasons why flooding within the zoned area has been occurring more frequently in recent times.

There was the need to consider temperatures trends over a period of at least 30 years in order to discuss the effects of climate change on the incidence of flooding in the zoned basin. In Appendix 5, Table 15 and Figure 9 generally show an increasing trend of temperatures over the 27 years under scrutiny. Mean annual temperature over 27 years was recorded as 28.73 ^{0}C. Deviations were therefore calculated from this average. Thus, the origin of the graph of Figure 4.4 represents the mean annual temperature.

It was very clear that deviation of temperature from the mean changed by -0.89 ^{0}C in 1989 to 0.83 ^{0}C in 2002. Temperature has increased slowly over the last 27 years. In 2002 for example, mean annual temperature was as high as 29.56 ^{0}C, an increase from the 1989 figure of 27.84 ^{0}C. Rising temperatures could lead to increases in evaporation from the river as well as evapotranspiration from the basin and thus increased rainfall. The fact that most water bodies including the zoned river have been exposed to direct sunlight accompanied by rising average temperatures lead to increased evaporation. Again, the soil upon drying up of its antecedent moisture becomes compact and does not allow easy infiltration and so generates excess runoff in the basin. All these lead to the incidence of floods in general and more specifically in the study area river basin. This is because more rainfall implies more discharge for the area river, the excess of which inundates the flood plains of the river which unfortunately is inhabited by human settlements.

4.7 Impacts of flooding

The main objective of the research was to find out the impacts of flooding on the social services in the Tamale Metropolis. The suggestions to the causes of flooding in some of the communities that are flood prone zones are both natural and man-made in nature. There is the need to throw more light on the impacts of flooding. The impacts have been divided mainly into social, economic, structural, and others.

4.7.1 Social Impacts

Some communities within the study area in the metropolis face a lot of social problems by floods. According to respondents' remarks, the main problems in the communities within the study area are the breeding of mosquitoes which results in malaria infection and other water borne and water related diseases. As high as 72.9 % of the respondents indicated that poor health can be associated with post-flood effects. Floods can result in the inability to go to school or work (14.3%), increased criminal activity (6.1 %), low standards of living (5.0 %), low self-esteem (1.0 %), and others (0.8 %). An unhealthy person obviously cannot contribute meaningfully to the development of a society and sometimes becomes a burden to those around them. More money is spent on treatment of water related diseases especially malaria due to the breeding of mosquitoes from stagnant dirty or muddy water which remains after the floods for a while before drying up. The environment consequently becomes susceptible to the outbreak of diseases such as malaria and cholera. Students and workers in these communities cannot go to school or work. During this period, crime increases since thieves take advantage of the situation to steal properties belonging to victims of the floods. All these lead to a low living standard in these areas since money is spent annually to repair or replace broken properties or properties carried away by flood water. Little money is left to maintain a good living standard which requires living in a safe, healthy environment and earning enough to provide food, shelter and other basic needs for one's self and the family. Flooding situations have also led to a low self-esteem among members of these communities. During floods, the smooth function of society is affected with the direct consequences borne mainly by members of affected communities.

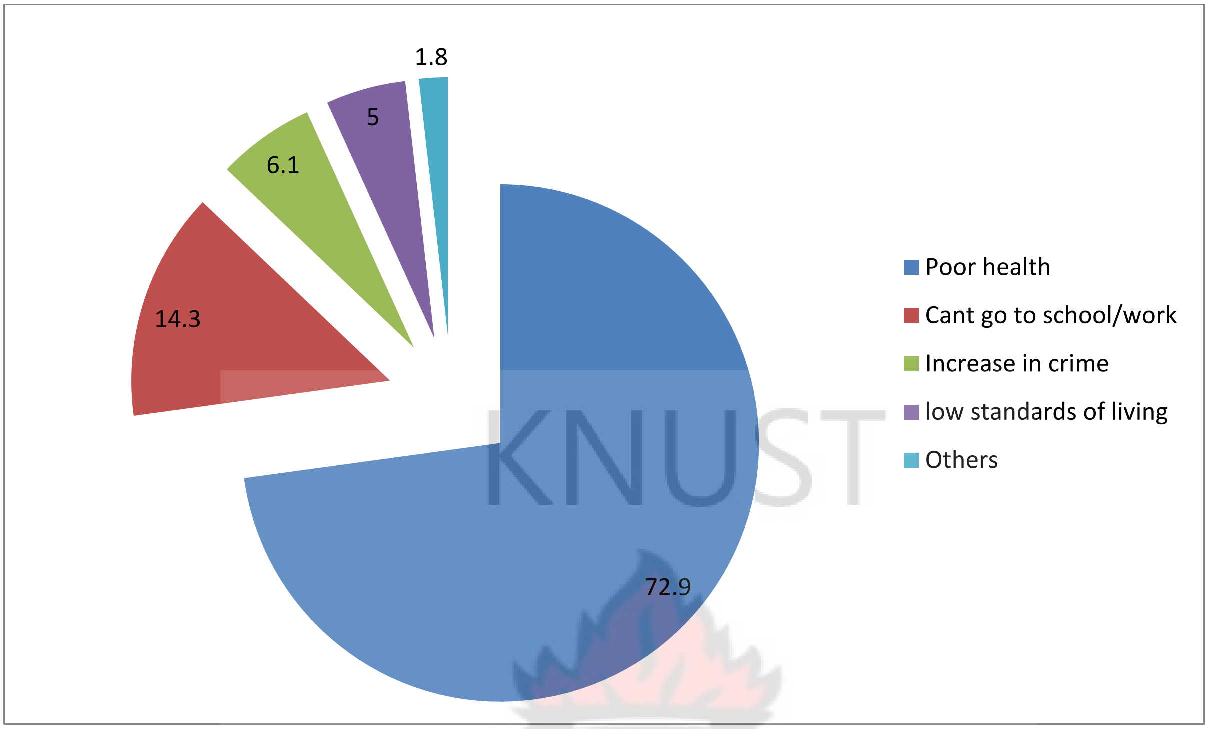

Figure 4.5: Social Effects of Floods.

Source: Field survey, 2014.

4.7.2 Property Damage

Another unfortunate effect of floods in the area of study is that of property damage. Properties destroyed by flood waters are mainly household furnishings and appliances. These include furniture and electric appliances such as television sets, radios and sound systems. About 61 % of respondents made this claim. Other properties are also destroyed as can be seen in Table 4.5 and all these bring untold difficulties to the victims.

Table 4.5: Property Damage due to Floods

Property damage	Frequency	Percentage
Interior room properties and electric appliances	231	61.5
Cloths, foodstuff and cooking utensils	65	17.2
Schools book, bags and shoes	46	12.2
Building material	5	1.2
No property damage	14	3.8

Other	15	4.1
Total	376	100.0

Source: Field survey, 2014.

4.7.3 Economic Effects of flooding

A very interesting assertion was made by respondents so far as economic effects of flooding are concerned. More than 90 % of respondents believed that they were economically affected one way or the other. These effects included increased poverty (25.7 %), expenditures on maintenance and replacement of damaged or lost property (19.3 %) increased in health expenditures (13.9 %), loss of productive man hours since people could not go to work (7.3 %) to earn an income, inability to save part of their incomes (9.0 %) or plough back profits to increase productivity since a lot more expenditures have to be made. Economic activities in the flood affected areas slowed down (11.6 %) and in some cases, ground to a halt for severely affected areas. About 5% of the respondents believed there were no negative economic impacts of flooding on them. These people were those working in the civil service or self-employed with their businesses located in other parts of the metropolis such as the Central Business District (CBD). Since their livelihoods are not directly affected, they believed that the floods did not have direct economic effects on them though they may have experienced it indirectly. Figure 4.6 gives a first-hand impression of economic effects of flooding in the area.

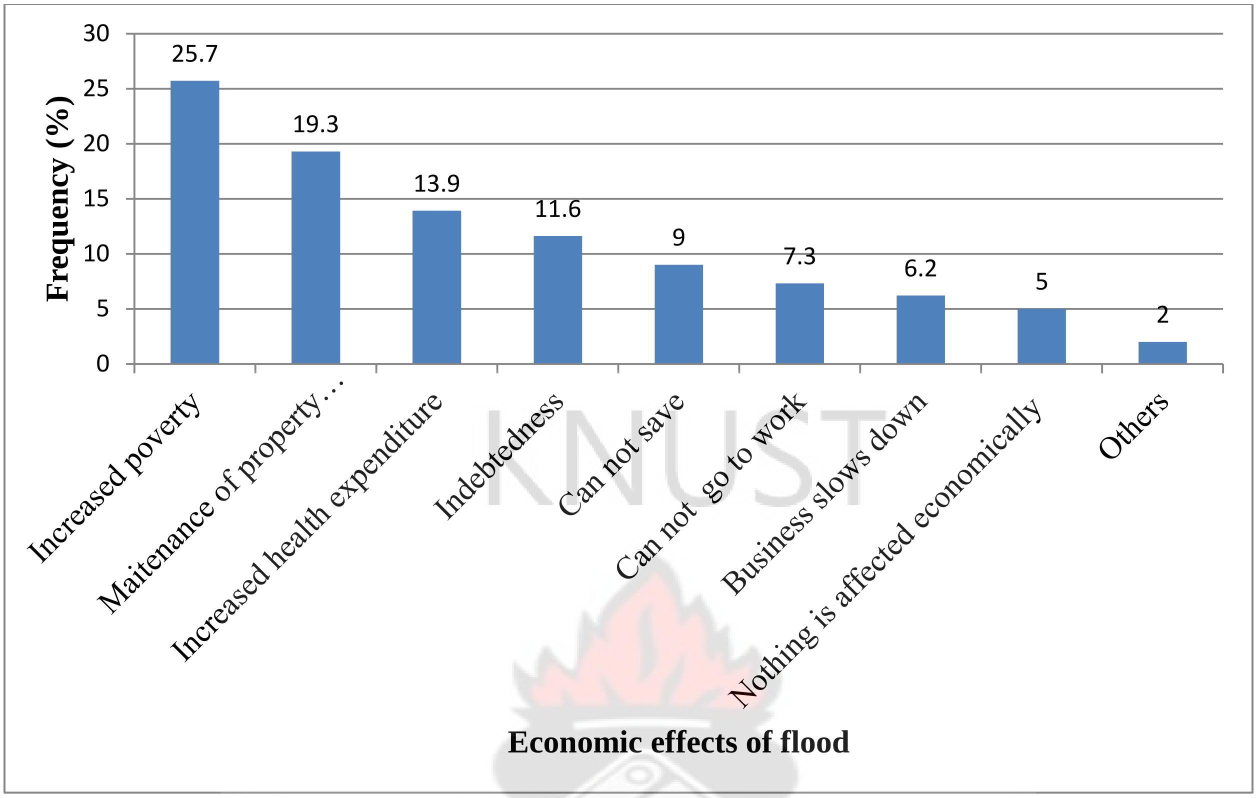

Figure 4.6: Economic Effects of Floods.

Source: Field survey, 2014.

4.7.4 Effects on physical structures (e.g. housing)

Flood affects the built-environment significantly in the study area. It was observed in the field that many structures were affected partially (foundations of some buildings exposed, cracks of walls and floors, leaking roofs e t c.) and completely (broken down walls and floors). Also some uncompleted buildings and completed ones were abandoned as a result of this annual occurrence. The main structural effect of floods according to respondents was show clearly in Figure 4.7.

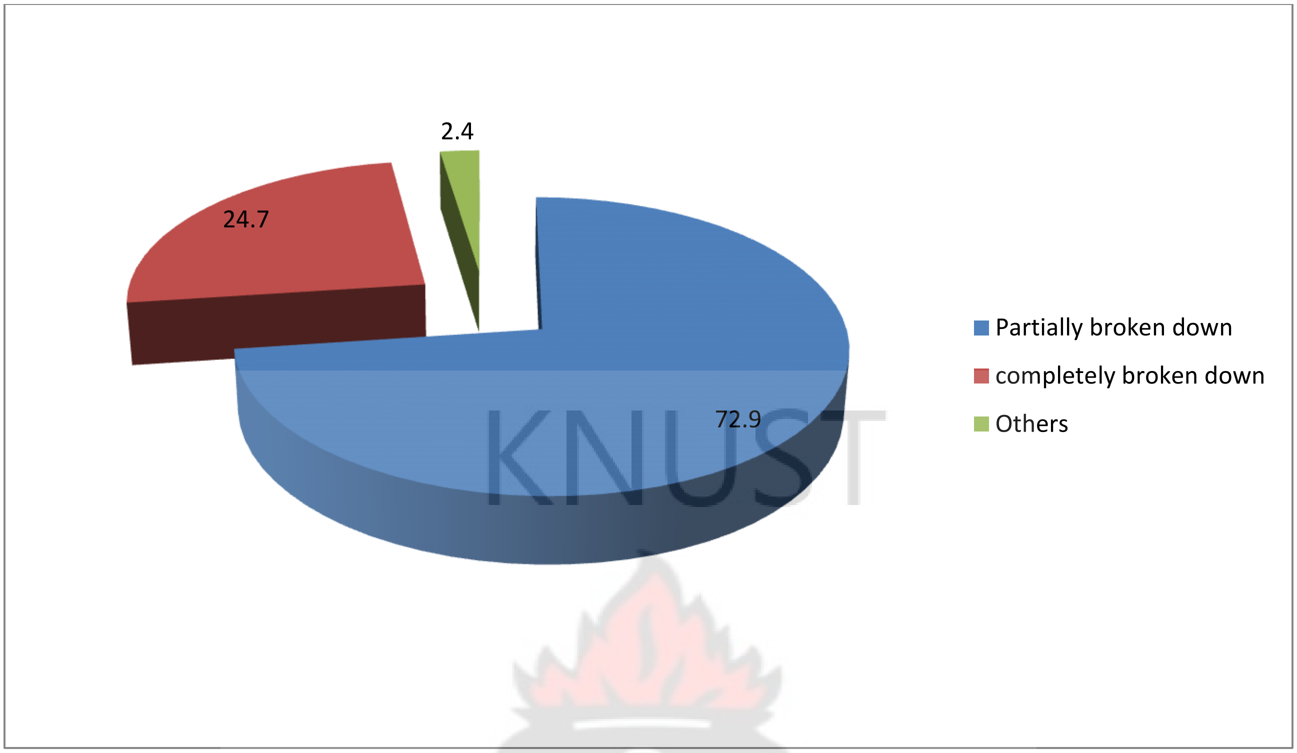

Figure 4.7: Effects of Floods on Housing.

Source: Field survey, 2014.

4.7.5 Other types of effects

The other types of effects of floods were mainly physical in nature. The flood caused serious erosion leading to the formation of gullies in some cases. The floods also left the area muddy and filthy leaving behind some of the load it carried in its rushing waters. It also brought along reptiles (such as snakes) and worms among others which could harm people living in the communities along the area. All these observations were made during visits to the affected communities.

4.8 Coping strategies of residents to floods

The question of how residents were coping with this phenomenon was inevitable for the study. Only 0.4 % of respondents indicated that some agencies or organizations came to their aid during the floods through rescue efforts to save lives and property. The remaining 99.6% stated otherwise with residents devising their own coping strategies to survive during and after the floods.

Coping strategies were examined before, during and after the floods. Before the floods set in, no efforts are made to clear choked drains (0.0 %) while temporal drains and bridges are constructed in some cases (14.4 %). About 29.3 % of respondents use sand and stone bags as barriers at the entrance of their houses to prevent flood waters from entering. Only 0.9 % of respondents just abandon their homes till the floods subside but 56.3 % of respondents do nothing before the floods set in. These activities took place before the floods actually occurred.

About 75.1 % of respondents claimed they simply stayed indoors when the floods occurred: 0.9% abandoned their houses for their own safety when the floods actually occurred: 18.7 % made efforts to safeguard their most valuable properties with the others (1.8 %) climbing up to the roofs and trees to escape the flood waters. About 1.4 % of respondents simply collected and threw out water as it entered their homes. Unfortunately, others (2.1 %) were unable to do anything and just had to bear the brunt of the floods anytime they occurred. This is rather unfortunate since such people (e.g. the aged and the sick) could easily lose their lives or be seriously injured.

After the floods, 97.1 % of respondents indicated that they put their homes in order. Those who abandoned their homes (1.9 %) return and then clean up the place as best as they can. Less than one percent (0.8 %) of respondents searched for lost properties hoping to find them. Far less than one percent (0.2 %) of respondents indicated that they sought for funds to undertake repair works, replacement of lost items and generally, return to normal life. There is generally a lot of fixing and drying after the floods. Unfortunately, reptiles and other dangerous animals may remain hiding in homes exposing people to risk of snake bites and other health hazards. The question then was, how were respondents generally coping with this annual hazard? Table 4.6 is a summary of the coping strategies adopted by people living in the flood prone areas in the Tamale Metropolis. Are these strategies sustainable? These strategies are more useful in the short term. In the long term however, it would be necessary for government to consider putting up affordable housing to relocate people living in the flood plain of the Metropolis as a lasting solution to the problem of annual floods.

Table 4.6: Strategies adopted to cope with the danger of floods

Coping with the danger of floods	Frequency	Percentage
Stay with friends and/ or relatives	8	2.2
Build walls/ steps to block the flood waters	177	47
Construct temporary bridges to access our property	54	14.4
Fill sacks with sand stones	110	29.3
Clear choked gutters	0.0	0.0
Other	27	7.1
Total	376	100

Source: Field survey, 2014

4.9 Flood prevention and management

4.9.1 Belief in flood prevention

Only 41.6 % of respondents believe that the incidence of floods which occur annually in the Tamale Metropolis can be prevented while 58.4 % believe floods cannot be prevented. Those who believed in flood prevention gave their opinions on how this can be achieved. Table 4.7 is a summary of suggestions made by respondents on how to prevent flooding in the area.

Table 4.7: Flood Prevention

Flood Prevention	Frequency	Percentage
Construct defence wall/big drains for the valley	76	20.3
Demolishing of structures on waterways and along the valley	27	7.3
Dredging the valley and natural drains	3	0.8
Clearing choked drains frequently	0	0.0
Stop dumping refuse along and into the valley	18	4.8
Building houses at the right places	24	6.3
Not applicable	220	58.4
Others	8	2.1
Total	376	100

Source: Field survey, 2014.

Belief in flood prevention clearly indicated in the table, majority of the respondents making up 58.4 % of respondents claim that floods cannot be prevented in their respective communities of the zoned areas, because it occurs as a result of nature. About 20.3 % of respondents believed that a defence wall or a big drain should be constructed in the valley. About 7.3 % believe that demolishing of structures in water ways and along the valley would help while 0.8 % suggested that the valley should be dredged. Surprisingly, no one suggested that choked drains be cleared. About 4.8 % of the respondents also believed that people should stop dumping refuse into and on the banks of the drains while 6.3 % claimed that houses should be built at the right places to prevent flooding. It is interesting to note that those making these suggestions were themselves living very close to the valley or dumping their waste materials into the valley. Thus, most people seemed to know the right things to be done yet they were not doing them to prevent the floods from affecting them. This also raised the question of who was responsible for ensuring that the right things were done.

Table 4.8: Reports made to authorities about annual floods

Flood report to authorities	Frequency	Percentage
Yes	287	76.2
No	89	23.8
Total	376	100

Source: Field survey, 2014.

From Table 4.8, it can be realized that majority of respondents making up 76.2 % of respondents had reported to the authorities in charge. Reports had been made mainly to the Assembly man or Unit committee members of their respective communities with a few people reporting the problem of flooding in the area to TaMA and NADMO. TaMA sometimes attempted to dredge materials from the drains which are placed on the banks of the drains. This temporarily raises the levels of the banks but the sediments are washed again back into the drains.

Table 4.9: Flood prevention

Effort at preventing floods	Frequency	Percentage
Yes	162	43.1
No	214	56.9
Total	376	100

Source: Field survey, 2014.

About 43 % members in the communities claimed that they had made efforts to prevent flooding in their respective communities by reporting to relevant authorities. They claimed that they contribute money and do discuss proper means of waste disposal and relocating people living in the flood prone zones. As indicated in Table 4.9, 56.9 % of respondents had made absolutely no attempt at flood prevention claiming that there was nobody to talk to since nobody cared about them and the situation was beyond their control. They also claimed the community layout was poor with some simply saying that nothing has been done. The reasons given by the latter are only an attempt to blame everybody else except themselves.

4.10 Role of stakeholders in flood mitigation

Investigations were made in the field to find out the various ways in which the problem of flooding could be effectively dealt with by the various stakeholders. These stakeholders include households, the communities, the Tamale Metropolitan Assembly and the Central government.

4.10.1 Households

About 31.7 % of households believed that proper building permits should be sought within the master plan of the metropolis. About 21.2 % of them suggested that construction of bridges, drains and walls would help channel the flood waters appropriately to either prevent or reduce the discharge from the valley. About 19.6 % of the respondents however believed that households should properly dispose of their waste products; 16.3 % of them believed that choked drains should be cleared while 7.4 % of respondents claimed that the situation was beyond their control. This group clearly indicated that buildings constructed in the valley was a major contributing factor to the problem of flooding since these buildings impede the smooth flow of water, causing the excess river water to overflow onto the adjacent land. Table 4.10 summaries the views of households about mitigating floods.

Table 4.10: Households views of solving flood problem in the zoned area

Households- views of solving flooding problem	Frequency	Percentage
Build according to TaMA plan	119	31.7
Construction of gutters/ walls/bridges	80	21.3
Proper disposal of refuse	74	19.6
Clearing of choked drains	62	16.5
It is beyond us (cannot do anything about it)	28	7.4
Others	13	3.5
Total	376	100.0

Source: Field survey, 2014.

4.10.2 Community

About 32.1 % of the respondents believed that communities should ensure that houses are not built across or close to the valley; 22.6 % suggested proper waste disposal; 15.0 %suggested sustained educational campaigns about flood mitigation; 10.6 % proposed construction of defence walls, drains and bridges to reduce the effect of flooding; while 9.2 % of the respondents believed that communal labour was needed to clean the valley as well as the few drains in the flood zones so that flood waters flow freely through these respective channels thus improving the flood situation. Table 4.11 summarises the views of respondents so far as the contribution of the respective communities to flood mitigation in the Metropolis flood prone zones is concerned.

Table 4.11: Community views about floods mitigation in the area of study

Communities views of floods mitigation	Frequency	Percentage
Houses should not be built across the valley	121	32.1
Put refuse at designated places	85	22.6
Sustained educational campaign on flood mitigation	56	15.0
Construct defence walls/drains/bridges over the valley	40	10.6
Communal labour to clean drains	35	9.3

It is beyond us (cannot do anything about it)	27	7.3
Others	12	3.1
Total	376	100.0

Source: Field survey, 2014.

4.10.3 Tamale Metropolitan Assembly (TaMA)

The Tamale Metropolis is governed by the TaMA whose duties are to ensure proper planning of land use in the metropolis while ensuring that people are able to live safe and healthy lives. TaMA must also ensure that proper sanitation is maintained in the metropolis. These are some of the reasons why various departments under the TaMA have been established to undertake specific duties thus ensuring that all is well in the metropolis.

Respondents indicated clearly what they expect from TaMA in mitigating floods in the metropolis. About 48.5 % of respondents believe it is the duty of the TaMA to ensure that proper roads, drains and bridges are constructed to provide proper channels which are large enough to carry flood waters away. About 4.9 % claimed that buildings in the waterways should be pulled down while 17.6 % suggested that proper permits are obtained to encourage proper land use practices. About 3.0 % said TaMA should relocate those staying on the flood plain with 2.1 % suggesting a re-planning. Only 0.4 % of the respondents expected TaMA to dredge the drains. Residents confirmed that the Tamale Metropolitan Assembly had facilitated the dredging of parts of it some years ago. However, only areas which are closer to the main road were dredged, leaving other areas even more prone to flooding. Sediments and debris from the valley bed were excavated and deposited on the banks of the valley, creating some form of levees to help hold back flood waters. On the other hand, these embankments may be gradually washed back into the valley during heavy downpour of rain. One very important suggestion made by respondents was the need for TaMA to provide areas and containers for refuse disposal. Even though this suggestion was made by only 8.7 % of the respondents, it is a very critical point. This is because observations made in the field showed that the areas provided with waste disposal bins were either inappropriate or insufficient. Thus, refuse containers are not emptied often enough and refuse dumps are overflowing. There is no control and TaMA has looked on as residents dumped refuse in and along the banks of the valley with others even defecating into it. Proper waste disposal will go a long way to curb the problem of flooding in the affected areas in the metropolis (Table 4.12).

Table 4.12: Metropolitan assembly views of flood mitigation (suggestion from respondents)

Metropolitan assembly views of flood mitigation	Frequency	Percentage
Construction of roads, gutters and walls	182	48.5
Ensure proper permits for building houses	66	17.6
Establish designated place for dumping of waste	49	12.9
Provision of dustbins	33	8.7
Pull down houses on water ways	17	4.6
Relocate victims	11	3.0
Restructure/Re-plan the area	8	2.1
Clear choked drains	3	0.9
Dredging the valley	2	0.4
Others	5	1.3
Total	376	100

Source: Field survey, 2014.

4.10.4 Central Government

The Central government is represented by the TaMA. About 43.6 % of respondents believe it is the duty of the central government to ensure that proper roads, drains and bridges are constructed to provide proper channels which are large enough to carry flood waters away. About 18.4 % also believe that the Central government needed to provide sufficient financial and other resources to relevant department to enable them carry out their mandate well. It must be noted that it is not unusual for relevant government departments including TaMA to be under-resourced therefore making it difficult for them to fully discharge their duties. About 11.0 % of respondents suggested that government's provision of affordable housing for them to relocate would be very helpful while 4.9 % of respondents believe that pulling down houses in waterways would help remedy the situation. Table 4.13 summarises what respondents expect from the central government in mitigating floods in the Tamale metropolis flood prone zones.

Table 4.13: Central Government- views of floods mitigation by residents

Central Government views by respondents	Frequency	Percentage
Construction of drains, bridges, walls and roads	179	47.6
Provision of Financial and other resources	69	18.4
Relocate us to affordable housing	41	11.0
Redevelop the area	33	8.9
Pull down houses on waterways	18	4.7
Dredging the valley	15	4.0
Bring us relief items	12	3.1
Others	9	2.3
Total	376	100

Source: Field work, 2014.

4.11 Institutional perspectives on floods in the zoned area

4.11.1 Town and Country Planning Department (TCPD)

According to the TCPD, their functions include the formulation of long term comprehensive plans technically referred to as strategic plan, preparation of land use planning schemes to guide spatial development which is done through revision of planning schemes, re-zoning, rectification of planning schemes and regularizing of layouts. They also perform the functions of development management or control, development promotion and research into emerging land use problems in the metropolis as well as the provision of advice to the Metropolitan Assembly. The department played its role in flood control and prevention in the flood prone zones. They indicated that they relied on maps from the Survey department which showed the topography of the metropolis, indicating the high and the low points. There are some areas earmarked as nature reserves. The nature reserve is made up of vegetative cover which would protect the water bodies. The department indicated that it was not their duty to ensure enforcement of these plans. They were aware of a project by city authorities to provide proper drains to channel the flood water in the valley. They collaborated with agencies such as the Lands Commission, Survey Department, TaMA, Utility companies and even the citizenry including land owners and chiefs when developing land use maps. Unfortunately, they were not satisfied with the level of collaboration because a lot of land owners and chiefs do not abide by the zoning plans when developing their pieces of lands.

The TCPD indicated that they were poorly resourced financially and had only two professionals and four technical assistant planners serving the 3 sub metros of the TaMA. Ideally, the number should be about 9. They had no computers for the use of modern software such as the Geographic Information Systems (GIS). There is also only one vehicle which is always not in good working condition. They indicated also the Act 462 which the department was governed by was inadequate. In an attempt to help itself, they tried to generate funds internally by charging a fee for their services but monies generated ended in the central government account and could not be accessed. Building plans and other records were not well kept simply because there was no place to keep them. There were also no current copies of plans or even soft copies of them to ensure easy access. The TCPD blamed the human behaviour and non-enforcement of settlement rules as the causes of the floods in TaMA. Removal of vegetation cover increased erosion and sediment deposition during floods.

4.11.2 Metropolitan Waste Management Department (MWMD), Tamale

According to the mission statement of the MWMD, the department is 'to keep the Metropolis clean and healthy by ensuring the efficient and effective removal and safe disposal of solid and liquid waste from all premises and public spaces to create an enabling environment for development and recreation'. The functions of the MWMD are as follows:

- Keep the metropolis tidy
- Clear away mess and nuisance
- Develop and continuously update a metropolitan environmental sanitation plan
- Educate the public on how to keep the local environment clean
- Provide conveniently situated refuse disposal points
- Remove solid waste
- Dispose of waste safely
- Identify needs for public toilets
- Manage public toilets
- Manage promotion and subsidy programs for household toilets

- Evacuate liquid waste from homes and public toilets
- License and enforce standards on private liquid waste hauliers
- Manage sullage disposal
- Cleanse and carry out routine maintenance of drains.

The question therefore is why waste disposal is such a major problem in the metropolis and why do people dump refuse indiscriminately and choke the river and other drains in the process? The MWMD has no special regulations to control activities in flood prone areas but believe that improper waste disposal activities are responsible for the annual floods in the metropolis although it is not the only cause. The department was however aware of projects aimed at reducing the incidence of flooding in the metropolis river basin which included the construction of storm drains from the Gariba lodge through Gumani to reduce flooding.

MWMD had also taken specific action to prevent flooding in the metropolis river basin. Granted that improper waste disposal was a major cause, the metropolis' city-wide Waste Collection levy scheme was launched. People were supposed to pay for waste collection. Ten Ghana pesewas per head load was charged for communal collection and three to five Ghana cedis charged monthly for house to house collection. Those in the river basin usually accessed the former but only very few people paid. The majority preferred dumping their waste free of charge into the river channel instead. The department indicated that it was NADMO's duty so far as flood management in the metropolis was concerned and so they played no role in that. MWMD also blamed human behaviour and non-compliance with sanitation rules as major causes of flooding in the metropolis.

4.11.3 National Disaster Management Organisation (NADMO), Tamale

Among the functions of NADMO are to coordinate activities of all stakeholders in disaster management and educate the public on prevention of man-made disasters. The department did not have any special policies or activities for flood prone areas including the study area and also had financial, logistics and equipment as well as legal challenges which the TaMA had tried to solve but to no avail. NADMO believed that pollution of the Metropolis flood prone zones was the main cause of flooding and so people should stop dumping refuse into the river. However NADMO did not have any sustained public education programmes on flood mitigation. NADMO is also under-resourced by central government and located in a poorly maintained office accommodation with a computer and very poor database on disaster-related activities in the metropolis.

4.11.4 Ghana Meteorological Agency (GMA), Tamale

The functions of the GMA include observation of the weather, compilation of meteorological information observed, analysis of data based on which forecasting is done and serving the general public, i.e. providing information/data to all who need it e.g. farmers, contractors, shippers, etc. The agency had no special schemes or regulation for flood control in flood prone areas but believed that giving prior warning of heavy rainfall alerted people and relevant agencies as NADMO to prepare for the floods. To help manage floods in the metropolis, the GMA meets with NADMO periodically to discuss weather-related issues; especially forecasting extreme weather events and the need to alert the public to that effect: usually took place before the rainy and dry seasons respectively. The GMA is also agreed that human behaviour and non-compliance with settlement rules were the causes of the flood in the metropolis.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclutions

5.1.1. Causes of flooding

It is clear that flooding is indeed a phenomenon that occurs annually in the Metropolis. This would not have been a problem if the flood plains around the river were uninhabited. Another major cause of flooding identified is the indiscriminate dumping of refuse into and on the banks of the river. This impedes the free flow of water resulting in the inundation of its flood plain.

Climate change on the other hand has led to increases in average temperature and rainfall over the last twenty-seven years. Even though there is a positive relationship between rise in temperature and increased rainfall, this relationship is not very strong. This means that though climate change is one of the factors which cause heavy rainfall and hence flooding in the Metropolis, other factors also play a significant role.

Another cause of flooding which was discovered in the Metropolis is the building of all sorts of structures, from mosques to houses and business structures very close to the river. Thus, the flood plains of the Metropolis which have been zoned as a nature reserve has been occupied depriving the river of the protection of vegetation which would slow down erosion and the consequent siltation of the river. The inactions of institutions responsible for controlling land use have also been a major contributing factor to the incidence of flooding in the Metropolis flood prone zones. Even though the laws are there, the institutions are unable to enforce them.

5.1.2 Impacts of flooding

The impacts of flooding are both natural and man-made in nature. The people of Sogunayili, Gbalo, Jisonayili, Gumani, and Fuo have suffered a lot from the annual floods in their respective communities.

Natural impacts of flooding: The natural impacts of flooding include erosion caused by the flood waters. Observations made in the field showed deep gullies created by the running water. Thus, the physical nature of the land is continually altered. The top soils are being washed away and this has led to the exposure of the foundations of some buildings in the area. There were also partial submergence leading to the cracking of walls and floors of buildings. These structural defects on buildings have led to some affected people abandoning their buildings. All these affect the economic activities of residents. A lot of vulnerable people especially children and the aged are traumatised by these flooding events leading to the separation of family units in some cases since children may have to stay with friends and relations during incidence of floods. A lot of people also live in fear because their buildings are so damaged that they could cave in on them any time.

Man-made impacts of flooding: Man-made impacts arise due to the fact that people chose to live in the flood-prone areas. Residents modify buildings to cope with the floods. Walls and steps are erected to protect buildings and the people living in them. By virtue of the fact that people inappropriately live in the flood plain of the river, the socio economic challenges associated with the pre, during and post-flood events are obvious. Some respondents indicated that they often have to borrow money to cope with the situation. Others claim that their businesses are affected while some are unable to report to work during the floods.

5.1.3 The role of the relevant institutions

Institutions are generally under-resourced especially the Town and Country Planning Department and the National Disaster Management Organisation. They are simply unable to work effectively in the Metropolis flood prone zones. This has led to the persistence of the problem. Even though the area around the river has been zoned as a nature reserve, people have put up all sorts of structures and continue to dump refuse with impunity. Unfortunately, the authorities concerned are not enforcing the law as they should. Efforts to dredge the drainage channel and clean it up have all proved futile because after these activities, people just go back to create the same problem exacerbating the flooding problem as time goes on.

5.1.4 Short term mitigation measures

In the short term, the central government should make conscious effort to provide adequate funding to the relevant institutions to be able to perform their duties. For example, the MWMD should be enabled to properly collect and dispose of waste in the study area.

The laws protecting lives as well as the environment must also be enforced and those who break them appropriately punished to serve as a deterrent to others. If this is done, people will stop building in the nature reserve in the river basin and also make a conscious effort to properly dispose of their waste. Regular and effective removal of refuse from the river basin is essential in solving the flooding problem. Lastly, well designed drains which are wider and deeper should be constructed to properly channel the river's discharge through the city. Regular de-silting of the river would be very helpful in checking the flooding problem.

5.1.5 Long term mitigation measures

In the long term, the TaMA should develop a programme to gradually and effectively pull down buildings and relocate residents in the river basin especially those in the nature reserve. This should be based on a well thought-out programme. This is because people may need to be compensated and the alternatives provided should be adequate in order not to make life difficult for people. As the relocation takes place, the nature reserve should be gradually re-developed by tree planting and maintenance of these plants. If this is done, the nature reserve will be put in place in the long run and the place can be used as a recreational park while still protecting the river.

The destruction associated with the flood in the Tamale metropolis is largely man-made because of the refusal of the people to comply with settlement rules. Surprisingly, even those affected rather blame the authorities for doing nothing to help them. Observation of simple sanitation rules in waste disposal is also key to mitigating the floods, but human attitudes are not changing despite warnings. The need for relevant government agencies to engage in sustained public education on flood mitigation cannot be over-emphasised.

5.2 Recommendations

Further studies could concentrate on a more quantitative assessment of the flood damage in TaMA. This should include the cost of the loss of productivity, the cost of repainting damaged infrastructure, the cost of disruption of social services such as education, health, water and telecommunications, the cost of treating health-related issues etc.

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APPENDIX 1

Calculation of sample size

Calculating Sample Size:

$n = N / 1 + N (\alpha^2)$

where n = sample size

N = sample frame = 6488

α = Standard Error = 5% = 0.05

$n = 6488 / 1 + 6488 (0.05^2)$

= 375.7712

Calculation for stratified sampling:

Total sample size / Total number of households.

375.7712/6488 = 0.0579

Sample from each community:

0.0579× total number of households in the community

Sogunayili: 0.0579× 119 = 7

Gbolo: 0.0579× 56 = 3

Jisonayili: 0.0579× 2802 = 22

Gumani: $0.0579 \times 33345 = 337$

Fuo: $0.0579 \times 110 = 6$

APPENDIX 2

Calculation of Standard deviation for rainfall

Standard Deviation = X - x

$x = \Sigma X / N$

Where X = Total Annual rainfall

and x = Mean total rainfall

N = total number of years.

Calculating mean annual rainfall:

$x = \Sigma X / N$

$\Sigma X = 29542.2$

$N = 27$

Therefore,

$x = 29542.2 / 27$

$= 1094.2$

APPENDIX 3

Calculating Standard Deviation for various years is presented in the table below;

Table 14: Annual mean rainfall (mm) and deviations from mean (mm) for 27 years

Year	Annual mean rainfall (mm)	Deviation from mean (mm)
1987	956.9	-137.3
1988	1139.9	45.7
1989	1427.3	333.1
1990	1129.8	35.6
1991	1579.8	485.6
1992	695.3	-398.9
1993	1000.5	-93.7
1994	1158.8	64.6
1995	996.1	-98.1
1995	1150.7	56.5
1997	1228.9	134.7
1998	937	-157.2
1999	1382.3	288.1
2000	1024	-70.2
2001	791.3	-302.9
2002	563.3	-530.9
2003	1269.3	175.1
2004	1067.9	-26.3

2005	1141.3	47.1
2006	921.5	-172.7
2007	1046.6	-47.6
2008	1470.2	-24
2009	1103.3	9.1
2010	1306.8	212.6
2011	1082.4	-11.8
2012	1062.2	-32
2013	908.8	-185.4
Total	29542.2	-401.2

Source: Meteorological Agency, Tamale (2014).

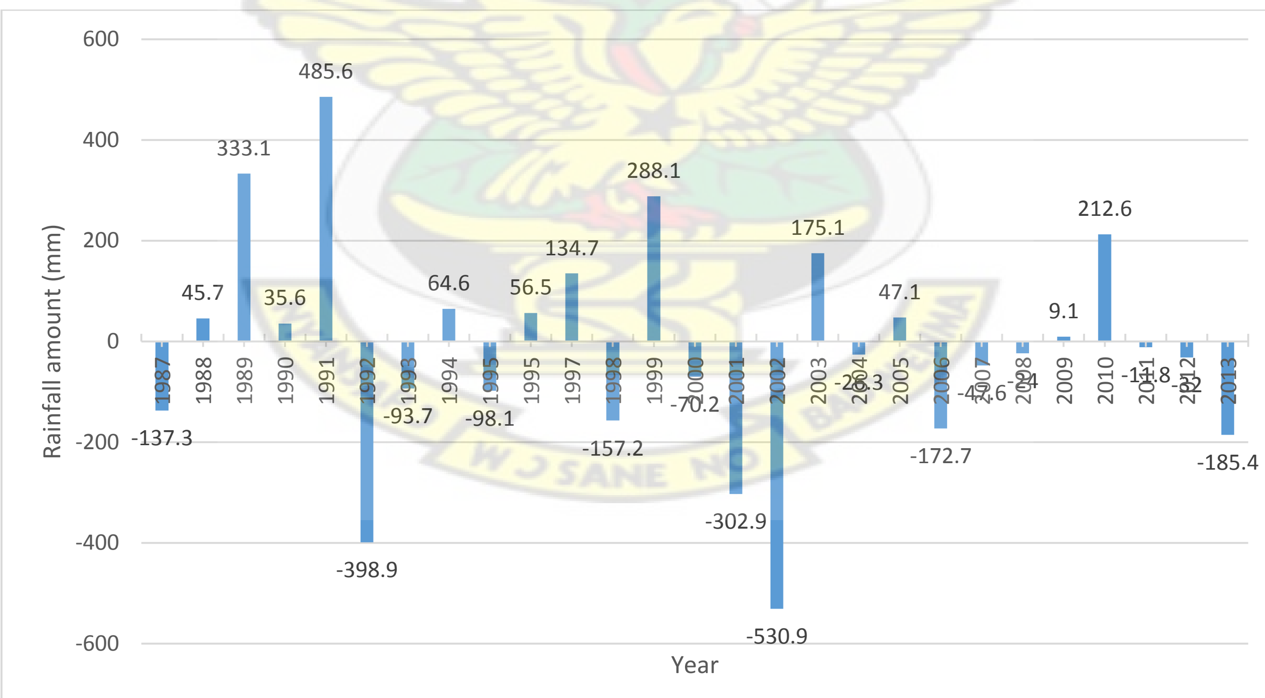

Figure 8: Graph showing deviations from annual mean rainfall (1987-2013)

Source: Field work, 2014.

APPENDIX 4

Calculation of Standard deviations for temperature

Standard Deviation = X - x

$x = \Sigma X / N$

Where X = Total mean annual temperature

x = Mean total temperature

N = total number of years.

Calculating mean annual rainfall:

$x = \Sigma X / N$

$\Sigma X = 775.7$

$N = 27$

Therefore,

$x = 775.7/27$

$= 28.73^0C$

APPENDIX 5

Calculating Standard Deviation from 1978 – 2013 is presented in the table below

Table 15: Annual mean temperature (^0C) and deviations from mean (^0C) for 27 years

Years	Annual mean Temperature (^0C)	Deviation from mean (^0C)
1987	28.56	-0.17
1988	28.43	-0.3
1989	27.84	-0.89
1990	28.78	0.05
1991	28.37	-0.36
1992	28.49	-0.24
1993	28.71	-0.02
1994	28.72	-0.01
1995	28.5	-0.23
1996	28.59	-0.14
1997	28.41	-0.32
1998	29.17	0.44
1999	28.64	-0.09
2000	28.68	-0.05
2001	28.84	0.11
2002	29.56	0.83
2003	28.58	-0.15

2004	28.45	-0.28
2005	28.85	0.12
2006	29.15	0.42
2007	28.93	0.2
2008	28.15	-0.58
2009	28.8	0.07
2010	29	0.73
2011	29.39	0.66
2012	29.02	0.29
2013	29.09	0.36
Total	775.7	

Source: Meteorological Agency, Tamale (2014).

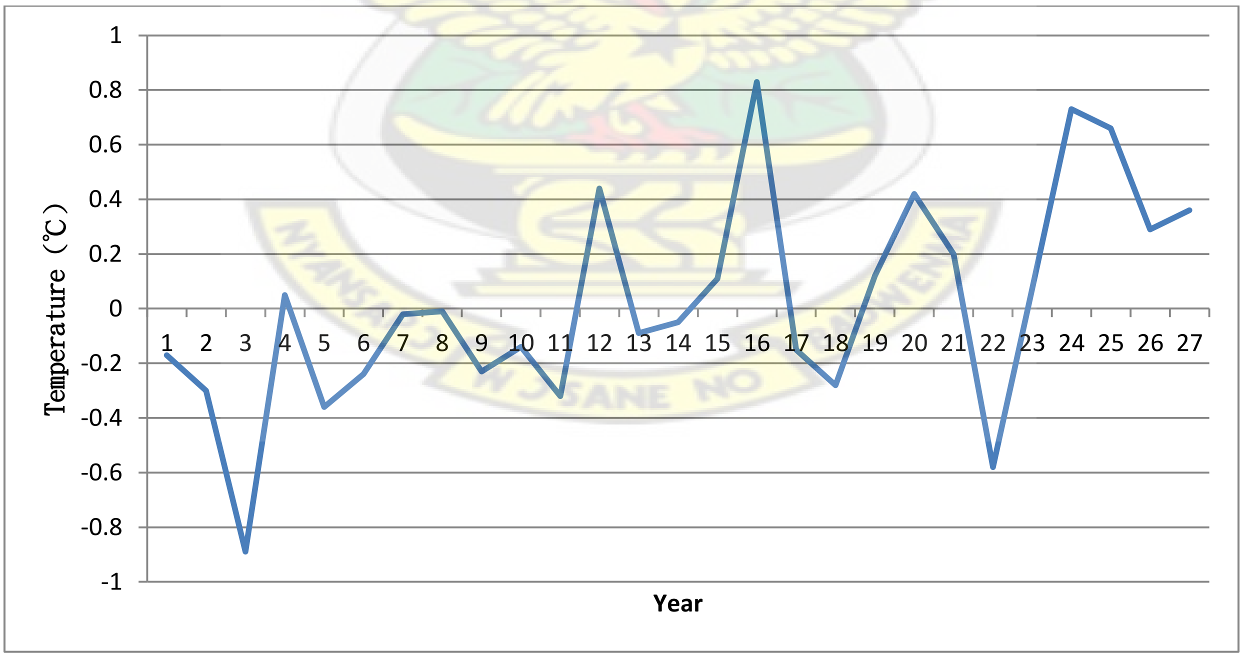

Figure 9: Graph showing deviations from total annual mean temperature (^{0}C) for 27 years

Source: Field work, 2014.

COLLAGE OF ENGINEERING

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

QUESTIONNAIR ON IMPACT OF FLOODING ON SOCIAL SERVICES IN THE TAMALE METROPOLIS OF GHANA

This research aims mainly at investigating the causes of flooding in the Tamale low land basin and the effects as a hazard on life, property and socio-economic activities of residents. It also aims at suggesting recommendations to remedy the problem.

This questionnaire is design to gather Information sole for academic purpose. I assure you that your identity and the information you provide will be treated with utmost confidentiality.

Kindly fill in the gaps and tick in the boxes with the most appropriate response(s). Thank you.

HOUSEHOLD QUESTIONNAIRE

1. (a) Name of Respondent:

…………………………………………………………………………………………

(b) Sex: Male [ ]　　Female [ ]

(c) Age: ....

(d) Ethnicity: ……………………………………..

(e) Household status………………………………

(f) Occupation: ……………………………………

(g) Educational attainment: (i) Primary [ ]　(ii) Secondary [ ]　(iii) Tertiary [ ]

(iv) None [ ]

(g) Length of stay in the community (i) 0 – 5 years [ ]　(ii) 6 – 10 years [ ]

(iii) 11 – 15 years [ ]　(iv) 16 – 20 years [ ]　(v) Above 20 years [ ]

(h) Residential status: Free occupant [ ] Tenant [ ] Owner-occupant [ ]

2. Has your household experienced flooding before?

Yes [ ] No [ ]

3. If yes, why do you still live here?

a. proximity to work [ ]

b. affordability of housing [ ]

c. did not face problems before [ ]

d. other [ ] , specify ....

4. What do you think are the causes of these floods?

Building in water courses [ ] Bad refuse Disposal [ ] Building Designs [ ]

Hard Landscaping [ ] Lack of Drains [ ] Poor design of Drains [ ]

Choked drains [ ], low lying nature of relief [ ], other [ ],

Specify …………...........………………

5. Are you willing to move out of this area in view of the floods?

Yes [ ] No [ ]

6. How often do floods occur in this area?

Once a year [ ] Twice a year [ ] Several times a year [ ]

7. When do floods occur during the year? ....

8. How long do the floods usually last?

(i) ....Hours (ii) ....Days (iii) ....Weeks (iv)...........Months

(v) Other [ ], specify...

9. Which agency (ies) or organization (s) comes to your aid during the floods?

a. National Disaster Management Organization (NADMO) [ ]

b. Tamale metro [ ]

c. Tamale Sub-metro [ ]

d. None [ ]

d. Other [ ], specify..

10. What did they do to help?

a. Provision of relief items (food, building materials, blankets, medicine, etc) [ ]

b. Rescue Effort [ ]

c. Other [ ], specify..

11. Do you think the procedures involved in locating any activity (land use) on land in this area/community are followed?

Yes [ ] No [ ]

12. How do you dispose of waste in this area?

(i) Public Dump [ ] (ii) Door to Door [ ] (iii) Dumping in the valley [ ]
(iv) Dumping at the banks of the valley [ ] (v) Burning [ ] (vi) Burying [ ]

(vii) Others [ ] specify...................……………………………………………

13. How much do you pay to dispose of waste in this area?

(i) 0 – 0.99 Ghana cedi [ ]

(ii) 1 – 1.99 Ghana cedis [ ]

(iii) 2 – 2.99 Ghana cedis [ ]

(iv) Above 3 Ghana cedis [ ]

(v) Nothing [ ]

14. How often do you pay this levy to enjoy the service and properly dispose of your waste?

a. Daily [ ]

b. Weekly [ ]

c. Monthly [ ]

d. Other [ ], specify...

15. What do you do when the floods occur?

....

....

....

16. In what ways are you affected by the floods?

(i) Social (Education, Health etc)

....

....

(ii) Property Damage

....

....

(iii) Economically

....

....

(iv) Housing (structure)

…………………………………………………………………………………………….........................

....

(v) Others (specify)

……………………………………………………………………………………………....

....

17. Do you think these floods can be prevented?

Yes [ ] No [ ]

18. If yes, how can these be achieved?

....

....

19. Have the members of this community made any efforts to prevent flooding?

Yes [ ] No [ ]

20. Give reasons for your answer.

....

....

....

21. What do you do before the floods set in?

....

....

....

22. What do you do when the floods actually occur?

....

....

....

23. How do you cope with the danger of incidence of annual flooding in your area?

(i) Stay with friends and/or relatives [ ]

(ii) Build walls/steps to block the flood waters [ ]

(iii) Construct temporary bridges to access our property [ ]

(iv) Construct temporary drains [ ]

(v) Clear choked gutters [ ]

(vii) We just hope and pray the floods do not occur [ ]

(viii) Other [ ], specify...

24. What do you do after the floods?

....

....

25. Do you usually report the incidence of flooding any authority?

Yes [ ]   No [ ]

26. If yes, which authorities did you report to?

(a) Tamale metro [ ]

(b) Tamale sub-metro [ ]

(c) Chief Palace [ ]

(d) Assemblyman/Unit Committee Member [ ]

(e) Other [ ] specify...

27. Are you aware of the city authorities' (TaMA) efforts to solve this problem?

Yes [ ]   No [ ]

28. If yes, what exactly have these efforts been?

....

....

....

29. What do you think the following should do to solve the problem of flooding in this area?

Households:

....

....

Community:

....

....

Tamale Metropolitan Assembly (South, Central and North sub-metros):

....

....

Central Government:

....

....

Additional Comment/Observation (if any):

………

………

………

………

………

COLLAGE OF ENGINEERING

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

QUESTIONNAIR ON IMPACT OF FLOODING ON SOCIAL SERVICES

IN THE TAMALE METROPOLIS OF GHANA

This research aims mainly at investigating the causes of flooding in the Tamale low land basin and the effects as a hazard on life, property and socio-economic activities of residents. It also aims at suggesting recommendations to remedy the problem.

This questionnaire is design to gather Information sole for academic purpose. I assure you that your identity and the information you provide will be treated with utmost confidentiality.

Kindly fill in the gaps and tick in the boxes with the most appropriate response(s). Thank you.

SAMPLE INSTITUTIONAL QUESTIONNAIRE

1. (a) Name of Respondent

…………………………………………………………………………………………………

(b) Name of Institution

……………………………………………………………………………………………………

(c) Official position Held

…………..……………………………………………………………………………………..

…………………………………………………………………………………………………

2. Major functions of institution

(i)………………………………………………………………………………………………

……………………………………………………………………………………………………

(ii)……………………………………………………………………………………………...

……………..

(iii)……………………………………………………………………………………………..

……………………………………..

(iv)……………………………………………………………………………………………..

……………………………………..

3. (a) Do you have any special regulations to control activities in flood prone areas of the Metropolis? Yes [ ] No [ ]

(b) If yes, are they being enforced? Yes [ ] No [ ]

(c) Do you think improper waste disposal activities are responsible for the flooding of communities in the Metropolis river basin? Yes [ ] No [ ]

Give reasons for response

(i)………………………………………………………………………………………………

...……………………………………………………………………………………………

(ii)……………………………………………………………………………………………...

…………………………..…………………...

(iii)…………………………………………………………………………….…..........................

....

(iv)……………………………………………………………………………………………..

………………………………………………………………………………………………

4. (a) Are you aware of any programmes/projects aimed at reducing the incidence of flooding in the Metropolis river basin? Yes [ ] No [ ]

(b) If yes, which one(s)

(i)…………………………………………………………………………………………………...

…...

(ii)……………………………………………………………………………………………...

………………………...………...

(iii)……………………………………………………………………………………………..

……………………………………………………………………………………………………

5. (a) What specific actions do you take in flood prevention in the Metropolis river basin?

(i) ………………………………………………………………………………………...

……………………………………...

(ii) ……………………………………………………………………………………………

……………………………………...

(b) What specific actions do you take in flood management in the river basin?

(i)…………………………………………………………………………………………………

……………………………………...

(ii)..

……………………………………………………………………………………………………

(iii)…………………………………...

....

(b) Is the institution adequately resourced to carry out its responsibilities?

Yes [ ] No [ ]

If No, in what areas are you challenged?

Human

……

……………………………………………………………………………………………...................

Financial

……

……

Logistics & Equipment

……

……

Legal

……

………………………………………………………………………………………………..............

Others (specify)

.................……………………………………………………………………….………………………

……

(c) What steps are being taken to address them?

(i)…………………………………………………………………………………………..........

……

(ii)………………………………………………………………………………………………

……………………………………………………………………………………………….

(iii)………………………………………………………………………………………………

……………………………………………………………………………………………....

8. (a) Do you collaborate with any agencies in flood management and prevention with specific reference to the TaMA river basin?

Yes [ ]   No [ ]

(b) If Yes, which one(s)?

(i)…………………………………………………………………………………………

……...

(ii)………………………………………………………………………………………......

…………..……………………………………………………………………………………..

(iii)……………………………………………...

....

(c) Are you satisfied with the level of collaboration? Yes [ ] No [ ]

(d) If no, why?

…………………………………………………………………………………………………

……………………………………………...

…………………………………………………………………………………………………....

9. What do you think are the causes of flooding in the river basin in the Metropolis?

(i)………………...

....

(ii)……………………………………………………………………………………...…

…………………………………………………………………………………………………

(iii)……………………………………………………………………………………………

…………………………………………………………………………………………………

(iv)……………………………………………………………………………………………….

…………………………………………………………………………………………………

10. (a) Do you involve the citizenry in the Metropolis river basin in the activities of the institution?

Yes [ ]   No [ ]

(b) If yes, at what level?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(c) How do you rate their level of participation?

High [ ]   Average [ ]   Low [ ]   Nil [ ]

(c) What do you think accounts for this level?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

(d) If No, why?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

11. What do you think the following should do to solve the problem of flooding in the Metropolis river basin?

Households

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Communities

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Metropolitan Waste Management Department, TaMA

……

……

Central Government

……

……

Additional Observation/Comments (if any):

……

……