

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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SCHOOL OF GRADUATE STUDIES

COLLEGE OF SCIENCE

**A GIS – BASED FLOOD RISK MAPPING: A CASE STUDY OF PRU
DISTRICT IN THE BRONG AHAFO REGION OF GHANA**

A Thesis Submitted to the Department of Environmental Science of the Kwame
Nkrumah University of Science and Technology in Partial Fulfillment of the
Requirements of
Master of Science Degree in Environmental Science

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DECLARATION

I, Frederick Kwame Sakyi hereby declare that this submission is my own work towards the MSc Environmental Science and that, to the best of my knowledge it contains no material previously published by another 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

Pru District of Ghana has been experiencing yearly flooding that affects properties and lives. But the floods of 2010 brought a lot of difficulties and untold hardships on the affected victims in the District. Hence there was the need to find a new method of identifying and mapping potential flood risk zones, determining the extent of land cover and land use changes, and determining the effects of flood on affected victims. Geographic Information System (GIS) and Remote Sensing were integrated to map out the flood risk zones and also determined the land use and land cover changes. A total of 226 household heads and 11 officials of National Disaster Management Organization, District Assembly, Environmental Health and Sanitation Department, District Agricultural Development Unit and the District Health Directorate in the District were interviewed. In determining the flood risk zones, the Shuttle Radar Topographic Mission 90 meters Digital Elevation Model was used to produce the flood risk map of the District and classified the flood risk zones into high, medium and low. It was realized that 3,246.26 km² (52.68%) of the land areas fall within the high flood risk zone, 754.54 km² (12.24%) fall within medium flood risk zone and 2,161.79 km² (35.08%) fall within the low flood risk zone. The Landsat Thematic Mapper and Enhanced Thematic Mapper plus images of 1990 and 2006 of the study area were used to determine the land cover and land use changes. It was shown that between 1990 and 2006, the vegetative cover decreased by 17.25%, built up / bare surfaces increased by 18.50% and water bodies decreased by 1.25%. About 283 houses got submerged by the flood at Banyawaya, Fante Akura and Yeji Nsuano with another 69 submerged at Kobre. About 68.53% of the farmers had their farms totally or partially inundated by the floods in 2010 resulting in food insecurity, psychological problems for farmers, and increase in the prices of some food commodities. The integrated use of GIS and Remote Sensing serve as valuable tool in identifying and monitoring flood risk zones.



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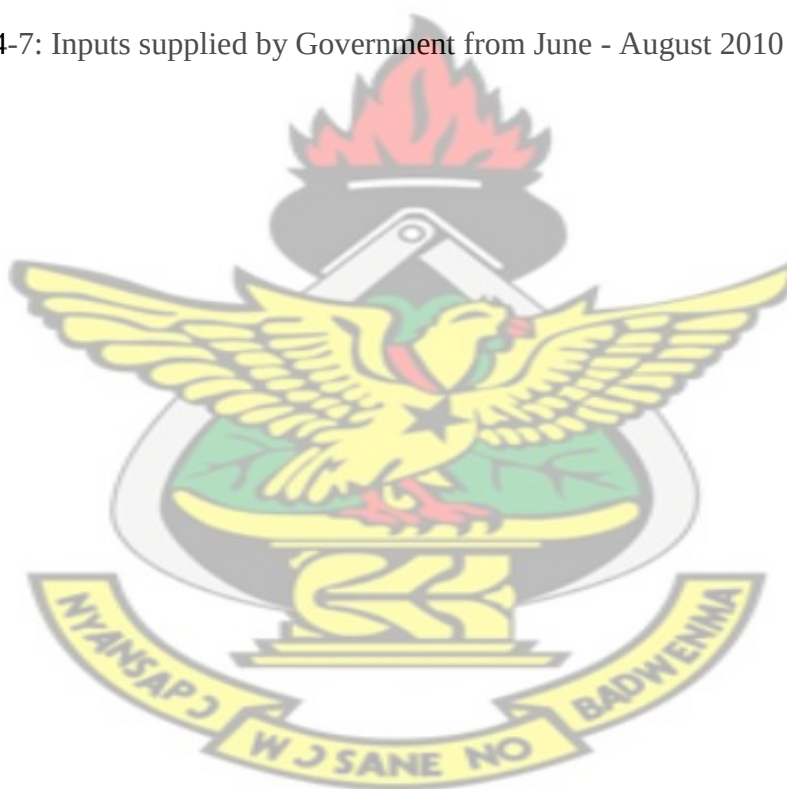
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LIST OF ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
ARB	African Research Bulletin
DADU	District Agricultural Development Unit
DEM	Digital Elevation Model
DHD	District Health Directorate
EC	European Commission
ESD	Environmental Health and Sanitation Department
ESRI	Environmental Systems Research Institute
ETM+	Enhanced Thematic Mapper Plus
GIS	Geographic Information Systems
GPS	Global Positioning System
IFRC	International Federation of Red Cross and Red Crescent Societies
MOFA	Ministry of Food and Agriculture
NADMO	National Disaster Management Organization
NASA	National Aeronautics and Space Administration
PDA	Pru District Assembly
PD	Pru District
SRTM	Shuttle Radar Topography Mission
STWSS	Small Town Water Supply System
TM	Thematic Mapper
USGS	United States Geological Survey
UCAR	University Corporation for Atmospheric Research
UNDP	United Nations Development Programme
UTM	Universal Transverse Mercator
WGS	World Geodetic System

CHAPTER ONE

1.0 Introduction

1.1 Background to the Study

The incidence of torrential rains and their effects on river discharge normally result in flooding within communities along river banks and also in certain parts of the communities having poor drainage systems and land forms. Flooding refers to the inundation of an area by unexpected rise of water to a certain depth by either dam failure or extreme rainfall duration and intensity where human and other animal lives and properties in the affected area are under risk. Risk is the probability of a loss, and this depends on three elements; hazard, vulnerability and exposure (Crichton, 1999). Where studies of risk cover issues like identification and estimation of risk, risk assessment and evaluation include monitoring and management of risk (Gerrard, 1995). A research carried out by Lutgens and Tarbuck (2012) indicated that the most deadly and most destructive risk of all geologic hazards is flood. Nevertheless, they are simply part of the natural behaviour of streams and rivers. Cunningham and Cunningham (2011) similarly show that among direct natural disasters, floods take the largest number of human lives and cause the most property damage. Globally, flooding has become one of the common occurrences of natural disasters that knows not boundary. As they are naturally occurring, they cannot be prevented and have the potential to lead to fatal causes such as displacement of people and damage to the environment (Adeoye *et al.*, 2009; IFRC, 2011). Cunningham and Cunningham (2011) reported that a flood on the Yangtze River in China in 1931 killed 3.7 million people, making it the most deadly natural disaster in recorded history. In another

flood on China's Yellow River in 1959, about 2 million people died, mostly due to famine and disease.

In Africa, flooding is a serious problem as most African countries lack the technological and financial resources in combating flooding impacts. In the period between 1996 and 2005, floods have had devastating effects on the continent of Africa and it is reported that during that period, there were 290 flood-disasters in Africa alone, which left 8,183 people dead and 23 million people affected, which caused economic losses of \$1.9 billion (Satterthwaite *et al.*, 2007). Also, media and aid organizations have reported a lot of flooding incidences in Sub-Saharan Africa which resulted from several days of rainfall (Paeth *et al.*, 2010). The cost of losses resulting from floods in Mozambique has been of the order of millions of United States dollars and the country has been affected by flooding almost yearly since it gained its independence from Portugal in 1975 (Wisner, 1979; ADB, 2007). Recently, GNA (2013) has reported the flooding incidence in Central Nigeria's Plateau State which resulted in the loss of at least 39 human lives. In similar reports, it was indicated that torrential rain has caused flooding paralyzing most parts of the Philippine Capital, Manila. Nigeria has recorded some of the highest death toll in the West African region. In the northern parts of the country, entire villages and agricultural land have been destroyed by flooding (ARB, 2010).

Flooding is a serious environmental issue affecting Ghana, and with rising sea levels it may become an even greater problem (Rain *et al.*, 2011). It is expected that an increased level of cyclonic storms to a great extent and storm surges to a lesser extent, will be associated with future climate change and may increase flood occurrence in spatial patterns similar to those of the present. Ghana ranks high amongst African countries most exposed to risks from multiple weather related

hazards particularly the natural hazards such as floods and droughts (UNDP/NADMO, 2009). Runoff in the Volta basin in Ghana is similarly sensitive to precipitation (Andreini *et al.*, 2000). When intense precipitation occurs, runoff increases with increase in velocity and width thereby being resultant effect of flooding in communities within the banks of the Volta River in the Pru District. It could be seen that Pru District faces the two major flooding types, namely flash flood and coastal flood as reported in Smith and Ward (1998). Smith and Ward (1998) further explained that, flash floods intensification is caused by drainage network and stream channels as rains increase within a spatial area over a short period of time. It leads to rising levels of shallow basins probably due to very dry conditions (semi-arid conditions). Over the years, the response of government and other relief agencies to floods in Pru District has been in the area of rescue and supply of relief materials to victims of flood. Nothing has been done to ensure that the hazard is prevented and its associated risk is reduced to the barest minimum (Jeb and Aggarwal, 2008). Reduction of risk of flooding will depend largely on the amount of information on floods that is available and knowledge of the areas that are likely to be affected during a flooding event.

1.2 Problem Statement

Seasonally, Pru District especially communities that are within the banks of the Volta River are flooded to the extent that damages are caused to human lives and other properties. In 2010 certain portions of the settlements in Pru District were flooded after torrential rains. During these periods about 48 residential buildings collapsed at Kobre, with another 360 houses being washed away and over 1000 residents displaced in Fante Akura (NADMO, 2010). Also, the lives of people living on some of the islands are severely threatened as almost all or majority of the island

communities are being inundated by the overflowing Volta Lake and also from intense rainfalls. Cherepo and Makpe in the Pru District were also affected by intense rainfall resulting in flash floods. A number of these settlements are, however, located on poorly drained land that is often prone to flooding after prolonged rain (Musungu and Motala, 2012). These areas were flooded beyond the reach of others. Affected victims and other people have to commute to and fro by using canoes. Even the difficulties encountered with movement cannot be wholly quantified in monetary terms. Some victims have to seek shelter in some of the school buildings, causing delays in schools' academic works which certainly affect the performance of school children, a situation which is irreversible in the lives of affected pupils. In 2010, some structures have also been totally washed away and some submerged by the River Volta including one of the restaurants in the town. The Small Town Water Supply System (STWSS) facilities in Yeji and Parambo/Sawaba got inundated by the overflowing Volta Lake which compelled people living in these towns to depend on the polluted lake which could potentially affect the health of the people (GNA, 2010). From a preliminary field study conducted in the district, it was revealed that, malaria, cholera, cold, diarrhoea, typhoid fever and headaches were the health problems associated with the floods. Malaria was the highest reported health problem suggested by the respondents and cholera being the least with 198 (87.61%) and 9 (3.98%) responses respectively (Appendix E). About 13 (5.75%) and 26 (11.5%) of the respondents also suggested the incidence of snake bites and swollen hands / legs respectively during the floods (Appendix E).

The Sustainable Rural Water Supply Project (SRWSP) was a World Bank (WB) and the International Development Agency (IDA) funded project for selected districts, in six regions of the country, with Pru District being a beneficiary but unfortunately

losing this project which was worth million dollars to the floods. The town is noted for its popular market attraction (The second largest market to Techiman Market in the Brong Ahafo Region of Ghana) across the country, but with this flooding crisis, the market could be potentially affected as traders have to relocate from their structures to places far from the original market site and adversely experience a fall in business. However, current flood risk management techniques such as provision of relief items and renovation of some damaged structures by the authorities of the Pru District Assembly (PDA) are not designed to provide a long term mechanism against floods. In fact, owing to inadequate information about the nature of flood risk within the individual informal settlements, the PDA has often implemented inappropriate remedies within such settlements.

1.3 Research Aim and Objectives

1.3.1 Overall Aim

The aim of this research was to map out flood risk areas in Pru District in the Brong Ahafo Region of Ghana using GIS.

1.3.2 Specific Objectives of Research

In order to achieve the aim of this research, the following specific research objectives have been developed. These include:

- 1) Mapping out flood prone areas in Pru District in the Brong Ahafo Region of Ghana using Remote Sensing and GIS,
- 2) Determining the extent of land cover and land use changes in Pru District of the Brong Ahafo Region of Ghana using GIS method and Remote Sensing data, and

- 3) Determining the effects of floods on affected victims in Pru District in the Brong Ahafo Region of Ghana.

1.4 Research Questions

The following research questions were addressed during the period of study:

- 1) Where are the areas that are most vulnerable to flooding?
- 2) How do changes in land cover and land use contribute to flooding?
- 3) What are the effects that these floods have on the affected victims?



CHAPTER TWO

2.0 Literature Review

2.1 Introduction

A flood is defined by the Oxford English Dictionary as “An overflowing or irruption of a great body of water over land in a built up area not usually submerged.” Floods are natural phenomena, but they become a cause for serious concern when they exceed the coping capacities of affected communities, damaging lives and property. Globally, floods are the most frequently occurring destructive natural events, affecting both rural and urban settlements (Jha *et al.*, 2012). Also Floods are normal events that cause damage when people get in the way. As rivers carve and shape the landscape, they build broad flood plains; level expands that are periodically inundated. Large rivers, such as the Volta, can have huge flood plains. Many communities have been built on these flat, fertile plains, which are so convenient to the river. Flood plains that flood very irregularly may appear safe for many years, but eventually, most flood plains do flood. Many climate scientists predict that global warming will cause more extreme weather events, including both severe droughts in some places and more intense rainfall in others with high runoff (Cunningham and Cunningham, 2011). The amount of runoff ranges from 2% to more than 25% with variations in climate, steepness of slope, soil and rock type and vegetation. Steady, continuous rains can saturate the ground and the atmosphere, however, and lead to floods as runoff approaches 100% of rainfall (Plummer and McGeary, 1993).

Understanding flood hazard requires knowledge of the different types of flooding, their probabilities of occurrence, how they can be modeled and mapped, what the

required data are for producing hazard maps and the possible data sources for these hazards (Jha *et al.*, 2012). 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.

This aspect of the research therefore focuses on issues relating to flooding in Ghana and the Pru District. In this light, relevant literature materials of concern to the study have been reviewed to provide a basis for having an explanation to flooding and its causes, the identification and assessment of flood prone areas, management of floods and scientific ways of addressing flooding problems.

2.2 Understanding Flood Damages

“Flood damages” refer to all varieties of harm caused by flooding. It encompasses a wide range of harmful effects on humans, their health and their belongings, on public infrastructure, cultural heritage, ecological systems, industrial production and the competitive strength of the affected economy. Flood damages differ occasionally but are mostly categorized firstly into Direct and Indirect damages and secondly, Tangible and Intangible damages (Parker *et al.*, 1987; Penning - Rowsell *et al.*, 2003; Messner and Meyer, 2005). The research works of (Parker *et al.*, 1987; Penning - Rowsell *et al.*, 2003; Messner and Meyer, 2005) explain that, direct flood damage covers all varieties of harm which relate to the immediate physical contact of flood water to humans, property and the environment. This includes, for example, damage to buildings, economic assets, loss of standing crops and livestock in agriculture, loss of human life, immediate health impacts, and loss of ecological goods. Indirect flood damages are damages caused by disruption of physical and economic linkages of the economy, and the extra costs of emergency and other actions taken to prevent flood damage and other losses. But damages which can be

specified in monetary terms such as loss of production are called tangible damages and those that cannot be valued in monetary terms such as casualties, health effects and damages to ecological goods which are not traded in the market are far more difficult to assess in monetary terms. Quantification of flood damages is quite difficult as it has other developed issues years after. But flooding and its damages in global, national and district perspectives are discussed below:

2.2.1 Flooding in Global Perspective

According to Cunningham and Cunningham (2011) floods occur when the flow of a stream becomes so great that it exceeds the capacity of its channel and overflows its banks. They further indicated situation where torrential rains in June 2008 caused massive flooding across the American Midwest, where many cities in Iowa, Wisconsin, Illinois and Indiana experienced their highest water levels in more than a century. In Cedar Rapids, Iowa, for example, almost the entire downtown was inundated by the overflowing Cedar River (Figure 2-1).



Figure 2-1: The flooding Cedar River; covers a large portion of Cedar Rapids, Iowa, on June 14, 2008. Source: (Cunningham and Cunningham, 2011).

The 2008 floods in the Mississippi River basin caused billions of dollars in property damage with the biggest economic loss usually not being the buildings and property they wash away, but rather the contamination they cause. Virtually everything floodwaters touch in a house: carpets, furniture, drapes, electronics, even drywall and insulation, must be removed and discarded because of the sewage, toxic chemicals, farm waste, dead animals, and smelly mud carried by the water (Cunningham and Cunningham, 2011). In some cases, sediment left behind by floods has completely buried whole towns. In 2008, more than 2 million ha (5 million acres) of rich farmland was inundated in the heart of America's corn (maize) and soybean producing area. The USDA estimates that this will result in loss of 200 million bushels (about 5 million metric tons) of corn and 40 million bushels of soybeans at a time when these commodities are already at record high prices. These losses are likely to exacerbate worldwide food shortages (Cunningham and Cunningham, 2011).

2.2.2 Flooding in Ghana

The heavy rains recorded in Ghana in June 2010 caused severe flooding, especially for many communities in the south (IFRC, 2011). The floods caused varying degrees of destruction leading to the displacement of thousands of people including children while property like houses, bridges and shops were washed away. Among the most affected areas was Ashaiman in the Greater Accra Region where 11 persons died (GNA, 2010). Residents living close to the river that runs through the town were particularly affected. Also in central Accra, heavy rain and the local rapid runoff of the Odaw River rose above its riverbanks and flooded the nearby areas (Figure 2-2).



Figure 2-2: Flooding in central Accra after a heavy rain. Source: (NADMO, 2011).

In Agona Kwanyako in the Central Region 10 deaths were reported, and hundreds of persons were rendered homeless. In the same region, the floods affected nine communities with many houses submerged as the Ayensu River burst its banks. In all, 1,300 people were displaced by the floods in Gomoa East District. Swedru Township was also divided into two halves following the collapse of the two main bridges (GNA, 2010). Agona Nyakrom was completely cut off from the rest of the country following the collapse of a bridge linking the town to the rest of Ghana. Government agencies and humanitarian actors including the Ghana Red Cross Society intervened to assist the affected population with evacuation, first aid, psychological support and provision of immediate basic food and non-food relief items.

In 1999 rainfall induced storm caused coastal floods that resulted in many deaths across the coastal parts of Ghana (Karley, 2009). In June 2001 torrential rain caused widespread flooding in Ghana and particularly Accra, leaving 11 people dead and over 100,000 without homes (Karley, 2009). Due to heavy rains, most rivers in the city centre broke their banks and several roads were submerged or washed away

completely. In 2005 Ghana was one of the worst hit of the countries in western Africa that experienced severe flooding. Reports indicated that this flooding resulted in 20 people killed across the Upper East, Upper West and Northern regions of the country (Karley, 2009). The National Disaster Management Organisation (NADMO) estimates that about 350,000 people were severely affected during these flooding incidents and several hundred hectares of crops of farmland were completely washed away (Figure 2-3). In more recent times, many deaths have occurred across Ghana attributable to flash floods, in addition to those resulting from the more usual cause of river flooding (Karley, 2009). Over 25% of the population of Accra lives on fluvial flood plains or areas identified as being subject to the risk of fluvial flooding and about 50% of the population in the greater Accra region lives on the floodplain of the Densu and tributaries of other rivers (Karley, 2009). Also, across mountainous areas in Ghana, the population are at risk of flash floods, the most recent occurrence of this being Mallam. Whilst heavy rainfalls have been the main cause of recent flooding in Ghana, this has been aggravated by human activities including damming and opening of dam gates as well as dumping refuse in water courses (Karley, 2009). For instance, water from the Bagre dam in Burkina Faso allows people living nearby to irrigate their land during the dry season. It also replenishes levels of water in the Akosombo Dam in Ghana, which when dropped to below minimum levels cause power outages across the country. However, the area is hit by floods when there is severe rainfall. In 2007, when the water from the dam reached very high levels the flood gate of the Bagre dam in the east of the country, was opened. This released water at a force of 900 m³ per second into the White Volta River, which flows into Ghana and caused severe flooding. This affected the whole country and the northern regions in particular (Karley, 2009).



Figure 2-3: Submerged farms in Northern Ghana, 2007. Source: (Karley, 2009)

In 2008 it was estimated that the summer flooding in July and August caused more than US\$1 million worth of damage in the country (Karley, 2009).

2.2.3 Flooding in Pru District

In 2008 and 2010 certain portions of the settlements in Pru District were flooded after torrential rains causing much difficulty to its affected victims (Figure 2-4).



Figure 2-4: Floods in Yeji town, 2010. Source: (GNA, 2010).

A number of these settlements are however located on poorly drained land that is often prone to flooding after prolonged rain (Musungu and Motala, 2012). These areas were flooded in such a way that they were beyond the reach of others. Affected victims and other people have to commute to and fro by using canoes (Figure 2-5).



Figure 2-5: MOFA Director and PDA Members on a visit to a flooded block farming community. Source: (MOFA, 2011)

Even the difficulties encountered with movement cannot be wholly quantified in monetary terms. Some victims have to seek shelter in some of the school buildings causing delays in schools' academic works which certainly affect the performance of school children, a situation which is irreversible in the lives of affected pupils (NADMO, 2010). The Small Town Water Supply System (STWSS) facilities in Yeji and Parambo/Sawaba got inundated by the overflowing Volta Lake which compelled people living in these towns to depend on the polluted lake (GNA, 2010) which could potentially affect the health of the people (Figure 2-6).



Figure 2-6: Abandoned STWSS Facility due to the 2010 Floods.

This Sustainable Rural Water Supply Project (SRWSP) was a World Bank (WB) and the International Development Agency (IDA) funded project for selected districts, in six regions of the country, including the Brong-Ahafo, which has 11 out of its 22 districts and municipalities benefiting with Pru District being a beneficiary but unfortunately losing this project to floods which was worth millions of dollars (GNA, 2010). The National Disaster Management Organization in the Pru district was able to identify few of the flood affected areas in 2010, the number of people affected, their sexes, the type of damages and the estimated amount needed to provide relief items for the affected victims (Table 2-1). It can be deduced that over 261 houses were affected with over 2,172 people affected at an estimated cost of GH¢ 122,233.36. The destructions caused by floods are so alarming that some have relocated far from the district due to the psychological, financial and emotional stresses they went through (NADMO, 2010).

Table. 2-1: Disaster Data Sheet

S/N	Date of Incident	Type of Disaster	Communities Affected	Number of Displaced Victims				Destructions		Estimates GH¢
				Adults		Children		Number of farms	Houses	
				Male	Female	Male	Female			
1	17/09/2010	Floods	Cherepo	99	110	123	131	-	53	26,112.60
2	18/09/2010	Floods	Kwayase	73	95	89	97	28	46	11,211.30
3	19/09/2010	Floods	Konkoma	12	36	46	52	19	23	9,234
4	20/09/2010	Floods	Jindinbisa	15	31	23	38	-	13	2,561.15
			South							
5	21/09/2010	Floods	Yeji central	9	20	35	41	-	21	2,012.12
6	22/09/2010	Floods	Yeji Nsuano	6	21	41	47	16	13	1,934.32
7	23/09/2010	Floods	Kobre	90	115	121	137	26	50	23,011.09
8	24/09/2010	Floods	Parambo/Saw	58	93	93	78	19	24	44,313.12
			aba							
9	25/09/2010	Floods	Kadua	25	32	15	25	16	18	1,843.58
Total				387	553	586	646	124	261	122,233.36

Source : (NADMO Pru District, 2010)

2.3 Types and Causes of Floods

Floods usually result from a combination of meteorological and hydrological extremes, such as extreme precipitation and flows (Jha *et al.*, 2012). However they can also occur as a result of human activities: flooding of property and land 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 (Jha *et al.*, 2012). 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 (or fluvial) floods, pluvial (or overland) floods, coastal floods, groundwater floods or the failure of artificial water systems (Jha *et al.*, 2012). Based on the speed of onset of flooding, floods are often described as flash floods, urban floods, semi-permanent floods, and slow rise floods.

But in Ghana, Actionaid (2012) identified four types and causes of flooding in Ghanaian towns and cities, these are:

1. Localised flooding due to inadequate drainage;
2. Flooding from small streams whose catchment areas lie almost entirely within the built-up area;
3. Flooding from major rivers on whose banks the towns and cities are built; and
4. Coastal flooding from the sea or by a combination of high tides and High River flows from inland.

Floods of the first and second types are much more frequent than those from major rivers. The fourth type of flooding occurs where settlements have been built on coastal wetlands and mangrove swamps.

2.4 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 also discussed below.

2.4.1 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. 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). Diarrhoea - related deaths are primarily caused by a lack of pure drinking water, improper storage and handling of drinking water, poor hygiene practices and the 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). 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).

2.4.2 Buildings and Contents

Buildings and their contents can be directly and indirectly affected by flooding in a range of ways. 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 floodwaters 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 (Jha *et al.*, 2012).

2.4.3 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 damage 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).

2.5 Indirect and Other Effects of Flooding

Indirectly certain features and people will be affected during and after flood events. Most of these indirect effects manifest years later. They have long lasting effects on people and the environmental components.

2.5.1 Human and Social Impacts

The survivors of floods have a range of immediate needs, including safe drinking water, food and shelter (Jha *et al.*, 2012). Such survivors are likely to be traumatized and vulnerable. It is a harsh truth that in cases where flood warnings, evacuations and safe havens have been successful this increases the demands after the flood in dealing with the larger number of displaced people than if these people had not survived. Lives saved during the emergency may result in increased hardship and deaths in the aftermath. This illustrates the need for flood warning and preparedness measures to be backed up by the stockpiling of immediate requirements and also by a workable flood recovery plan (Jha *et al.*, 2012).

2.5.1.1. 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 diarrhoea 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 overflow 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 (Alirol *et al.*, 2010).

2.5.1.2. 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 (Bartlett, 2008).

2.5.2 Economic and Financial Impacts

The direct impacts of flooding identified 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 (ActionAid, 2012).

2.5.2.1. 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 (Bartlett, 2008).

Also the following negative effects can arise due to flooding (EC, 2009; Klijn, 2009):

- Health problems (increase in the spreading of diseases, e.g. diarrhoea or leptospirosis);
- Injuries and death;
- Damages and loss to infrastructure such as roads, bridges and telephone lines;
- Damages and loss to settlements;
- Temporary or permanent closure of businesses and industries;
- Financial services cost for insurance and reinsurance;
- Isolation of communities due to damaged roads and bridges;
- Disruption of water supply;
- Damage to agricultural land and crops; and
- Damage to ecosystems.

2.6 Management and Control of Floods in Ghana

The Government of Ghana is the primary initiator of measures for the management of floods in Ghana (Karley, 2009). Various institutions, policies and regulations have been set-up by government to address issues relating to floods and activities that

promote / influence flooding in Ghana. The national regulations relating to environmental management can be found in the 1992 constitution of Ghana. They are presented in the form of Acts, Legislative Instruments, Environmental standards, and Guidelines. The principal regulatory body is:

2.6.1 National Disaster Management Organization (NADMO)

Ghana's compliance with the requirement of the Yokohama Strategy for a Safe World resulted in the establishment of NADMO by Act 517 of 1996, "to manage disasters and similar have far better fire service and other disaster related emergencies" by coordinating the resources of government institutions and non-governmental agencies and developing the capacity of communities to respond effectively to disasters (NADMO, 2011). After its restructure in 2002, NADMO was given the added responsibility to improve the livelihood of communities affected by disaster through social mobilization and poverty reduction projects.

2.7 Remote Sensing and GIS for Flood Risk Mapping

Remote sensing is defined by Lillesand and Kiefer (1987) as the science of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with object, area, or phenomenon under investigation. Remote sensing has been determined to be a cost-effective approach to document changes over large areas and even geographic regions and it has been of immense help in monitoring the changing pattern of vegetation (Lunetta *et al.*, 2004). The use of remote sensing techniques has great advantages because of their characteristics in the application to monitoring, evaluating and forecasting any change in vegetation (Shoopala, 2008). By using remote sensing techniques, the user

can grasp the present situation, evaluate processes such as land degradation trends in macroscopic range, and also provide a scientific basis for the prevention and administration of vegetative change (Shoopala, 2008).

2.8 Land Cover and Land Use Change Detection

Land-cover refers to the surface cover on the ground, whether vegetation, urban infrastructure, water, or bare soil. Identifying, delineating and mapping land-cover is important for global monitoring studies, resource management and planning activities (CCRS, 2004). Identification of land-cover establishes the baseline from which monitoring activities (change detection) can be performed and provides the ground cover information for baseline thematic maps (CCRS, 2004). Land-use is likened to the purpose the land serves, for example, recreation, forestry, or agriculture. Land use applications involve both baseline mapping and subsequent monitoring, since timely information is required to know what current quantity of land is in what type of use and to identify the land use changes from year to year.

Many change detection techniques have been developed to detect vegetation change using remote sensing data (Cakir *et al.*, 2006). However, despite the wide diversity of algorithms currently available, all of these techniques can usually be separated into two main categories: post-classification spectral change detection and pre-classification change detection. Post-classification methods involve the independent thematic classification of two different images taken on two different dates. Thematic maps are then further compared and analyzed to map any type of changes uncovered (Jensen, 1996). Land cover and land use information may be used for planning, monitoring and evaluation of development or industrial activity. Detection

of long term changes in land cover may reveal a response to a shift in local or regional climatic conditions, which is the basis of terrestrial global monitoring. (CCRS, 2004).

2.9 Flood Risk Maps

Areas at risk of flooding can be dynamic in nature. With a changing level of development, the nature and degree of risk also changes (Jha *et al.*, 2012). Jha *et al.*, (2012) explained that flood risk increases mainly because of an increased level of exposure of the elements under threat. For example, there are occasions when infrastructure or other buildings are constructed in areas already at risk, thereby automatically falling within a risk zone. There are also instances when, at the time of construction, the assets and infrastructures are thought to be outside the risk region, but there are newer effects arising from changing land uses as urban development proceeds. These can include increased rates of runoff, lack of drainage systems, lack of storage systems, overwhelming amounts of rainfall leading to overflow, and the channelization of rivers which may reduce the amount of discharge they can accommodate (Jha *et al.*, 2012). All these factors can increase the number of elements at risk of flooding in an area. Continuous updating and monitoring of risk maps is, therefore, most important for proper flood risk management: decision-makers need up-to-date information in order to allocate resources appropriately. It has been argued that, even without an increase in flood hazard over time, the impact of flooding has risen (and will continue to rise) because of the increased exposure of primary and secondary receptors (Jha *et al.*, 2012).

CHAPTER THREE

3.0 Methodology

3.1 Study Area

The Pru District is located at the north – eastern portion of the Brong Ahafo Region of Ghana (Figure 3-1). It lies between latitude 7° 50' N and 8° 22' N and longitude 0° 30' W and 1° 26' W. The district capital is Yeji which has the second largest market centre after Techiman market in the Brong Ahafo Region of Ghana. It has a total land area of 2,195 km² with its adjoining districts being East Gonja District to the North (N / R), Sene District to the East, Nkoranza and Atebubu – Amanten to the South and Kintampo North and Kintampo South to the West (MOFA, 2011), (Figure 3-1).

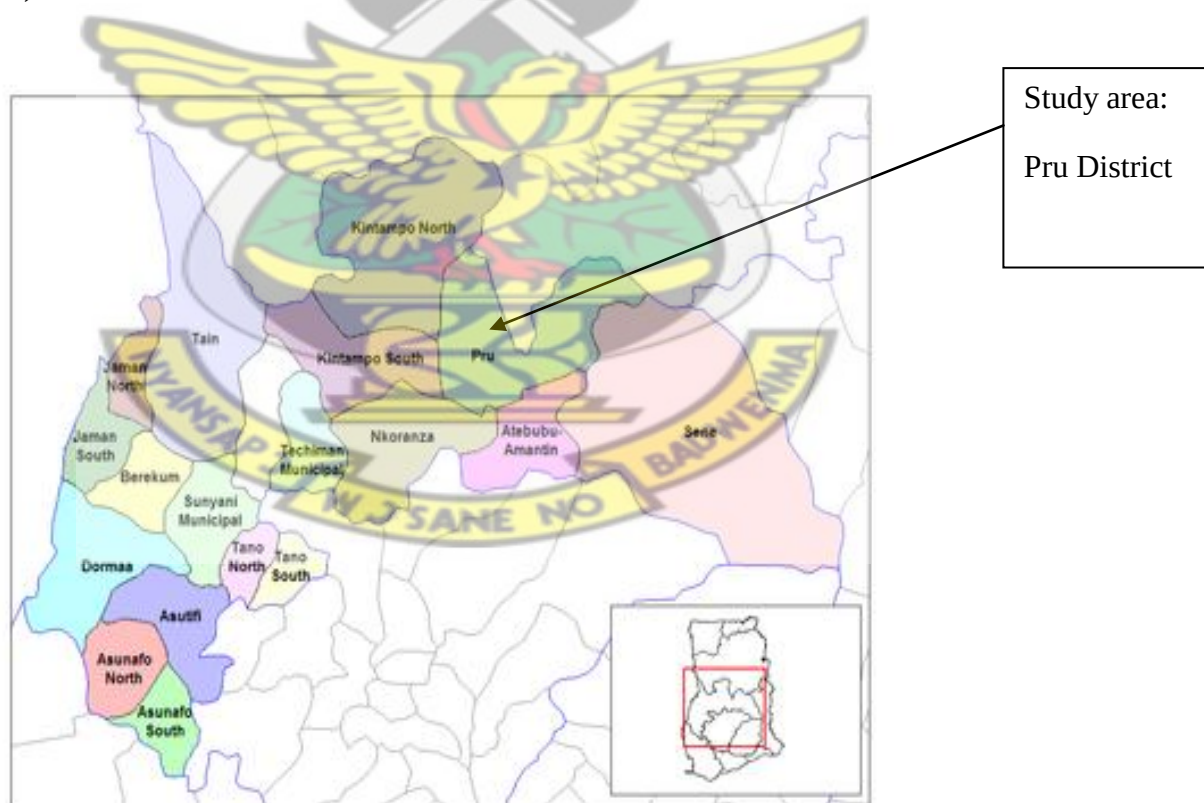


Figure 3-1: District Map of Brong Ahafo Region of Ghana indicating the study area.

Source: (Google images, 2012)

But a more projected map of Pru district shows some of the communities, rivers and roads (Figure 3-2).

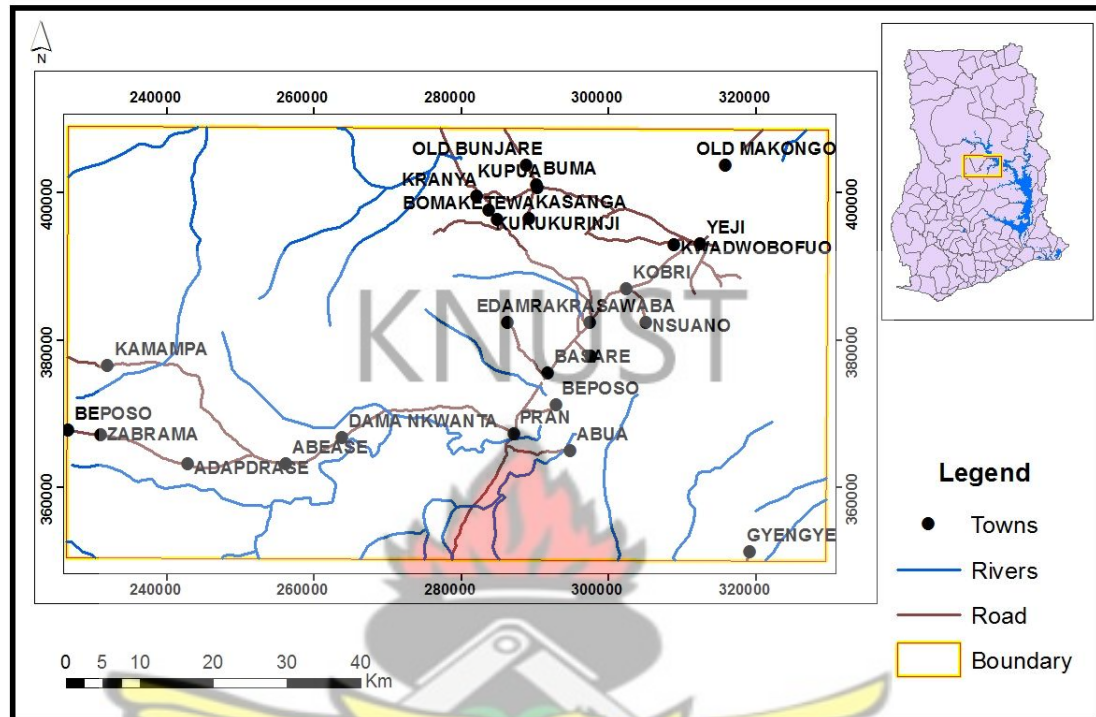


Figure 3-2: Projected map of Pru District in Brong Ahafo Region of Ghana.

3.1.1 Topography and Climate

The topography of the district shows that it lies in between the northern part of the central uplands of the Brong Ahafo Region dominated by plains with rolling and undulating land surface with land elevation between 60 m to 300 m above sea level. Yeji and its surrounding communities fall within the Volta basin and drained by the Volta Lake, Pru River, Nyomo, Tanfi and Nwansi. The District experiences the tropical continental or interior savanna type of climate which is a modified form of the tropical continental or wet semi-equatorial type. The regime in the area is double maxima type, the first from April to June and the second from July to October. Annual rainfall amounts ranges between 1400 mm – 1800 mm. Dry season occurs from November to March. The mean annual temperature ranges between 26.5 °C

and 27.2 °C and mean monthly temperature ranges from 24 °C to 30 °C. Climatic conditions are unstable in the District. January to April constitutes the hottest months while December has the lowest temperatures. The highest relative humidity is 75% - 80% in wet seasons; and the lowest relative humidity is 70% - 72% in dry season (MOFA, 2011).

3.1.2 Soils and Vegetation Types

The Soils are agriculturally important and support cultivation of yam, cassava, maize, rice, groundnuts, garden eggs, okro, tomatoes, and pepper (MOFA, 2011). The cultivation of rice is widespread and commonly found along the water bodies. The area has good soils which develop under Savanna vegetation belonging to the “ground water lateritic soil” formed over the voltaic shale and granite and classified under the Damongo – Murugu / Ejura - Sene compound, Kowani-Kasele / Kpelesawgu - Limo compound, and Kpalsawgu – Changnaili - Lima compound associations (MOFA, 2011). Compound associations are fine textured, ranging from fine sandy loams and mostly poorly drained. Vegetation types consist of grassland, wooded savanna or tree savanna and “fringe forest”. Trees such as the Baobab, Dawadawa, Acacia and the Shea butter are found in the zone, trees are few and scattered along the margins of the Moist Deciduous Forest where trees often grow quite close together (MOFA, 2011). Grasses grow tussocks and can reach a height of 10ft or more. Some common timber species include Krayie (Rose wood), Papao (Afzelia), Senya, Potrodum, Ceiba and Odum. However, due to logging, fuel wood cutting and yearly burning, the original forest is now reduced to secondary forest (MOFA, 2011).

3.1.3 Agriculture and Economic Activities

Agriculture and trading are the mainstay of the economy of the area. Majority of the people are into subsistence agriculture. Agriculture employs about 65% of the population with specialization in animal husbandry / poultry production, food / vegetable production and fisheries, where average farm size is a hectare per farmer. Fishing is a major activity on the Volta Lake and other rivers in the area. The processing and manufacturing sectors are poorly developed and limited to processing cassava into gari. Other economic activities in the area include carpentry, dressmaking and block moulding (MOFA, 2011).

3.1.4 Livelihood Problems

The problems of livelihoods in the area include poor mechanization of agriculture, no irrigation schemes for dry season farming, and dependence of the people on streams and rivers with the only funded Small Town Water Supply System (STWSS) facilities by World Bank in Yeji and Parambo / Sawaba being inundated by the overflowing Volta Lake which compelled people living in these towns to depend on the polluted lake (GNA, 2011). Moreover there are problems of poor housing conditions, poor infrastructure and increasing environmental degradation especially seasonal flooding (NADMO, 2010).

3.2 Materials

3.2.1 Criteria for Material Selection

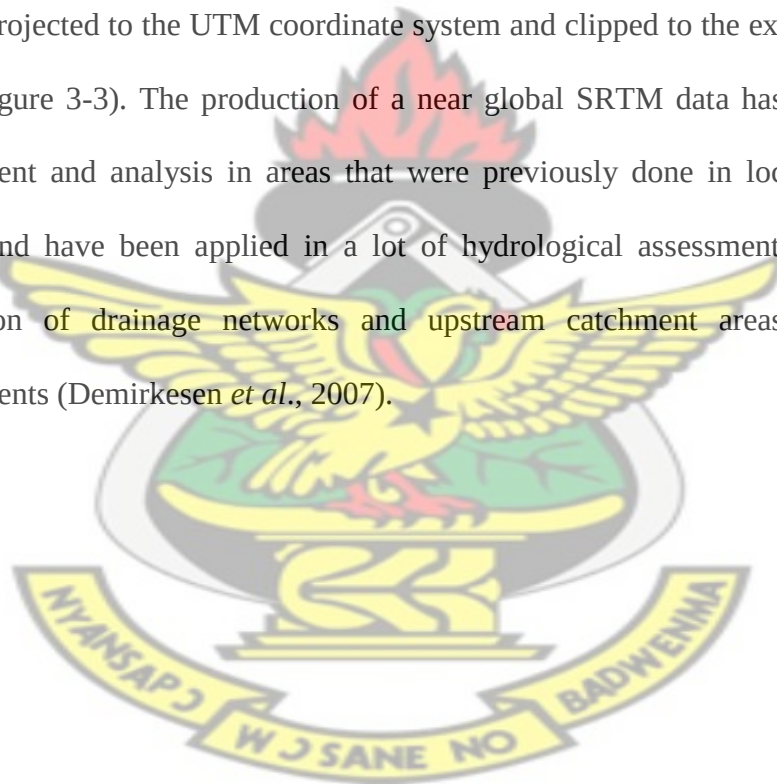
- The SRTM DEM data acquired had a 90 m resolution and was already geometrically processed.
- Landsat TM and ETM+ data acquired had cloud cover of less than 10%.

- The Landsat images were terrain corrected (L1T) and systematic corrected (L1G) (USGS, 2011). This meant that all images were radiometrically and geometrically accurate (USGS, 2011).

3.2.2 Material Type and Acquisition

- **SRTM 90 m DEM**

SRTM 90 m DEM of the study area was derived from USGS / NASA SRTM data and was in decimal degrees and datum WGS 84. The data was downloaded from the CIAT-CSI SRTM website (<http://srtm.csi.cgiar.org>) provided by Jarvis *et al.* (2008). It was projected to the UTM coordinate system and clipped to the extent of the study area (Figure 3-3). The production of a near global SRTM data has enabled global assessment and analysis in areas that were previously done in local and regional levels and have been applied in a lot of hydrological assessments especially for extraction of drainage networks and upstream catchment areas in flood risk assessments (Demirkesen *et al.*, 2007).



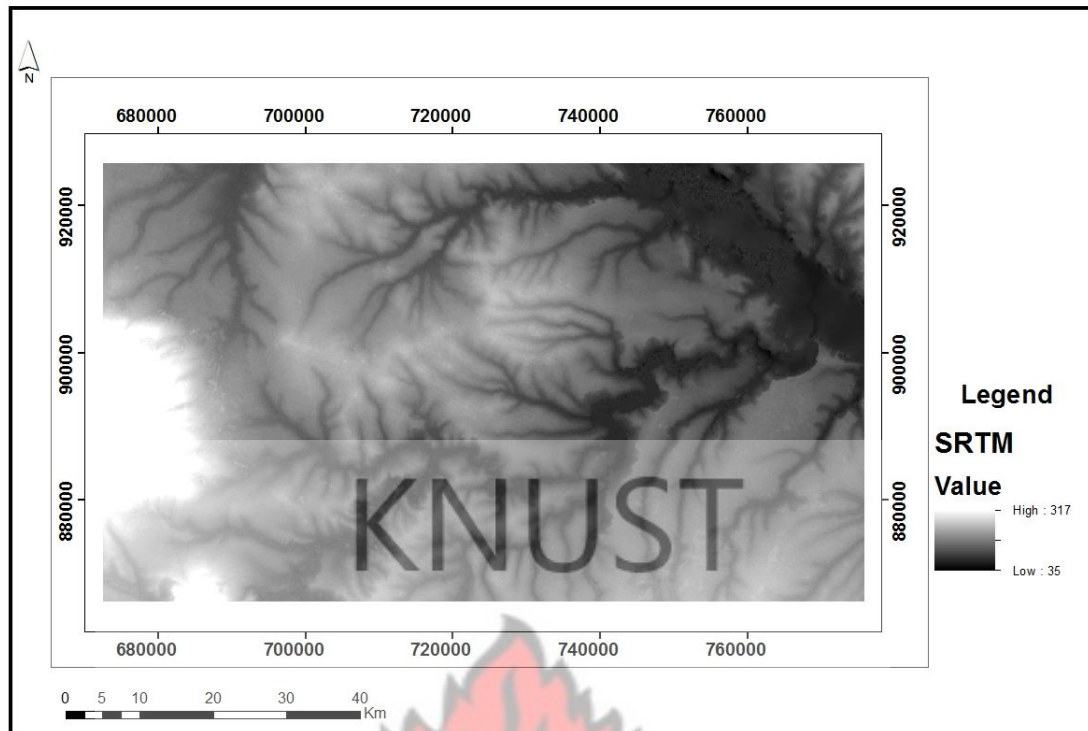


Figure 3-3: SRTM 90 m DEM of the study area. Source Jarvis *et al.* (2008).

- **Landsat 5 TM and 7 ETM+ Images**

Two Landsat images were acquired from the USGS earth explorer (<http://edcns17.cr.usgs.gov/NewEarthExplorer/>) and glovis (<http://glovis.usgs.gov/>) websites (Figure 3-4). Landsat 5 TM was acquired in 1990 and Landsat 7 ETM+ was acquired in 2006 (Table 3-1). Landsat images are generally known to be efficient, simple and first choice when it comes to mapping of flood vulnerable areas (Ho *et al.*, 2010).

Table 3-1: Summary of satellite images acquired

Landsat Satellite	Date Acquired	Path / Row
Landsat 5 TM	September, 1990	194 / 54
Landsat 7 ETM+	March, 2006	194 / 54

These images were selected because they have cloud cover of less than 10% each and therefore have the best visibility in terms of clarity. Figure 3-4 shows the

acquired Landsat images of 1990 and 2006. An additional but recent image could have been obtained but those images had cloud covers of more than 10%.

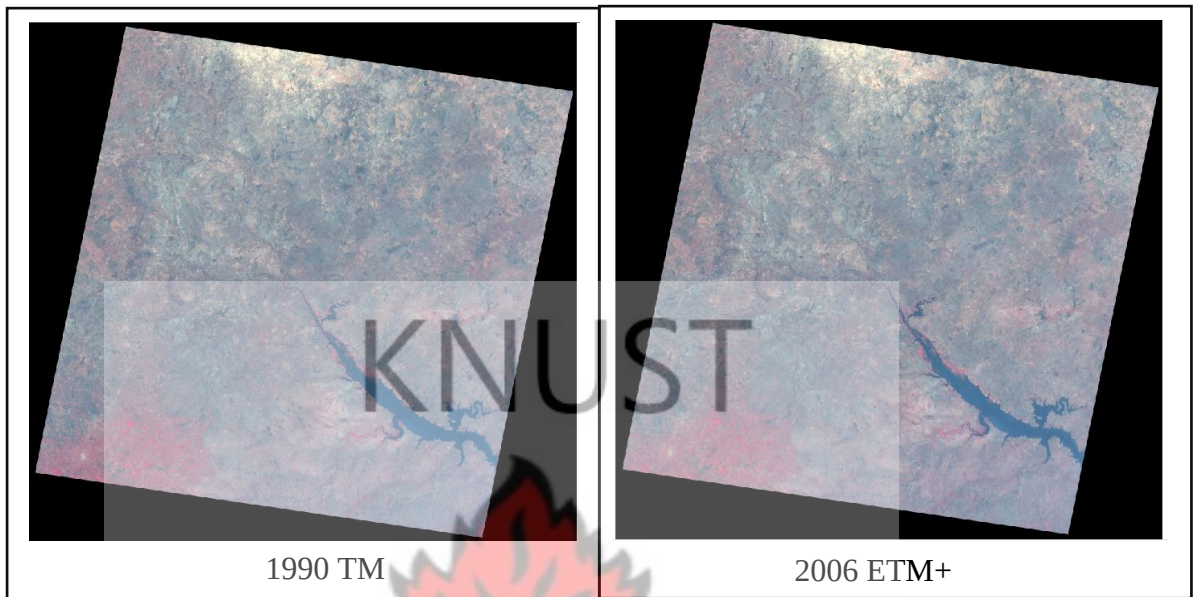


Figure 3-4: Landsat images used for the study

3.2.3 Software used

ArcGIS 10.0 (GIS software) and ERDAS IMAGINE 9.2 (Remote sensing software) were used. The ERDAS IMAGINE was used in the image processing including pre-processing, image classification, accuracy assessment and production of a change map.

3.2.4 Field Data

Using the Garmin high sensitivity hand-held GPS device at a navigation accuracy of 3 m – 4 m, about 137 GPS coordinates of the flood affected communities in the District were captured during the field work (Appendix A). Two weeks was used in picking of points in the flood affected communities in the District. Also a topographic map of the area was taken from the survey department of the Pru district to serve as a reference material.

3.2.5 Questionnaires

Two separate forms of questionnaires were designed to meet questions relating to the effects of floods on affected victims in the District. Household questionnaires were designed for household heads in some of the flood affected communities so as to have a fair idea of what they have been going through in times of flood (Appendix B1). Another set of questionnaires was designed for officials of the National Disaster Management Organization (NADMO), District Agricultural Development Unit (DADU), Pru District Assembly (PDA), Environmental and Sanitation Department (ESD) and the District Health Directorate of the Pru district (DHD) (Appendix B2).

3.2.6 Secondary Data

Secondary data on flood related issues were taken from NADMO, PDA, DADU, ESD and DHD to ascertain flood related issues of the District. The secondary data include: topographical map of Pru district, 2010 flood disaster data sheet, reported health problems from 2008 to 2011 and annual agricultural reports for 2008, 2009 and 2010.

3.2.7 Interviews

Interviews were held with some Sub - Chiefs and Elders of Cherepo, Kobre, Banyawaya and Parambo in the Pru District and this was done through the use of questionnaires.

3.3.0 Methodology

This is the step-wise procedure followed in processing and analyzing of the data acquired from the study area and USGS resource centre.

3.3.1 SRTM 90 m DEM

- **Filling of Sinks**

In order to carry out hydrology analysis on DEM, all depressions have to be filled. Such depressions are called sinks (ESRI, 2009a). The SRTM 90 m DEM sinks were filled using the 'Fill' tool in the hydrology tool of the spatial analyst tools in ArcGIS.

- **Determination of Flow Direction**

The depressionless DEM was used to generate a flow direction raster. The flow direction shows the possible direction of water run-off on the elevation model. This analysis was performed using the flow direction tool in Arc Toolbox's Spatial Analyst tools found under hydrology.

- **Delineation of Drainage Basins**

The drainage basins in the study area were delineated using the basin tool under hydrology of the spatial analyst tools in ArcGIS and further analysis were performed to understand the flow of water on the surface of these basins and then creation of stream channels. Understanding the risk of flooding in an area begins with knowledge of the mechanism of drainage basins and their stream networks (Ajibade *et al.*, 2010).

- **Determination of Flow Accumulation**

Determination of flow accumulation is the next step after flow direction and it shows the cells within the study area where water accumulates as it flows downwards. Thus, settlements around these cells will receive much water during an event of rainfall or any sudden release of water. This was done using the flow accumulation tool under hydrology of the spatial analyst tool in Arc Tool box.

- **Determination of Stream Network and Buffer Zone**

The stream network was created from the flow accumulation raster to show the path of streams on the elevation. A reclassification of the flow accumulation results was performed using the reclassification tool in Spatial Analyst tools in this manner:

Table 3-2: Reclassified values of flow accumulation

Old values	New values
≥ 500	1
< 500	0

Source: (Orok, 2011)

The result of the stream network analysis was reclassified to create a buffer zone around areas that are within 1 km of the stream network. Such areas were assigned a new value of “1” while areas farther than 1 km were assigned “0” value. The reclassified stream buffer zone was multiplied by 10 to get values of 0/10 using the raster calculator. The resultant new layer was an arrangement that showed areas around the streams from the nearest to the farthest (Orok, 2011).

- **Generation of Slope and Reclassification of Slope**

The slope angles of the DEM were then calculated using the spatial analyst tools and a reclassification was performed to create three categories:

- ❖ Areas with slope angles above 4.4 (High slope areas),
- ❖ Areas with slope angles between 1.3 and 4.4 (medium slope areas),
- ❖ Areas with slope angles below 1.3 (low slope areas).

The total areas of these slopes were also determined.

- **Overlaying of Layers and Production of Flood Risk Maps**

After determination of slope and creation of stream buffer areas, the next major step was the addition of these two resultant layers in the raster calculator to produce a new layer showing three risk zones:

- ❖ Areas within the stream buffer zone and in the low slope areas (High risk zone)
- ❖ Areas within the stream buffer zone and in the medium slope areas (Medium risk zone)
- ❖ Areas without the stream buffer zone and in the high slope areas (Low risk zone).

The supervised map produced from the GPS coordinates taken from the communities was laid over the flood risk zones to produce the flood risk maps (“A” and “B”) of the area showing the areas within the study area that are in the different flood risk zones.

3.3.2 Subset Generation for Landsat Images

The two Landsat 5 TM and Landsat 7 ETM+ images were reduced to cover only the area of Pru district and also to be generally the same size (Figure 3-5). This eliminated unnecessary data amounts, which also speeds up processing. Therefore using the subset tool in the Data Preparation toolbar of ERDAS Imagine, the two subsets were created using the Area of Interest tool.

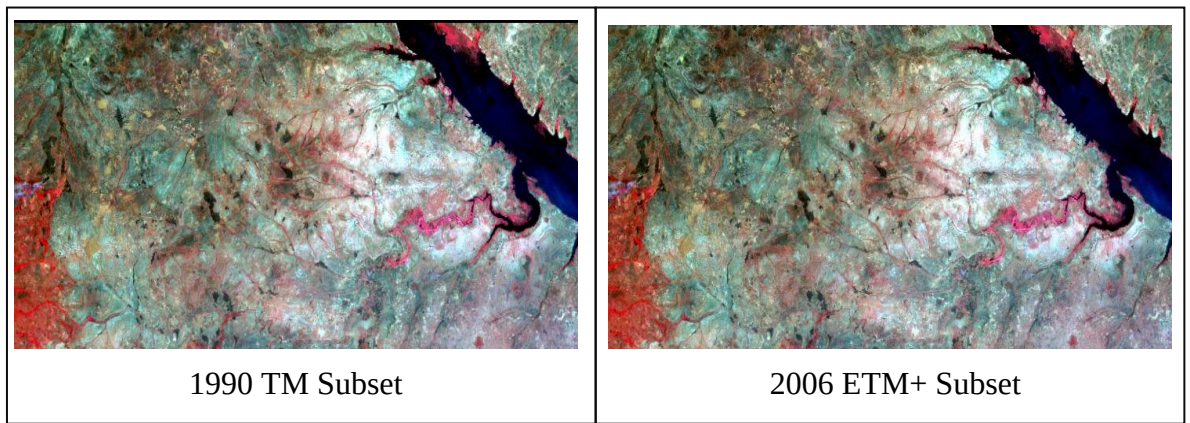


Figure 3-5: Subset images of 1990 TM and 2006 ETM+ images of the study area.

3.3.3 Supervised Classification

Classification of images is of two types: supervised and unsupervised and its objective is to designate classes to cells or pixels in a study area. Each class description relates to features / properties / characteristics / conditions of those cells that make it up (ESRI, 2009b; Yoon *et al.*, 2004). When the features of pixels in an image are known, supervised classification is performed on the image but when the features are unknown, unsupervised classification is carried out (ESRI, 2009b). The images were classified by grouping / clustering cells with similar reflectance values (Boakye *et al.*, 2008). Three classes were generated from the classification namely: water bodies, built-up areas and vegetation.

3.3.4 Overlaying of Layers

The classified land cover maps of 1990 and 2006 were overlaid to produce the classified land cover change detection map of the area. This indicated the changes that occurred in the 3 classes (water bodies, built-up areas and vegetation) within the 16 year change detection period between 1990 and 2006.

3.3.5 Social Survey

Social survey is an objective and quantitative approach to the study of social processes within a well – defined area at a given time through one or more institutions, by means of a schedule, or a questionnaire and the data thus obtained related statistically (Kumekpor, 2002). It is therefore a method of collecting facts by putting questions to people. Social survey can equally be considered as an exploration or investigation into the current or existing social, political, economic and environmental conditions of a place or people (Kumekpor, 2002).

3.3.5.1 Questionnaire Administration

- **Household Heads Questionnaire Administration**

About 226 household questionnaires for household heads in 15 flood affected communities were administered. According to NADMO, (2010) about 14 communities were affected by floods in 2008 and 2010 and most of the affected flood victims have relocated to far and near-by places. In all, over 2,172 people were affected by floods in 2010 but due to relocation only less than 1000 people are still living in their original homes (NADMO, 2010) (Appendix C). This was ascertained through field survey as in some flood affected areas, majority of the inhabitants have relocated and difficult to trace. Based on this data from NADMO (2010), it became necessary to design the questionnaire to meet household heads of about 226 households in all the communities. The number of household heads interviewed in each community is based on the projected number of inhabitants still living in those communities as made available by NADMO (Appendix D).

The study design took into consideration the fact that the majority of the population are either illiterate or made up of people who may, for some reason, not feel disposed to complete the questionnaire themselves. The administration of some of the household questionnaires thus took the form of the research completing the forms as respondents provided the responses. Purposive sampling was used as flood affected victims have to be identified since they have information relevant to the study.

The exercise started on Wednesday, 2nd January, 2013 to Saturday, 16th March, 2013. The time for questionnaire administration was in the morning from 6:30 am to evening 5:30 pm. During this time most respondents were found at home and this was mostly done on non-market days of the Yeji market, and these days are: Wednesday, Thursday, Friday and Saturday, while some of the market days were used to collect secondary data from the Government agencies and also interview the Chiefs and Elders of some communities. On the average it took 30 minutes to interview each respondent. Averagely 12 household heads were interviewed per day. Three questionnaires were given to officials of NADMO, DADU and ESD each. While a questionnaire each was given to PDA and DHD.

The questionnaires had questions on:

- The causes of floods in the district
- Occurrence of floods in the district
- Health effects of floods on affected victims
- Water and sanitation effects of floods on affected victims
- Educational effects of floods on affected communities
- Infrastructural and transport effects of floods on affected victims

- Agricultural and economic effects of floods on affected victims
- Social and emotional effects of floods on affected victims
- Evacuation and coping strategies adopted during floods

3.3.5.2 Data Processing and Analysis

Results from questionnaire administration and interviews were analyzed using Microsoft Excel and outcomes presented in tables and charts. In terms of the charts, the 2-D column and 3-D columns were used as they help compare the contribution of each value to a total across categories by using vertical rectangles.



CHAPTER FOUR

4.0 Results

4.1 Results for Flood Risk Mapping in the Pru District

The flood risk maps were produced using the following procedures:

4.1.1 Filling of SRTM Sinks

The depressions in the subset of the SRTM acquired was filled using the “Filling” tool under the hydrology of the spatial analyst tools in ArcGIS which made it possible for the hydrological analysis (Figure 4-1). The darkened portions in the image show areas of low elevation where water bodies easily get collected such as the Volta Lake, and the lightly darkened portions show areas of high elevation.

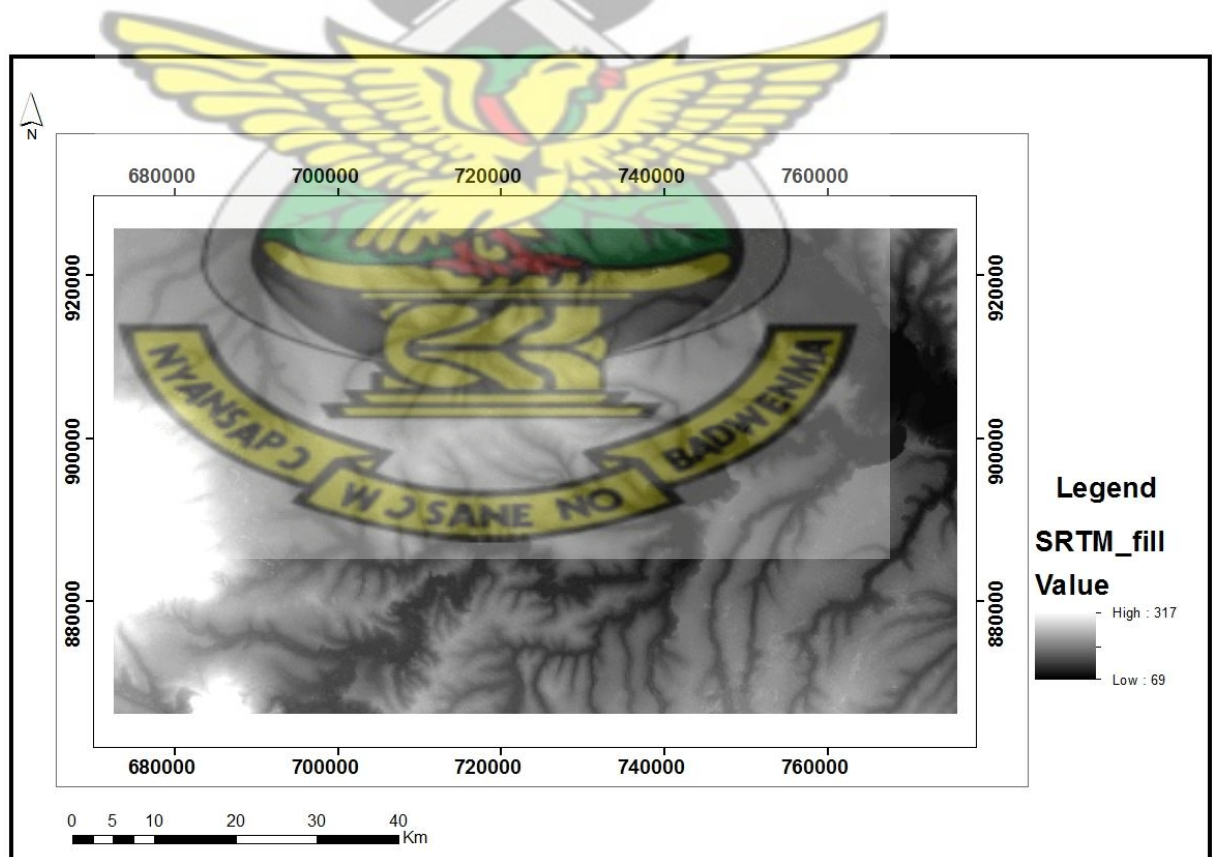


Figure 4-1: Filled sinks of SRTM of Pru district.

4.1.2 The Flow Direction of Water

In order to determine the flow accumulation of water bodies in the Pru District (PD), the flow direction was then determined (Figure 4-2). This made it possible to delineate the various stream networks in the district as it shows the downward paths taken by water bodies and how they easily spread out on a land surface. The flow of water increases from the yellowish portions to the brownish portions as shown in Figure 4-2.

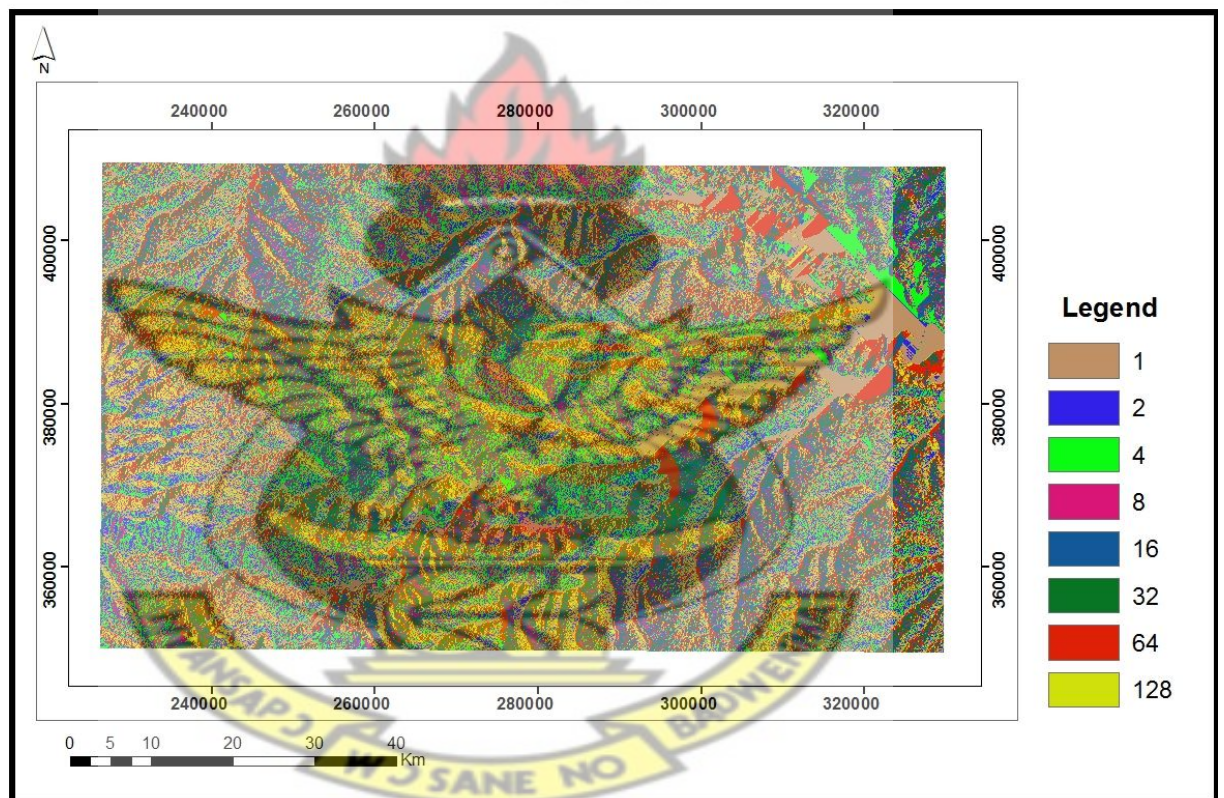


Figure 4-2: Flow directions on DEM of Pru district.

4.1.3 Delineation of Drainage Basins

The delineated drainage basins show how water flows on the land surface from a particular source to other areas in the Pru District (Figure 4-3). It made it possible to determine the area of flow accumulation and the various stream networks

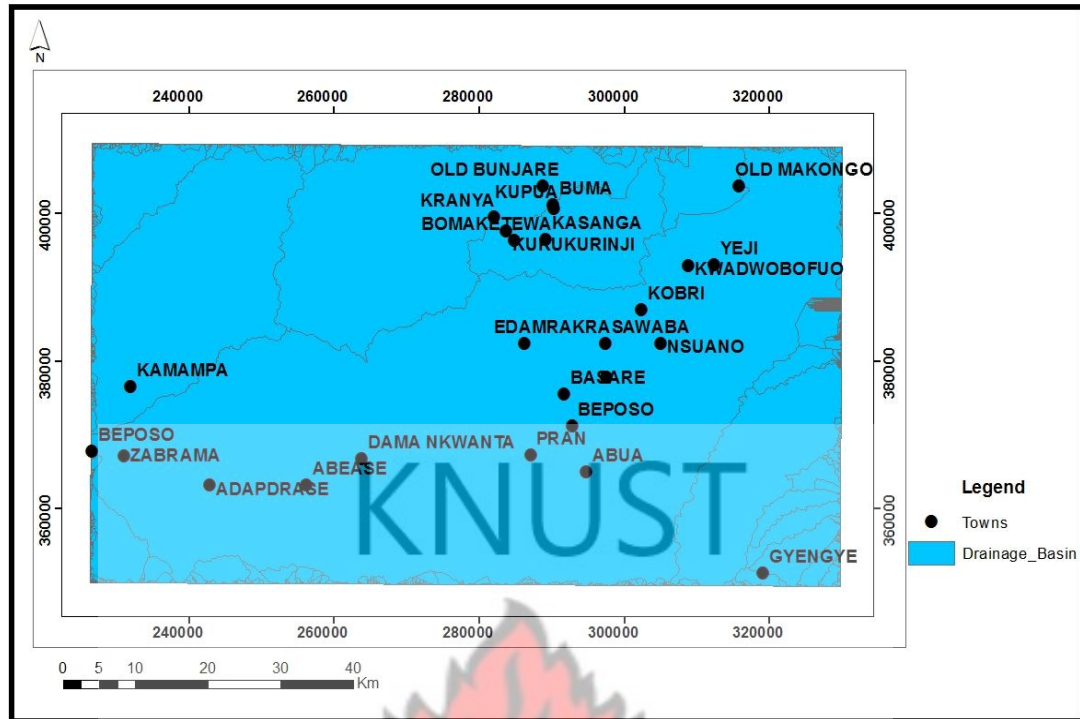


Figure 4-3: Delineation of drainage basins of Pru district.

4.1.4 Determination of Flow Accumulation

The areas that are deeply darkened have low accumulation values and will have minimum water accumulation and the areas that are lightly darkened have high accumulation values and will have maximum water accumulating on the land surfaces (Figure 4-4).

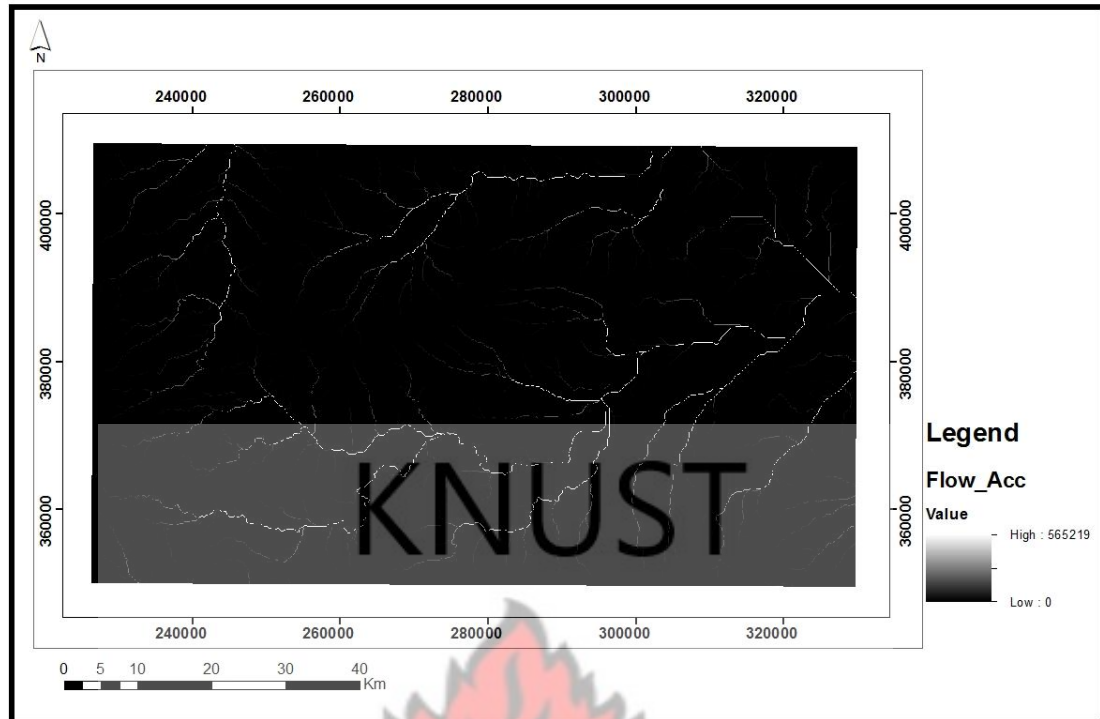


Figure 4-4: Flow accumulations in Pru district.

4.1.5 Generation of Stream Network / Stream Link

The flow accumulation values were reclassified to generate the stream networks. The cells with threshold values ≥ 500 are stream paths which are shown by the blue lines (Figure 4-5). These paths actually show the path of flow of large bodies of surface water in case of rainfall or when a water body overflows its banks.

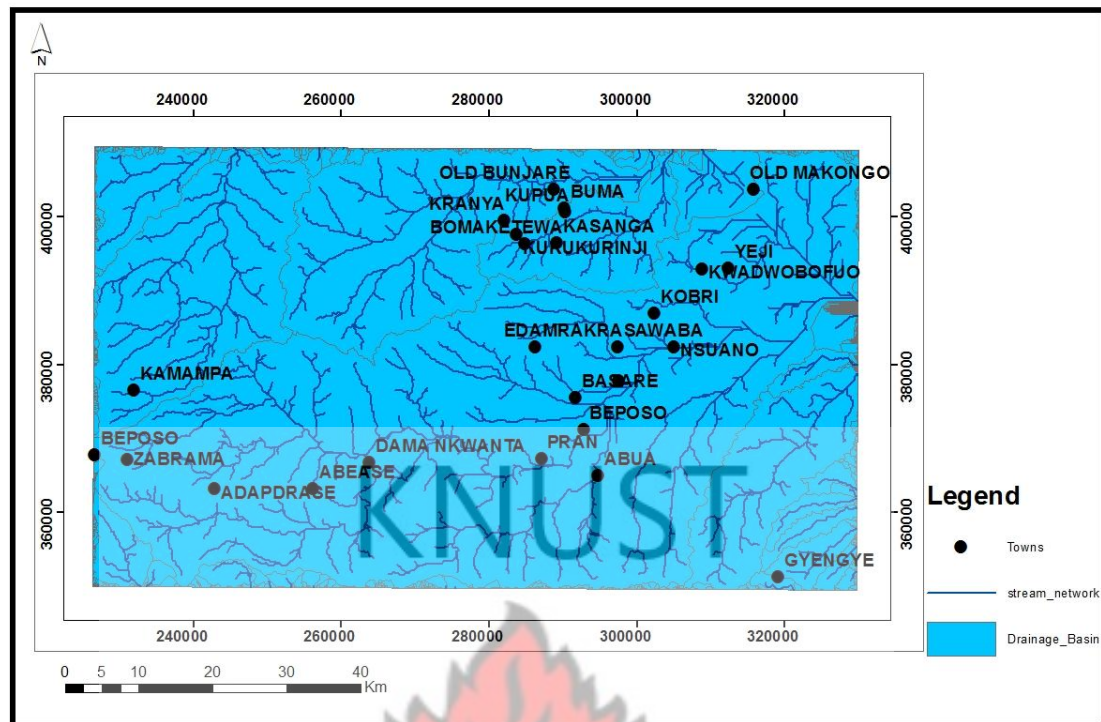


Figure 4-5: Stream network / stream link in Pru district.

4.1.6 Creation of Buffer Zone and Stream Network

Buffer zones of 1 km were created within the stream networks (Figure 4-6). It was realized that areas within stream buffer zones of 1 km in the Pru District covered a total of 4053.87 km² (65.78%) while areas outside or above the buffer zones covered a total of 2,108.72 km² (34.22%) (Table 4-1). In this case, built – up areas and agricultural farmlands within the stream buffer zones are likely to be inundated when there is the release of water. The blue indicates areas within the 1 km buffer zones while the lightly darkened portions show areas above or outside the 1 km buffer zones.

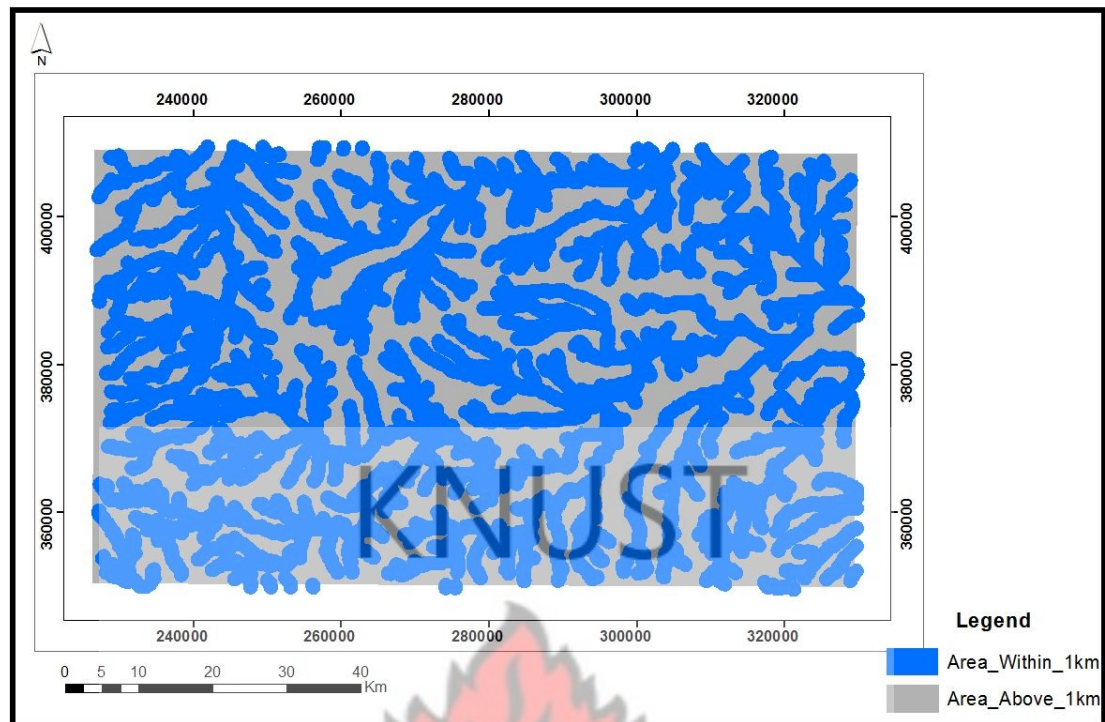


Figure 4-6: Buffer zones around stream network in Pru district

Table 4-1: Areas of stream buffer zones in Pru District.

Stream Buffer Zone	Area_Km ²	Percentage (%) Area
Areas Within 1 km	4053.87	65.78
Areas Above 1 km	2,108.72	34.22
Total	6,162.59	100

4.1.7 Creation of Slope and Reclassification of Slope

Elevations within and outside the buffer zones affect the degree of water movement and hence flooding. Calculation of the slope angles of the DEM of the area reveals that areas within and outside the buffer zones have varying slope angles. It was realized that areas having slope angle values of 0 – 1.3 are low slope areas and when they fall within the stream buffer zone are likely to be the most vulnerable to water inundation when there is the release of water or rainfall (Figure 4-7). Areas having slope values of 1.3 – 4.4 are of medium slope and depending on the intensity of water within the area and it being within a stream buffer zone could be subjected to

water inundation. But areas within slope values of 4.4 – 13.2 which are mostly high slope areas and outside stream buffer zones are not likely to be inundated by water (Figure 4-7).

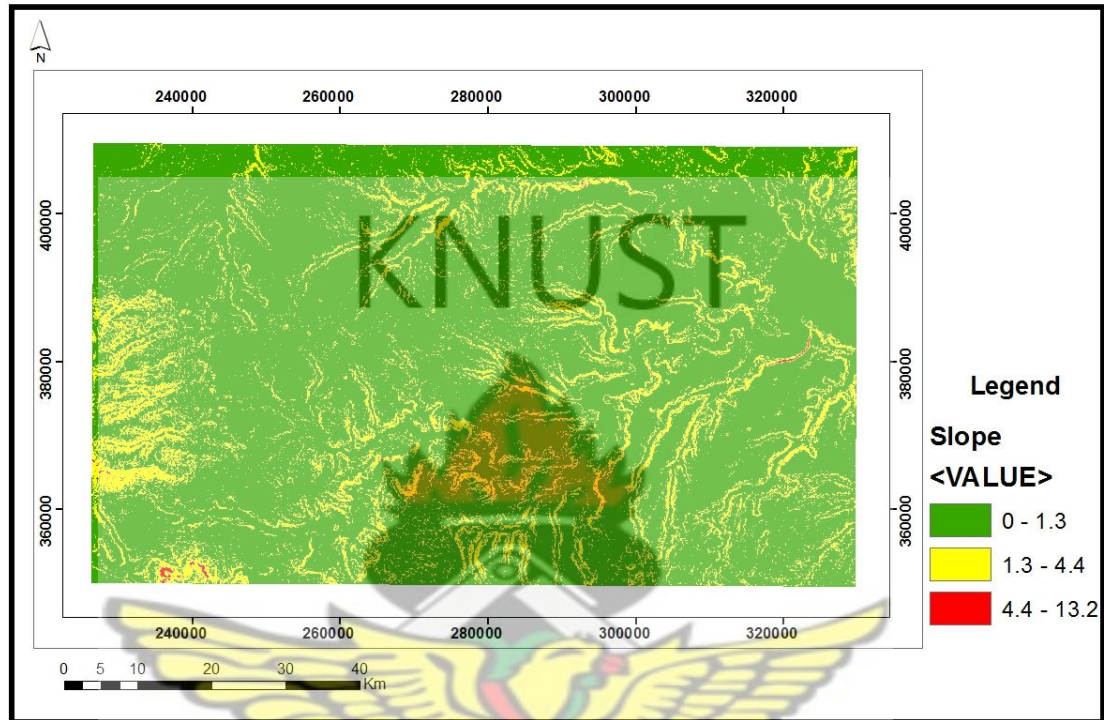


Figure 4-7: Slope angles on DEM of Pru District

Therefore it is possible that some areas within the stream buffer zone are well above water level than other areas and as such those areas will be less vulnerable to flooding than others. These slope angles have been reclassified into high, medium and low slope areas (Figure 4-8). The total area of each slope category was also calculated and it was realized that low slope areas covered a total of 5185.19 km² (84.14%), medium slope areas covered an area of 971.69 km² (15.77%) while high slope areas were the least in the Pru District covering a total of 5.71 km² (0.09%), characterizing the district to be predominantly a low – lying area (Table 4-2).

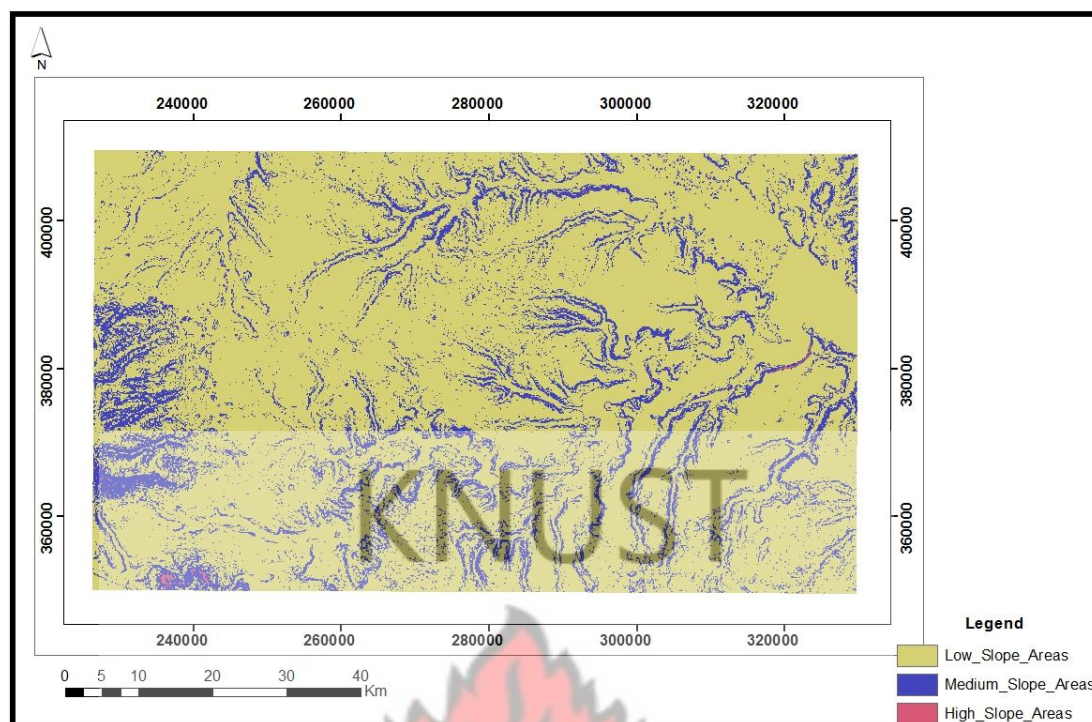


Figure 4-8: Reclassified slope areas on DEM of Pru district

Table 4-2: Area of Slope Categories in Pru district

Slope Category	Area_Km ²	Percentage area (%)
Low Slope Areas	5185.19	84.14
Medium Slope Areas	971.69	15.77
High Slope Areas	5.71	0.09
Total	6,162.59	100

4.1.8 Overlaying of Layers and Production of Flood Risk Maps

The stream buffer zone and the reclassified slope steepness maps were overlaid to produce the flood risk maps of the Pru District (Figure 4-9). The map generated from the field works showing the locations of the flood prone areas was laid over the flood risk map which shows the various study areas within the flood risk zones (Figure 4-10). The total areas of these classified flood risk zones were also calculated (Table 4-3). It was realized that 2,161.79 km² (35.08%) of the land area fall within low flood

risk zone, 754.54 km² (12.24%) are within the medium flood risk zone while 3,246.26 km² (52.68%) of the land area are within the high flood risk zone in PD.

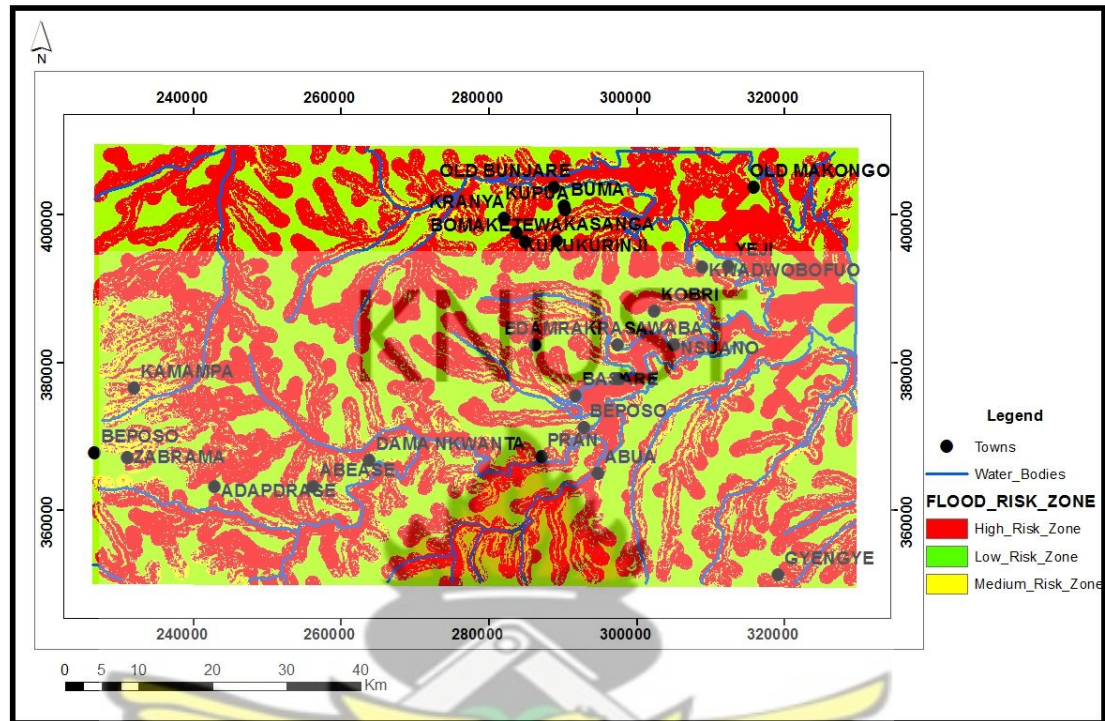


Figure 4-9: Flood risk map A of Pru District showing water bodies and towns.

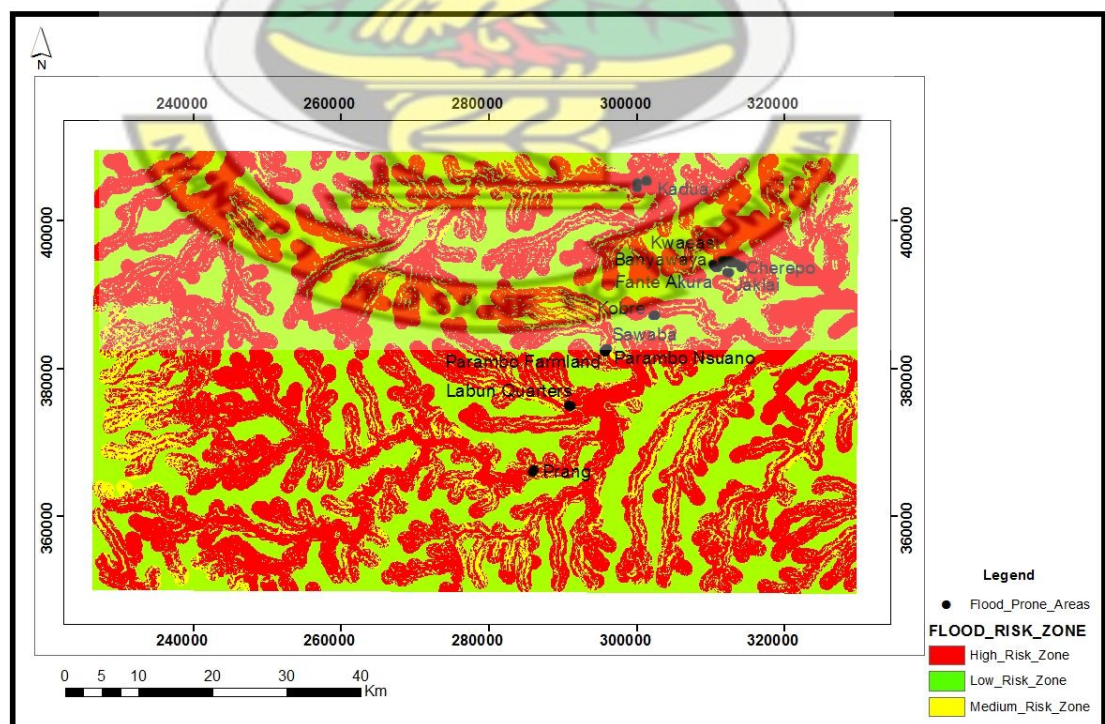


Figure 4-10: Flood risk map B of Pru District showing supervised flood prone areas.

Table 4-3: Areas of Flood Risk Zones in Pru District

Flood Risk Zone	Area_Km²	Percentage area (%)
Low Risk Zone	2,161.79	35.08
Medium Risk Zone	754.54	12.24
High Risk Zone	3,246.26	52.68
Total	6,162.59	100

During the field data collection, it was realized that most of the badly hit communities by floods are concentrated in the North – Eastern portions and part of the middle portions of the district. From the field survey it was realized that the major water bodies identified within flood affected communities in the Pru district are located in: Yeji, Parambo/Sawaba, Labun Quarters, Kadua, Vutideke, and Prang and these water bodies are Pru River, Lake Volta and Labun River.

4.2. Determination of Land Cover and Land Use Changes in Pru District

The result of the supervised classification was categorized into three different land use areas, namely: Built up / Bare surfaces, vegetation and water bodies. The classified image of Landsat 5 TM of 1990 showed an extended water body within the South – Western and middle portions of the District aside the water bodies found in the North – Eastern parts of the District which are common to both Landsat 5 TM of 1990 and Landsat 7 ETM+ of 2006 images. The presence of water bodies in the South – Western parts of the District as shown in Landsat 5 TM of September, 1990 (Figure 4-11) clearly proves the period within which there is increase in the water bodies in the district as it is after the major rains in the district and the period within which flooding occurs. The blue coloured portions in South – Western portions in Landsat 5 TM of 1990 could possibly be likened to wetlands and other seasonal

water bodies. That was why such water bodies were not present in Landsat 7 ETM+ (Figure 4-12) image which was taken in March, 2006, a dry period in the District.

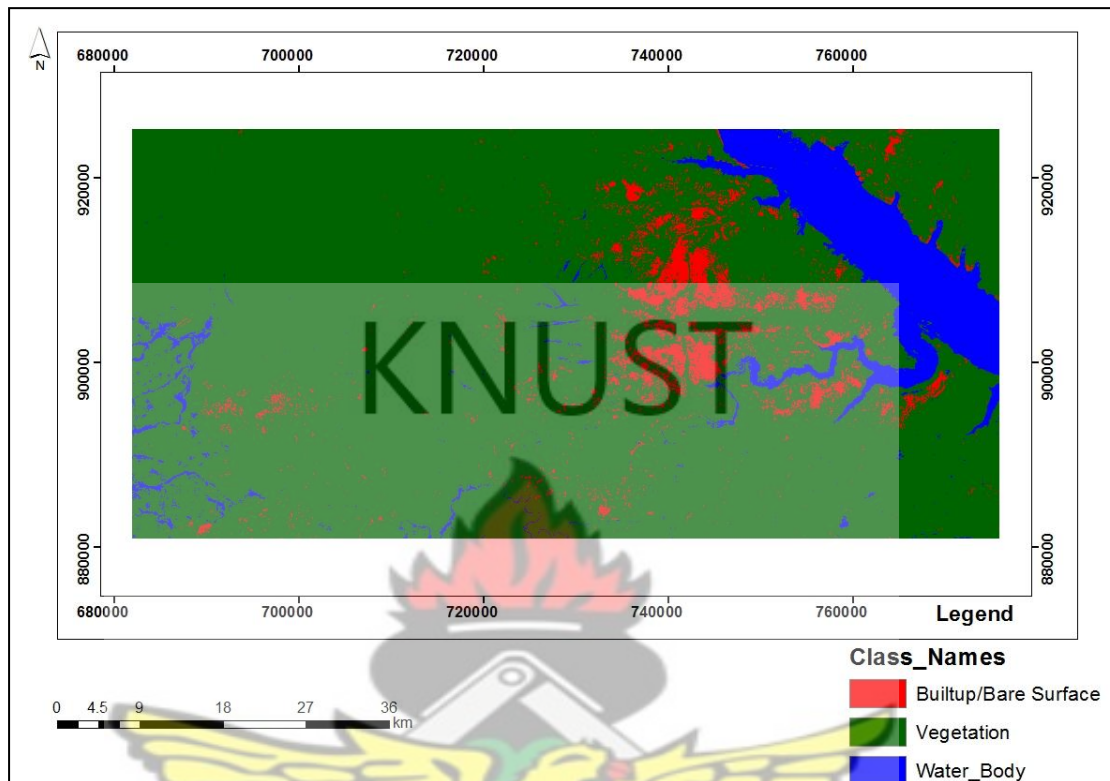


Figure 4-11: Classified Land cover map of the 1990 TM image of Pru district.

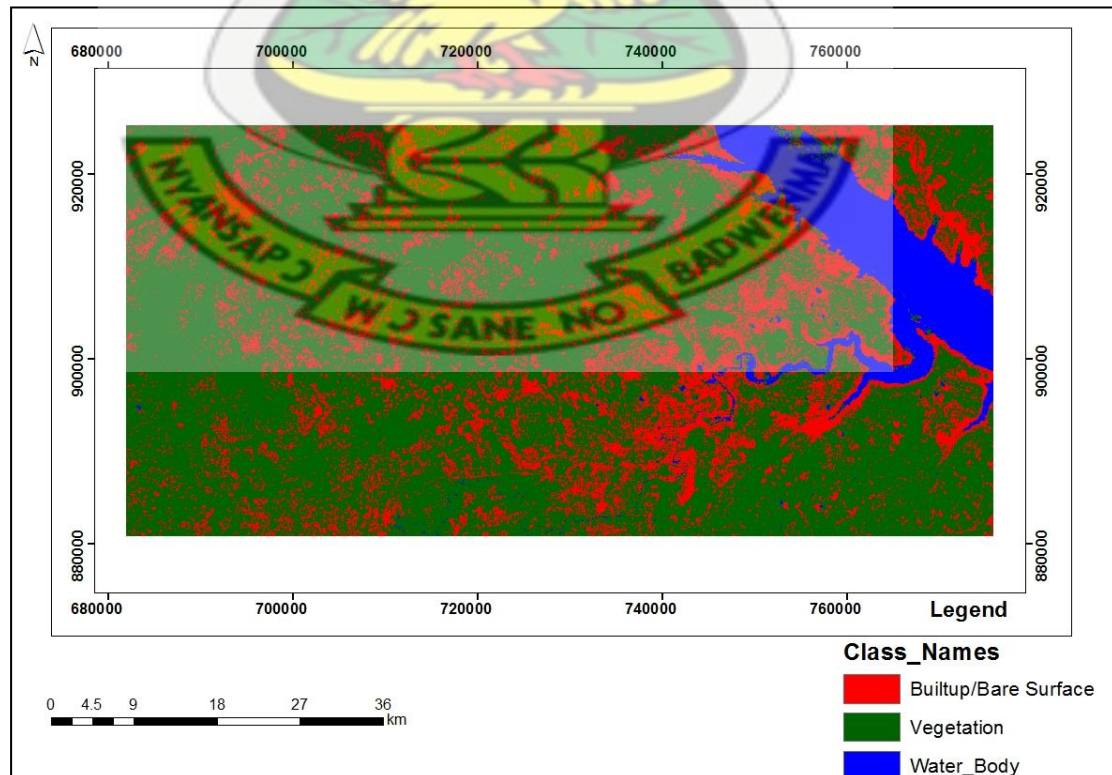


Figure 4-12: Classified Land cover map of the 2006 ETM+ image of Pru district.

The change detection matrix was also calculated to determine the extent of land cover changes, land use changes and urbanization from 1990 to 2006 (Table 4-4). The combined images of Land cover maps of the 1990 Landsat 5 TM and 2006 Landsat 7 ETM+ produced a change detection map which shows the various changes of the features (Figure 4-13).

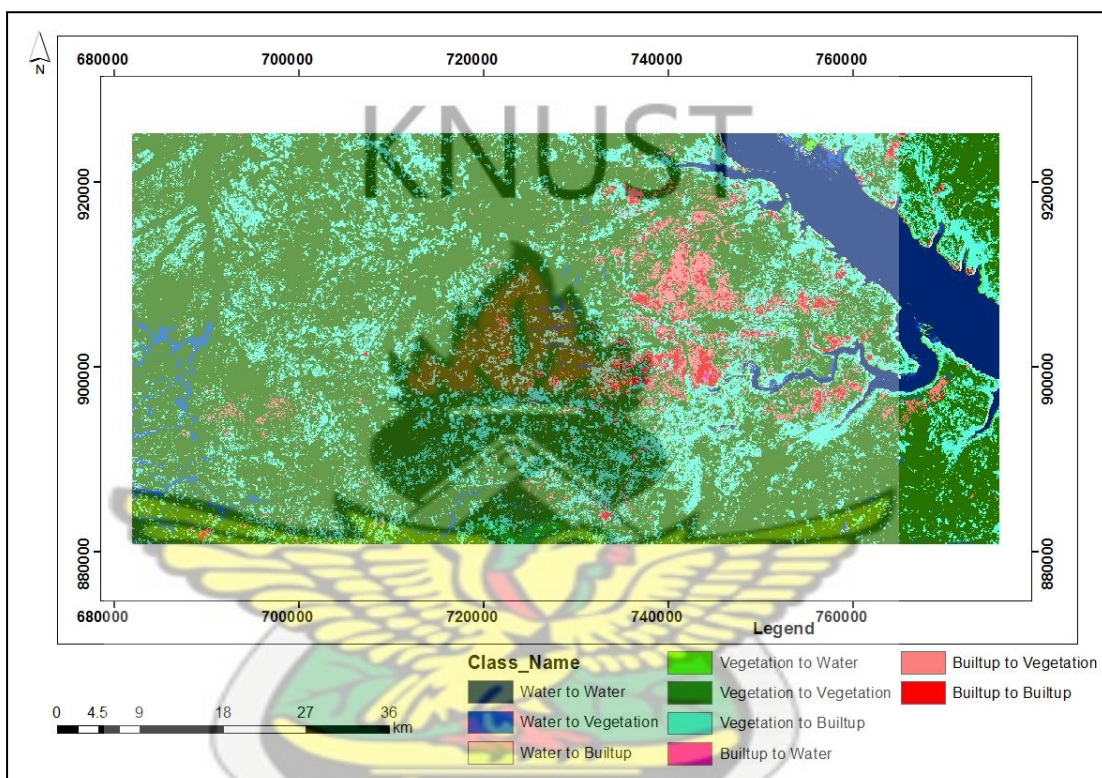


Figure 4-13: Land cover map change detection of 1990 to 2006 in Pru district

Table 4-4: Change detection matrix of 1990 to 2006 (Km²).

		2006		
	Class	water body	Built up / Bare surface	Vegetation
1990	Water_Body	297.27	15.13	55.07
	Builtup/Bare Surface	1.35	71.77	118.62
	Vegetation	16.68	876.99	2721.02
	Total	315.30	963.89	2894.71
				Total
				4173.90

From Table 4-4, it can be realized that a total land area of 315.30 km² inundated by water in 2006 was as a result of a conversion of 16.68 km² of the vegetative land area in 1990 into water in 2006 while 1.35 km² of the built up / bare surface land area in 1990 was converted into water body in 2006. An area of 297.27 km² which was covered by water in 1990 did not undergo any change. Also a total land area of 963.89 km² was shown for built up / bare surface area with the reason being that, 15.13 km² of land under water in 1990 got dried up and converted into built up / bare surface area in 2006 while 876.99 km² of the vegetative land area was converted into built up / bare surface areas. This was a very sharp change in land cover and land use. About 71.77 km² of the land area under built up / bare surfaces in 1990 did not undergo any change.

From Table 4-5, the water body depreciated from 1990 to 2006. That explains the presence of less blue coloured portions indicating water in the 2006 Landsat 7 ETM+ image. But built up / bare surface areas saw a sharp increase of 191.73 km² from 1990 to 963.89 km² in 2006. This explains the increase in built up areas and an indication for urbanization. Validating these deductions is a proof of a sharp decrease in vegetation from 3614.70 km² in 1990 to 2894.71 km² in 2006. There has therefore been 17.25% decrease in vegetation as at 2006, 18.50% increase in built up / bare surface areas and 1.25% decrease in water bodies (Table 4-5).

Table 4-5: Land Cover Types with their Corresponding Areas.

Land Cover Class	1990		2006	
	Area (km ²)	Area (%)	Area (km ²)	Area (%)
Water Body	367.47	8.80	315.30	7.55
Built up / Bare Surface	191.73	4.59	963.89	23.09
Vegetation	3614.70	86.60	2894.71	69.36
Total Area	4173.90	100.00	4173.90	100.00

4.3 Determining the Effects of Floods on Affected Victims in Pru District

In determining the effects of floods on affected victims, the frequency of flood occurrence, how long they last and their causes were also determined through interviews. It was realized that 206 out of 226 respondents indicated that major floods that had worst effects in the district occurred in 2008 and 2010. But 8.85% of these respondents indicated that floods were also recorded in the later parts of 1968. All 226 respondents interviewed suggested that, 2010 was the last previous year for the occurrence of floods in the district, which had huge adverse effects on the dwellers in the affected communities. Usually floods last for a period of 1-4 months as indicated by 221 (97.79%) respondents. The causes of flooding identified in the District as suggested by both household respondents and officials of the government agencies include the following: Torrential rains; Lack of drainage systems; Opening of Bagre dam in Burkina Faso; and Water bodies overflowing their banks.

4.3.1 Water and Sanitation Effects of Floods

An interview conducted with some household heads in the flood affected communities, revealed the following as their sources of water (Figure 4-14): Unprotected wells; Bore holes; Public taps; Rivers; and Streams.

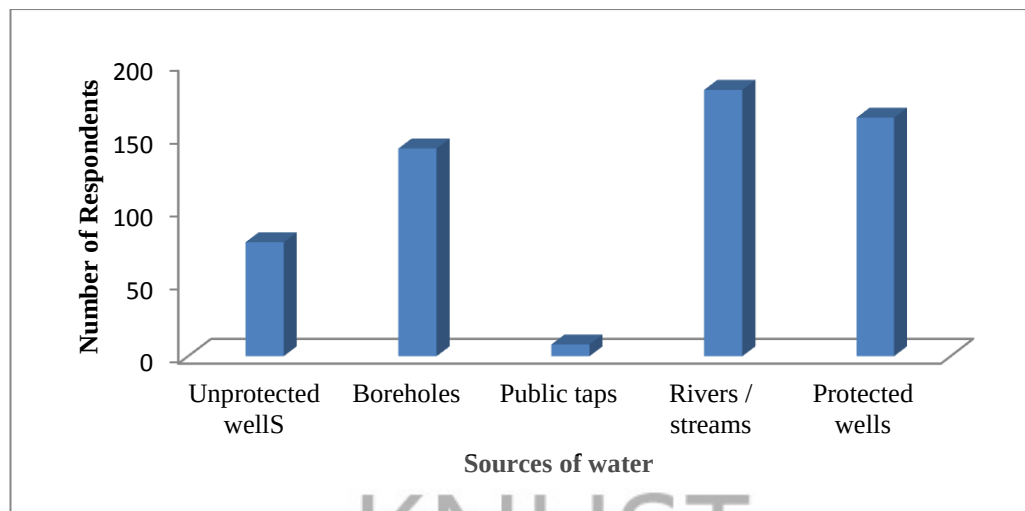


Figure 4-14: Sources of water of respondents in Pru district.

Also their sources of water that got affected by the floods in 2010 (Figure 4-15) include: Unprotected wells; Boreholes; Rivers; and Streams

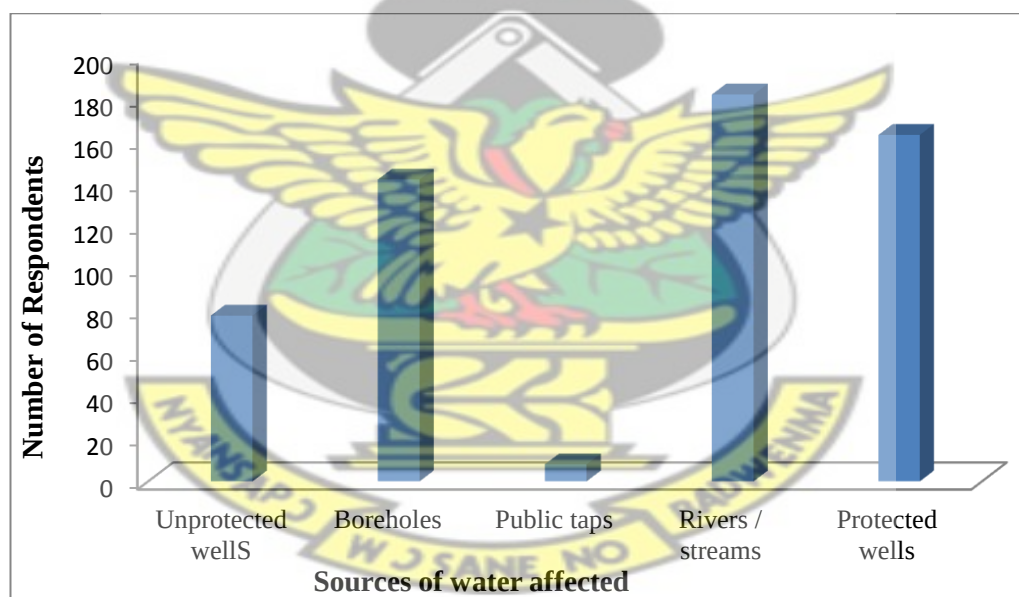


Figure 4-15: Sources of water of Respondents that got affected by floods in Pru district.

In the case of flood events, their sources of water (Figure 4-16) tend to be: Unprotected wells; protected wells; Rivers; Streams; and Boreholes.

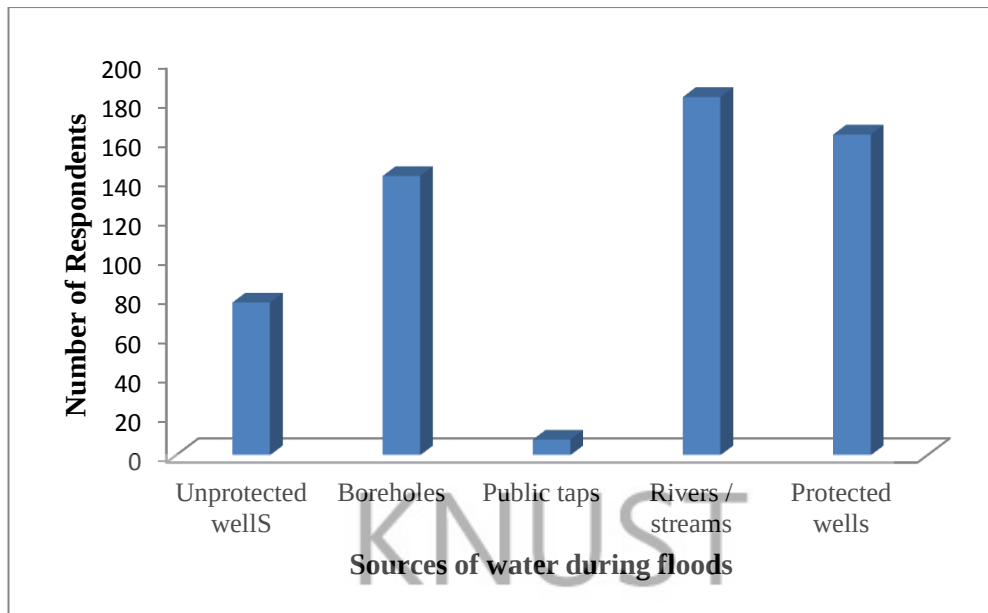


Figure 4-16: Sources of water of Respondents during the floods in Pru district

But the major sources of water in the district are unprotected wells, boreholes and rivers. One hundred and twenty - eight respondents, who live in communities within the reach of a river, mostly depend on the river for their sources of water. These communities include; Banyawaya, Fante Akura, Jaklai, Parambo / Sawaba, Labun Quarters, Kadua, Vutideke, Adjantrewa and Accra town. Figure 4-17 shows a sample of an unprotected well at Kobre which 156 respondents rely on for water, while 108 of the respondents rely on boreholes (Figure 4-18).



Figure 4-17: Sample of unprotected wells at Kobre in Pru district.



Figure 4-18: One of the only two boreholes at Cherepo in Pru District.

The research also identified the following as waste disposal means in the Pru district: Open places; Public refuse dumps; and Backyard refuse dumps.

All the 226 respondents representing 100% response indicated that they dispose of waste in open places and on near-by public refuse dumps (Figure 4-19).



Figure 4-19: Open - place waste disposal at Banyawaya in Pru district.

That of sanitary facilities received varying responses from the respondents interviewed in the district (Figure 4-20).

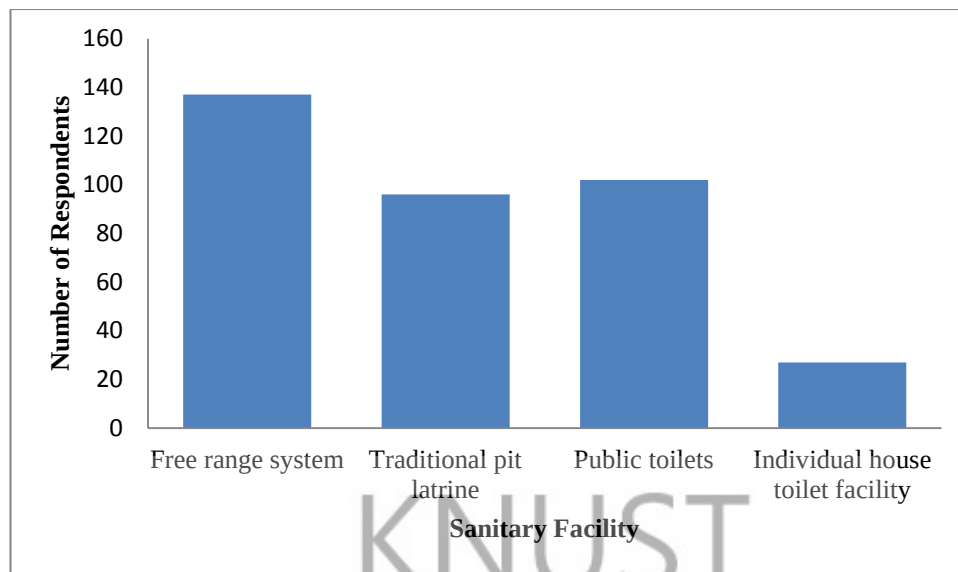


Figure 4-20: Types of sanitary facilities used by respondents in Pru District.

From the study it was realized that only 27 respondents representing 11.95% have individual house toilet facilities with the majority of the respondents (137) free ranging. The research also interviewed the respondents to know the kind of sanitary facilities that were affected during the flooding period, and it was identified that almost all the sanitary facilities in the flood affected communities were also flooded with free range system being the worst hit as 56.64% of the respondents indicated. Moreover, 88 respondents also revealed that their traditional pit latrines were affected. Most of these traditional pit latrines were located in villages, such as Vutideke, Accra town, Kadua, Adjantrewa and parts of Kobre. It was also identified that some of the public toilets at Cherepo, Banyawaya, Kobre, Kwaease, Parambo and Labun got affected by the floods as this was revealed by 96 respondents. Eighteen out of the 27 respondents, who have individual house toilet facilities at their homes, had their toilet facilities being affected by the floods. All these facilities that were affected were all within the flood buffer zones and are on low terrain.

4.3.2 Educational Effects of Flood on Affected Victims

All the communities visited have educational facilities. In the exception of Cherepo in Yeji and Prang which have schools from the Kindergarten level to Senior High Schools, the rest of the communities had up to the Junior High School Level. There are only two public Senior High Schools in the whole district, Yeji Senior High Technical School at Cherepo in Yeji and Prang Senior High School at Prang.

Sixty – seven (67) respondents in the flood affected communities indicated that, schools such as Methodist School, Yeji Senior High Technical School and Vutideke D/A Primary and Accra town D/A Primary had minor flood effects as it couldn't stop academic works of the school.

But 28 of the respondents at Kobre indicated that, in 2010 the Kobre D/A primary and JHS had to close down for about four weeks in order to accommodate the flood victims at Kobre (Figure 4-21). This affected Academic works of the pupils of the school as they had to stay home for such a period when other schools were still in session.



Figure 4-21: Kobre D/A Primary and JHS in Pru district.

Some of the respondents (67.26%) suggested that, during the flood periods of 2008 and 2010, the roads within the communities were impassable for their wards to go to school. Another 42.48% of the respondents also reported that, there have been

disruptions in their wards' school attendances as they needed them at home to help manage the flood damages.

4.3.3 Infrastructural and Transport Effects of Floods on Affected Victims

From the interviews conducted with the flood victims, it was noticed that, 90.27% of them own their homes with the remaining renting apartments. Some of the buildings were built of clay, brick and others were built of cement blocks. About 109 respondents representing 48.23% have their homes built of clay, 91 of the respondents who represent 40.27% have their homes built of cement blocks and the remaining 26 of the respondents that represent 11.50% have their homes built of brick. The effect of floods on infrastructure was a very serious concern. About 98 of the respondents that form 43.36% had flood water at the ground / floor levels in their homes, with 102 respondents indicating flood water between ground and window levels in their homes. The rest of the 26 respondents who represent 11.50% had their homes and other infrastructure totally submerged by the floods. One of the respondents who put up a magnificent restaurant at the lake – side to serve tourist, visitors and people of the District, had his restaurant totally submerged by the flood which subsequently collapsed after 2 years of the flood (Figure 4-22).

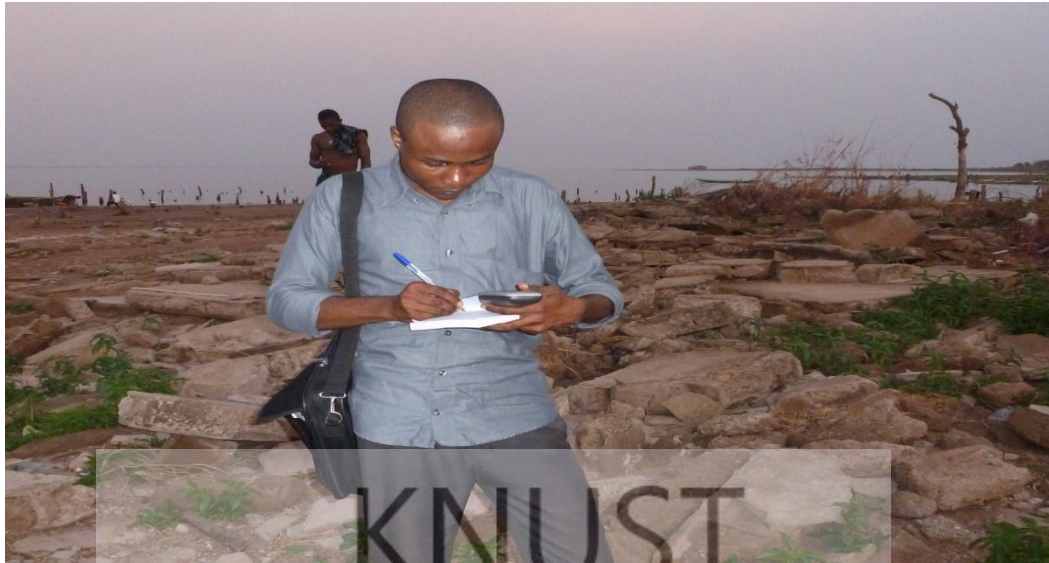


Figure 4-22: Researcher taking records at the collapsed restaurant in Yeji Nsuano.

Through field survey, about 283 homes built of clay and cement blocks totally collapsed within Banyawaya, Fante Akura and Yeji Nsuano with another 69 collapsed at Kobre (Figure 4-23).



Figure 4-23: Sample of collapsed buildings after the 2010 floods in Fante Akura.

After the 2 years of the flood, even there were still buildings standing in the lake (Figure 4.24).

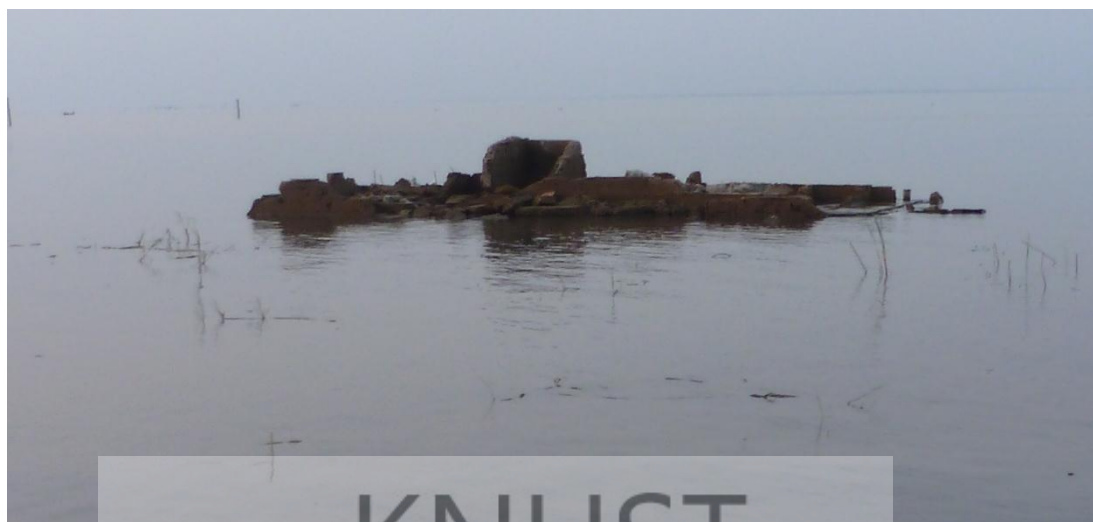


Figure 4-24: A collapsed building still standing in Lake Volta after the 2010 floods at Yeji.

Most of the flood affected victims had to relocate to far places such as Kpando, Makango, Kete – Krachi, Kajaji, Kwame Danso, Atebubu, Abease, Zabrama and other near – by communities in the District. One of the positive aspects of these floods was that, it happened at a slow pace in that, 98.23% of the respondents didn't experience destruction in the gadgets and other living materials in their rooms. They had enough time to move out of their rooms or buildings. The relocation and inundation of the roads by floods actually affected businesses and other services in the District.

Also data collected through interviews with the Pru – district NADMO officials, revealed that, over the 1 billion Ghana cedi funded project by World Bank to construct a Small Town Water Supply Facility at Yeji and Parambo to serve the communities in the two major towns of the district was lost to the floods in 2010.

4.3.4 Agricultural and Economic Effects of Floods on affected victims

One hundred and forty – three respondents are into farming with farmland sizes ranging between 2 acres – 58 acres and 68.53% of the farmers had their farms totally or partially inundated by the floods. Farmers with huge farm sizes are corporate entities under the Block Farming Programme established by the Ministry of Food and Agriculture in 2009. It consists of 10 – 50 members. In 2010, a total of 148 acres of farmlands own by farmers under the Block Farming Concept were all inundated by the floods (Table 4-6). Mostly, rice farmers were badly hit by the 2010 floods and they had to move through the flood water which was within their shoulder heights with some experiencing snake bites (Figure 4-25). Also 78 (34.51%) of the respondents rear farm animals such as goats, sheep, cattle, duck, pigs, chicken and guinea fowls. About 39.74% of the animal farmers had their farm animals affected by the floods. Seventy – two of the respondents are also fishermen and they all indicated that, the floods have actually increased their fish harvest as Lake Volta overflows its banks, fish catch is in abundant.

Table 4-6: Flood effects on Block farmers in 2010 in Pru District (PD)

Community	Crops Cultivated	Size of Farmland Inundated by Floods
Vutideke	Maize, Rice, Pepper	21 acres
Kobre	Rice, Pepper, Cassava	15 acres
Adjantrewa	Yam, Rice, Guinea corn	38 acres
Kade	Rice, Pepper, Cassava	22 acres
Kadua	Cassava, Rice, Maize	25 acres
Parambo	Groundnut, Rice, Tomato	27 acres
Total		148 acres

Source: (Pru - MOFA, 2010).



Figure 4-25: Rice farm inundated by floods at Kadua in Pru District. Source: (Pru District MOFA, 2010).

These situations resulted in food insecurity, psychological problems for farmers, and increase in the prices of some food commodities. Farmers who were psychologically affected decided never to go into farming again as they even took subsidized farm inputs from the government under the Block Farming Programme and had to pay back those inputs (Table 4-7).

Table 4-7: Inputs supplied by Government from June - August 2010 in PD

Inputs	Quantity received by Farmers
NPK 16:16:16 50kg	3,060
Sulphate of Ammonia 50kg	1,500
Seed Rice(40kg)	930
Seed maize(45kg)	120 mini bags
Orizoplus (weedicide)	894 liters

Sourec: (Pru District MOFA, 2010)

From the interviews, 55.75% of the respondents indicated that due to the floods, they have lost between GH¢1000 - GH¢5000. Another 3.98% of the respondents lost

between GH¢10,000 - GH¢ 50,000. The 3.98% of the respondents were the restaurant owner, 6 large scale farmers and 2 other traders. Most of the respondents forming 87.61% could not give an estimated cost of damages to their homes caused by the floods, while 10.18% of the respondents estimated between GH¢ 1000 - GH¢ 5000 of total cost damages to their homes by the floods.

4.3.5 Effects of Floods on Social and Emotional Well – Being of Victims

During the interviews, respondents were asked if they had experienced each of the following “problems” during the 2010 floods as compared to before the floods: Stress; Loss of sleep; Depression; and Difficulty coping with problem.

There was no reported case for the above stated problems before the floods. But it was identified that 224 of the respondents mostly reported of depression and 183 reported of stress during the floods. About 148 respondents also reported of loss of sleep and 139 had difficulties coping with problems during the flood. After the floods, the number of reported cases for each problem by respondents decreased slightly (Figure 4-26). This could be the fact that, some of them had accommodations and other relief items from friends, Chiefs, the District Assembly, NADMO and Churches.

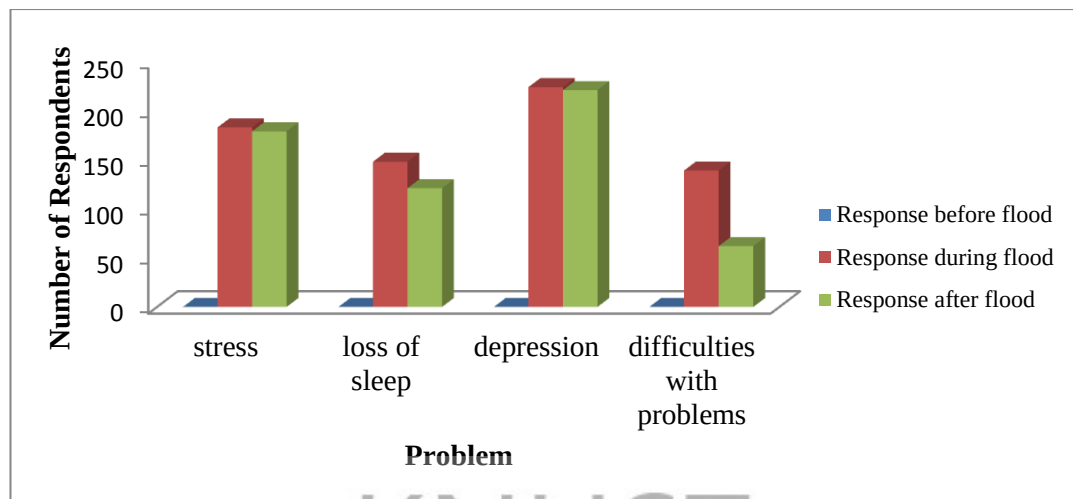


Figure 4-26: Emotional problems of victims in 2010 floods in Pru district.

During flood periods, the respondents indicated that, usually their emotional sense of control become poor and also they become highly confused without knowing what step to take in order to manage the floods. They then have to sort for assistance from friends, churches and government agencies that help them with relief items and some coping strategies.

4.3.6 Evacuation and Coping Strategies of Flood Victims during Floods

Movement from one place to another during floods is a major problem in flood affected communities. It was revealed by 74.34% of the respondents that, their means of movement from home to other places within the flood affected boundary was walking through flood water. Another 34.96% are able to secure canoes which they use as means of transport to other places, and others have to pay for the service of being transported from their locality to other places (Figure 4-27). They were totally separated from the reach of other localities. Most could not send their produce to the Yeji market which starts on every Sunday and ends on Tuesday evening which normally affected the business of trading in the District contributing to low revenue generation for the District Assembly.



Figure 4-27: Canoe used as means of transport during floods at Kade in Pru district.

Evacuation alert is needed to pre – inform the community dwellers on the likelihood of flooding in their communities. But this was not the case as all the 226 respondents revealed that they did not receive any evacuation alert.

During the interviews the following coping strategies were identified from the respondents: Support from NADMO; Support from District Assembly and Chiefs; Relocated to friends' homes, church premises and school class room blocks; Collected flood water from rooms; and Built up barriers by heaping up soil to prevent inflow of water into their rooms.

On the contrary, 189 respondents suggested that, the strategies adopted were not effective as the supports from NADMO and District Assembly were inadequate. This was because only a few victims received mattresses, mosquito nets and cups from these Authorities in the form of relief items. According to 88 respondents, a 5 kg bag of rice was given to 3 houses with over 10 households and 35 people to share. This

does not help in any way. They indicated that, better flood management and control techniques will be much of help to them.

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CHAPTER FIVE

5.0 Discussion

5.1 Flood Risk Zones in Pru district

From a supervised classification, it was identified that, the flood risk zones are situated within the North – Western parts of the Pru District. The flood zones produced were classified into: high risk zones, medium risk zones and low risk zones. Different parts of the Pru District belong to one of the three flood risk zones as presented in the flood risk maps. According to Jha *et al.*, (2012) areas at risk of flooding can be dynamic in nature. With a changing level of development, the nature and degree of risk also changes. They further explained that flood risk increases mainly because of an increased level of exposure of the elements under threat. For example, there are occasions when infrastructure or other buildings are constructed in areas already at risk, thereby automatically falling within a risk zone. There are also instances when, at the time of construction, the assets and infrastructures are thought to be outside the risk region, but there are newer effects arising from changing land uses as urban development proceeds. These can include increased rates of runoff, lack of drainage systems, lack of storage systems, overwhelming amounts of rainfall leading to overflow, and the channelization of rivers which may reduce the amount of discharge they can accommodate. All these factors can increase the number of elements at risk of flooding in an area (Jha *et al.*, 2012).

It is therefore worth noting that the flood risk maps generated for Pru District provide a network of the vulnerability of communities in the District to flooding. In accordance with the extent used, Pru District lies on a geographical land area of 6,162.59 km². The flood risk maps revealed about 3,246.26 km² of its land area to be

a high flood risk zone, with 754.54 km² falling within medium flood risk zones while the remaining 2,161.79 km² of land fall within the low risk zones. The high flood risk zones are areas in the Pru District that are highly prone to flooding and the low flood risk zones are also areas that are less prone to flooding. The research works of Beeson and Jones (1988), Kebbeh *et al.*, (2003), and Orok (2011) confirms my research findings in that, their works also consider the categorization of flood risk zones to be as a result of the combination of several geographical and remote sensing data of a study area. In actual fact, Low slope angles and other terrain characteristics such as the presence of valleys influence flooding.

A combination of the stream buffer zones and the reclassified slope maps was used in the production of the flood risk map. A 1 km stream buffer zone was created to delineate the extent to which an area could be flooded. This 1 km chosen was based on field survey as during flooding, areas within 1 km stretch are likely to be affected. It was therefore realized that 4053.87 km² of the area in the district are within the buffer zone while 2,108.72 km² were outside the buffer zone. The reclassified slope map delineates the areas into low slope areas, medium slope areas and high slope areas. The low slope areas covered a total of 5185.19 km² and the high slope areas covered a total of 5.71 km². The low slope areas are areas that have high accumulation of water and do not allow water to drain down the slope easily. But that of the high slope areas easily allow water to drain down the slope. The work of Orok (2011) also shows that overlaid maps of a stream buffer zone map and a reclassified slope map help to delineate areas of high flood risk, medium flood risk and low flood risk.

It was therefore deduced that, areas within the stream buffer zones and also within a low slope area have high flood risks and are shown by the red-colored portions on

the flood risk map (Some of those areas include; Kadua, Cherepo, Fante Akura, Prang, Parambo, Kobre and Banyawaya). Communities within the stream buffer zone but on medium slope areas have medium flood risk and also communities outside the buffer zone but on high slope areas are low flood risk areas. In this case, communities outside the stream buffer zones and lay on high slope areas have high possibility of not experiencing flooding. Nevertheless, the nature of settlement in these areas could also alter the vulnerability of the areas to flooding. This is because in a research work carried out by Ologunorisa (2004) and Adeoye *et al.* (2009) shows that the effect of flooding in the vulnerability of people is that, buildings and diversions could lead to an obstruction of the natural course of water during rainfall and especially as there are no good drainages in an area, flooding will be inevitable.

The drainage basins identified during the field survey revealed that areas within 1 km – 2 km of the drainage basins could be potentially affected by floods depending on the densities of the drainage basins. Even according to UCAR (2010) the density of stream networks in an area largely influences the potential runoff. Drainage basins with large numbers of channels / tributaries dividing the area have higher stream density (UCAR, 2010). The natural stream network of the study area is illustrated in Figure 4.5. However, development interventions in the urban areas cause an artificial increase in stream density as there exist more road grids and drainages that act as tributaries increasing the flow of water to lower lying parts of a city and nearby stream channels (UCAR, 2010). This increases the risk of flooding as the rates of infiltration is lower than it should naturally be.

As shown by the flood risk maps, areas with low slope angles that are closer to stream channels will get flooded quicker than high land areas. Also the slope of the basins will affect both the speed of runoff and infiltration of water. Lower slopes

indicate that the rate of infiltration would be higher and surface runoff would decrease, thus, increasing the risk of flooding. Pru district is characterized by low lying areas with slope angles of less than 4 degrees. Thus, land use planners would want to develop infrastructures with this information at the back of their minds and ensure that such developments are either built on natural or artificially made higher grounds to avoid flooding.

5.2 Land Cover and Land Use Changes in Pru District

Although the major floods of 1968, 2008 and 2010 as indicated during interviews, may have negative effects on the vegetative cover of the area, it also came with some positive impacts. Areas that used to have vegetative cover have been converted into built – up areas and water bodies. This has created room for the urban expansion of the area and inundated water areas have tended to serve the communities around with natural resources needed for their survival. From the classified land cover map of 1990 which was acquired from USGS, water bodies depicted by the blue colour were more than that of the land cover map for 2006. This explains the time of the year in which Landsat images were acquired. From Table 4-5 the water body depreciated from 1990 to 2006. That explains the presence of less blue coloured portions indicating water in the 2006 Landsat 7 ETM+ image. But built up / bare surface areas saw a sharp increase of 191.73 km² in 1990 to 963.89 km² in 2006. This Explains the increase in built up areas and an indication for urbanization. Validating these deductions is a proof of a sharp decrease in vegetation of 3614.69 km² in 1990 to 2894.71 km² in 2006. There has therefore been 17.25% decrease in vegetation as at 2006, 18.50% increase in built up / bare surface areas and 1.25% decrease in water body (Table 4-5).

Critically analyzing the change trend, it could be seen that from 1990 to 2006, a land cover area of 297.27 km² was lost to water bodies (Table 4-4). A land cover area of 15.13 km² which was covered by water bodies in 1990 receded or dried up and was converted into either built up areas / bare surfaces. The demand for lands within drainage basins is very common in the Pru District as it was shown during interviews that, 178 of respondents live within the stretch of a water body. Some of the areas that were wetlands in 1990 and few years thereafter have been turned into built up areas. In situations where urban areas are often located in hazard-prone locations such as low-elevation coastal zones and wetlands, they are at risk from sea-level rise, or in other areas at risk from flooding and extreme weather events (OECD, 2009; WDR, 2010). Moreover 55.07 km² of the land covered by water in 1990 have changed into vegetation which have made more arable lands available to farmers for cultivation. It is worth noting to realize that such lands cannot be surety for agricultural or infrastructural purposes as any increase in the level of drainage basins within the area could trigger flooding and affect the farmlands and settlements within the flood plains. More so, torrential rains could also cause flooding in past wetland areas that have been converted into built up areas. This explains the fact that within the 16 year change detection period about 18.03 km² of built up and vegetation areas were converted into water bodies, making flooding a major problem among natural disasters in the District. Urbanization has become one of the major contributing factors to flooding in Ghana since settlements alter the flow direction and flow accumulation of moving water within an area. It can even be noted in Satterthwaite (2011) that urbanization is accompanied by increasingly larger-scale urban spatial expansion as cities and towns swell and grow outwards in order to accommodate population increases. So, 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. This becomes worse off when there are no drainage basins in such areas. Pru District virtually lacks drainage systems and is making most of the areas difficult to allow the easy drainage of water after torrential rains. The research has revealed that 876.99 km² of vegetative land cover has been converted into built up areas (Table 4-4). The annual conversion rate of 6.25% is very alarming during this 16 year period. Even with the creation of additional Districts which will require the construction of more infrastructure and place high pressure on the vegetative resources in the district, it is likely that the annual conversion rate from vegetation to build up areas could be higher than the 6.25%. According to works done by UCAR (2010) and Ahmad *et al.*, (2010), the impacts of decrease in vegetation on landscape can include: increase in runoff volumes due to increase in stream channels, road grids and percentage of compacted and impervious surfaces and soils. But the presence of vegetation in an area reduces the amount of runoff to streams as vegetation intercepts rainfall and uses it for growth purposes thus impeding overflow of water (Conservation Ontario, 2001).

Analysis of the overlaid land cover change detection maps of 1990 – 2006 explains the high conversion rates that occurred between some of the land cover features than others. This is been clarified as between 1990 and 2006, the light blue portions show some areas that were covered with water in 1990 and probably due to climate factors such places have changed into vegetation in 2006. Land has therefore been made available for agricultural and building purposes but more especially rice cultivation as there could be the potentials of such lands to hold some water for rice cultivation Jha *et al.* (2012) reveals that when a water body recedes such land areas along the water body become suitable for rice cultivation. On the other hand, these same

available lands for agricultural and infrastructural purposes have been converted again into water bodies which are being depicted by the light green colour in Figure 4-13. Every settlement or agricultural land that falls within these vegetative land covers are likely to be inundated by water. High levels of land cover and land use changes (urbanization) in river flood plains and other areas of catchments might also change the frequency of occurrence of flooding (Jha *et al.*, 2012). They further clarified that, in the mid-1970s, when urbanization was just starting to accelerate, the occurrence of small floods increased up to 10 times with rapid land cover and land use changes, 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).

It is therefore necessary to acquire past land cover trends of some years to examine the rate at which these changes occur and the extent to which these changes may occur. The factors that affect land cover and land use changes are diverse and can generally be grouped into biophysical and anthropogenic (Boserup, 1981). The biophysical factors includes flooding, drought, bushfire, while the anthropogenic factors includes deforestation, urbanisation and increase in population. Among the biophysical factors, flooding is seen to be the main factor which affected the land cover changes in the study area.

Within the 16 year change detection period, the land cover in Pru District has undergone drastic change with several factors such as urbanization, land clearing for agriculture and climate change accounting for it. If these trend continuous, much of

the land areas in the district will be highly prone to flooding and places that are already highly prone to flooding will record worse cases in the history of the district.

5.3 Analysis of Flooding Effects on Affected Victims in Pru District

Flood effects on the lives of affected victims become a great challenge to them and the government in battling with hardships that are left on them. The difficulties and problems that come alongside flooding are not different from what happens to the victims in Pru District. They normally face problems such as, health, education, water and sanitation, agriculture / economic, infrastructure and transport and emotional well – being.

5.3.1 Analysis of Water and Sanitation in Relation to Floods on Affected Victims in Pru District.

Sources of water in the District include: unprotected wells, boreholes, public taps, rivers / streams and protected wells. It was indicated that 69.03% of the respondents get their sources of water from unprotected wells with another 16.37% obtaining their source of water from protected wells. But the majority (78.76%) gets their sources of water from the river / stream and the few (4.87%) of the respondents get their sources of water from the public taps. The public taps sometimes face difficulties and at times water does not flow through the taps for months. Some will then have to tend to other sources of water especially rivers / streams and wells. It was also shown by 73.89% of the respondents that, rivers and streams within their catchment areas got affected by floods and 80.53% still relied on them for their sources of water. The protected wells were also affected by the floods as indicated by 45.13% of the respondents. Only a few (5.31%) respondents indicated flood effects on the boreholes within their communities.

In terms of waste disposal, open places, public refuse dumps and backyard refuse dumps are the common waste disposal means. Wastes are found in all the flood affected communities and are not attended to for proper disposal. Most of the children were found on this close – by open refuse dumps free ranging themselves. Majority of the respondents which is about 60.62% defecate in open places which are close to their homes. Another 96 respondents use the traditional pit latrine, but these latrines are found in the remote communities of the District. The public toilet facilities which are in their bad shapes at the time of visit were used by 45.13% of the respondents. The individual house toilet facilities were only used by 27 respondents suggesting the low number of toilet facilities built by house owners. During flood periods all these sanitary facilities were affected to a certain degree. The floods wash these waste materials into rooms and other places affecting the people health-wise. This debris is also washed into their water bodies and some infiltrate the soil and join their underground sources of water such as the wells. According to Jha *et al.* (2012) floods can pose a high risk of water contamination due to an increase in a number of pit latrines that could collapse as well as flood the unprotected shallow wells and infiltrate into underground water.

5.3.2 Understanding Educational Effects of Flood on Affected Victims

The education sector throughout some of the assessed areas was affected negatively by the floods by way of damaged classroom blocks, staff houses and toilets and school closure. Notably Kobre D/A Primary and JHS in the District were most affected as they have to close down for a month in order to accommodate the flood victims. School children of the schools in Vutideke and Accra town were unable to attend classes because most of the roads were impassable. According to Nana Adankwah, a sub-chief of Akuamuhene, the 2008 and 2010 floods were big

challenges to people and students living within the Cherepo community. The land is so flat that, any torrential rain makes the whole area flooded and introduces snakes and frogs into the classrooms and dormitories of students at Yeji Sen. High Tech. School and also homes of the community dwellers. According to Klijn (2009) flood disruptions to education, which over a long term period can lead to children suffering academically must be well assessed and managed in order to reduce the long term effects on the children.

5.3.3 Infrastructural and Transportation Effects of Floods on Affected Victims

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 (Jha *et al.*, 2012). Direct impacts are the physical damages 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. All the 226 respondents indicated that there was some degree of damage to their buildings due to the slow rise floods experienced in 2008 and 2010. What could not be established was the effect of these floods on the victims after they move into their homes after the floods receded since the inner and outer walls of the buildings that were able to stand the floods became greenish. According to a research conducted by Jha *et al.*, (2012), a slow rise flood can damage buildings in the following ways:

- 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; and
- Water can cause failure of electrical systems resulting in secondary damage.

Fast flowing floodwaters are also 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 (Jha *et al.*, 2012).

Floods also inundate roads leading to towns and their farmlands making movement difficult. From the research findings in PD, most of the communities were cut from the reach of other communities as their roads got inundated. Transportation of food and other commodities of business nature encountered so much difficulty as vehicles could not access the areas. Foods were left rotten on farmlands and at home affecting the livelihoods of farmers. More so, the Small Town Water Supply (STWSS) facility that got affected by the 2010 floods brought a lot of challenges and un-told hardships on the people of Yeji and Parambo including their surrounding communities. When an interview was carried out with some officials of the District Assembly, NADMO, Chiefs and Elders of the communities, it was categorically stated that, the location of

the STWSS facility was based on a past record whereby a similar project which was sponsored by the Rural and Small Town Water Supply Department was located quite far from the Lake Volta. Surprisingly, the Lake receded so far from the water facility in that, the pumps were lying in the open far from the lake and could not pump water to the facility for further distribution to the communities. It became necessary to advice the recent contractor of the STWSS facility in 2009 to situate the facility at proximity capable of having the pumps to transfer water to the facility for distribution to the communities. Unfortunately, as we lack more advanced scientific facilities in forecasting the occurrence of flood disaster couple with climate modeling, the unexpected happened in 2010 when there was an increase in the volume of the drainage basins in the district thereby overflowing their banks and subsequently inundating the STWSS facility which was sponsored by World Bank. A great loss to the district upon several years of using wells and rivers after the collapse of the first STWSS facility in 1972.

5.3.4 Analysis of Agricultural and Economic Effects of Floods on Affected Victims

Agriculture which is the main occupation of the people receives great attention when these people especially farmers are hit by disasters such floods of this nature. About 63.27% of the respondents who are into farming actually have farmland sizes ranging from 2 acres – 58 acres with food crops such as, rice, maize, pepper, cassava, yams, tomato and guinea corn. The research identified rice, maize and yams to be the most cultivated food crops in the district. It was identified that 148 acres of cultivated farmlands were inundated by the floods in 2010 (Table 4-6). These farmers got farm inputs from the District Agricultural Development Unit under the Ministry of Food and Agriculture in the Pru District. These inputs are given to the farmers at subsidized prices to

aid food production in the District. But the farmers received the shocking part of their lives as their farmlands and crops were all inundated by flood water at a stage where the crops were not in their harvestable stages. Those who harvested their food crops prematurely only realized that their food crops were rotting. This affected the food supply chain for certain food crops in the District especially rice and maize. According to Weir (2009), Loss of agricultural production will, however, affect the food supply chain on which the populations of urban areas are highly dependent. 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. Also, according to IFRC (2010), 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. The farming communities that were badly hit include Vutideke, Kadua, Kobre, Adjantrewa and Parambo. The interesting part of these floods is that, it increased the fish catch of the fishermen within the Lake Volta catchment area. This was actually an indication from 31.86% of the respondents that are fishermen. About 34.51% of the respondents also rear animals and these animals were likewise affected during the floods with chicken recording the highest fatalities. The cost of damages to farmlands, business and homes was within the range of GH¢ 1000 – GH¢ 5000 cedis for small and medium class respondents while others of large scale farming and huge businesses suffered damage costs of GH¢ 10,000 – GH¢ 50,000.

5.3.5 Analysis of Floods on Social and Emotional Well – Being of Victims

Stress, loss of sleep, depression and difficulties coping with problems were some of the reported emotional problems by respondents in the district. Depression which was the highest recorded emotional problem tends to affect a lot of flood victims

worldwide. This is because one may not be able to withstand losses such as collapsing of an entire building, death of family members and loss of businesses due flooding in an area (Mason *et al.*, 2010). The thought of restarting life all over again is a huge trauma to surviving flood victims. Definitely with this kind of situation at hand, affected and depressed flood victims will find it difficult to sleep and be able to analyse situations in order to bring things under control. This affects their emotional sense of control and could lead to other secondary social problems such as alcoholism, theft and smoking. 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). Fischer (2005) and Miller (2005) suggest 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. The situation is not different from what happens in Ghana.

5.3.6 Evacuation and Coping Strategies of Flood Victims in Pru District

It is very essential to pre-inform an area of an impending flood disaster so as evacuation could be carried out on time. But such flood evacuation alert is absent in Pru District as all 226 respondents indicated that, they were not given any evacuation alert. The NADMO officials need to stem up their activities and should not only wait for the occurrence of flood before assisting. Even the relief items provided by NADMO are not up to standard in terms of helping relief flood victims to even the barest minimum. This could be attributed to inadequate rescue materials in the stores

of NADMO. In fact, flood management in an area can be made highly effective by means of vulnerability zoning, in which areas are classified from higher to lower levels of vulnerability. This further helps in the proposition of flood defense mechanisms, effective flood control measures, evacuation planning and flood warning (Jha *et al.*, 2012). Most evacuation and coping strategies which include collection of flood water from rooms; and build up of barriers by heaping up soil to prevent inflow of water into their rooms were not effective in helping manage the floods. It is therefore necessary that these areas are zoned into high, medium and low flood risk zones for better flood management techniques.



CHAPTER SIX

6.0 Conclusion and Recommendation

6.1 Conclusion

6.1.1 Flood Risk Maps of Pru District

The use of GIS and Remote Sensing for the supervised classification and mapping obviously reflects the true features on the ground as field survey proofs it. From the SRTM DEM analysis and field survey it could be concluded that not all areas in Pru District are highly prone to flooding. The total area of lands in the District that fall within the high flood risk zone is about 3,246.26 km² representing 52.68% of the land area. The medium flood risk zones cover 754.54 km² of land which represents 12.24% of the total land area with the low flood risk zones covering an entire area of 2,161.79 km² representing 35.08% of the total land area. Two main forms of flooding were identified in the District during the study, these are: flash floods and River floods, with River floods being the most commonly encountered form of flooding in the District.

6.1.2 Land Cover and Land Use Changes in Pru District

From the Land cover maps produced using Landsat 5 TM of 1990 and Landsat 7 ETM+ of 2006; it was known that the collection of water within certain areas in the District is subject to the time of the year. There was much water bodies in the classified land cover map of 1990 Landsat 5 TM than that of the 2006 classified Landsat 7 ETM+ image. The variation was such that, in 1990 a total land area of 367.47 km² was covered by water while in 2006 a total land area of 315.31 km² was covered by water. The land cover change for vegetation saw a sharp decrease from

1990 to 2006 of about 17.25%. This is confirmed by the proofing change in built up / bare surface area from 1990 to 2006 where there has been an expansion in built up / bare surface areas of 18.5%. This is therefore an indication of high level of land cover and land use changes which have urbanization, infrastructural development and agricultural activities to be the contributing factors, but there are several other factors that could have affected the vegetation, such as warmer climate, rain sink and sand encroachment. If these trend continuous, much of the land areas in the district will be highly prone to flooding and places that are already highly prone to flooding will record worse cases in the history of the District.

6.1.3 Effects of Floods on Affected Victims in Pru District.

Depending on the infrastructural materials, location of infrastructure, intensity of flood and time taken for flood to recede, an infrastructure could totally collapse or partially experience cracks. When an entire area becomes inundated with flood, several buildings especially those built of clay / mud and poles cannot withstand it and certainly collapse with time. The destruction of crops by the floods makes it imperative for the community members to shift dependence on agriculture income to non-agriculture income or diversify their agricultural livelihoods. In all 68.53% of the farmers had their farms inundated by the flood which left economic, financial, psychological and emotional problems on them. Therefore it is necessary to have a more integrated approach of identifying these flood zones.

6.2 Recommendations

From the research, it is recommended that the following are established and undertaken to address the identified problems in the District:

- Chlorine and other water treatment materials should be supplied on time to flood victims during flooding periods and they should be trained on how to use the required amounts of these substances in treating water.
- More boreholes should be drilled and the STWSS facilities re-constructed at sites outside the flood risk zones to make more safe water accessible to the communities for domestic use to stop the dependency on rivers and unprotected wells.
- Two sanitary facilities of about 10 – seaters should be constructed in each flood affected community outside a flood risk zone and policies guiding house owners to put up decent sanitary facilities in their homes should be enforced to prevent free ranging.
- There should be stringent policies preventing the establishment of infrastructure within at least 1.5 km of a River.
- Riparian buffer strips (trees, shrubs and grasses grown along water bodies) should be established along the River bodies. This is because they have the potential of providing high level of infiltration through litter falls and grasses thereby stabilizing stream banks.
- There should be insurance policies for farmers in order to be able to recover from costs and damages due flooding.
- Sufficient boats should be made available based on a projected population likely to be affected by floods for better and fast rescue activities which could ensure efficiency and effectiveness in emergency operation with matching staff officials.
- Drainage systems should be well constructed in the flood risk zones to allow easy passage of water after rains.

- Further research should be conducted on floods and climate change modeling to identify the links between climate change and floods while looking at populations likely to be affected in Pru District.
- Further research should be conducted to establish the link between reported health problems and floods as preliminary field study revealed.

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APPENDICES

Appendix A: GPS coordinates of flood risk zones in Pru district during field work

ID	Latitude			Longitude			Y	X	Description of flood Area
	Deg.	Min.	Sec.	Deg.	Min.	Sec.			
1	8	13	20.3	0	39	19.1	8.22231	-0.6553	Cherepo
2	8	13	19.1	0	39	17.3	8.22197	-0.6548	Cherepo
3	8	13	18.1	0	39	15.4	8.22169	-0.6543	Cherepo
4	8	13	16.8	0	39	13.4	8.22133	-0.6537	Cherepo
5	8	13	15.8	0	39	11.7	8.22106	-0.6533	Cherepo
6	8	13	16.5	0	39	10.3	8.22125	-0.6529	Cherepo
7	8	13	18.7	0	39	9.6	8.22186	-0.6527	Cherepo
8	8	13	21.2	0	39	8.6	8.22256	-0.6524	Cherepo
9	8	13	22.7	0	39	10.2	8.22297	-0.6528	Cherepo
10	8	13	21.6	0	39	12.2	8.22267	-0.6534	Cherepo
11	8	13	21.7	0	39	12.5	8.22269	-0.6535	Cherepo
12	8	13	20.5	0	39	14.5	8.22236	-0.654	Cherepo
13	8	13	22.2	0	39	15.5	8.22283	-0.6543	Cherepo
14	8	13	22.1	0	39	16.8	8.22281	-0.6547	Cherepo
15	8	13	22.4	0	39	18.4	8.22289	-0.6551	Cherepo
16	8	13	20.7	0	39	18.7	8.22242	-0.6552	Cherepo
17	8	14	6.8	0	39	35.7	8.23522	-0.6599	Banyawaya
18	8	14	12.7	0	39	39.3	8.23686	-0.6609	Banyawaya
19	8	14	13.9	0	39	39.3	8.23719	-0.6609	Banyawaya
20	8	14	15.4	0	39	39.5	8.23761	-0.661	Banyawaya
21	8	14	14.8	0	39	39.8	8.23744	-0.6611	Banyawaya
22	8	14	15.4	0	39	37.4	8.23761	-0.6604	Banyawaya
23	8	14	15	0	39	36	8.2375	-0.66	Banyawaya
24	8	14	14.7	0	39	34.1	8.23742	-0.6595	Banyawaya
25	8	14	11.8	0	39	32.2	8.23661	-0.6589	Banyawaya
26	8	14	2.9	0	39	34.4	8.23414	-0.6596	Banyawaya
27	8	14	4.6	0	39	30.5	8.23461	-0.6585	Banyawaya
28	8	14	11.9	0	39	25.9	8.23664	-0.6572	Banyawaya
29	8	14	11.6	0	39	25.3	8.23656	-0.657	Banyawaya
30	8	14	1.6	0	39	1.6	8.23378	-0.6504	Fante Akura
31	8	14	4.3	0	39	1.6	8.23453	-0.6504	Fante Akura
32	8	14	3.2	0	39	0.5	8.23422	-0.6501	Fante Akura
33	8	14	5.8	0	39	0.1	8.23494	-0.65	Fante Akura
34	8	14	7.8	0	39	1.3	8.2355	-0.6504	Fante Akura
35	8	14	8.8	0	39	0.8	8.23578	-0.6502	Fante Akura
36	8	14	10	0	39	0.4	8.23611	-0.6501	Fante Akura
37	8	14	11.4	0	39	1.7	8.2365	-0.6505	Fante Akura
38	8	14	12.4	0	39	3.7	8.23678	-0.651	Fante Akura

39	8	14	12.4	0	39	5.6	8.23678	-0.6516	Fante Akura
40	8	14	12.2	0	39	7.2	8.23672	-0.652	Fante Akura
41	8	14	12.1	0	39	2.8	8.23669	-0.6508	Fante Akura
42	8	14	11.2	0	39	3.1	8.23644	-0.6509	Fante Akura
43	8	14	8.4	0	39	3.3	8.23567	-0.6509	Fante Akura
44	8	14	5.3	0	39	3.4	8.23481	-0.6509	Fante Akura
45	8	14	0.8	0	38	42.3	8.23356	-0.6451	Yeji Nsuano
46	8	14	0.2	0	38	41.6	8.23339	-0.6449	Yeji Nsuano
47	8	14	0	0	38	40.4	8.23333	-0.6446	Yeji Nsuano
48	8	14	0.7	0	38	39.2	8.23353	-0.6442	Yeji Nsuano
49	8	14	0.7	0	38	38.5	8.23353	-0.644	Yeji Nsuano
50	8	14	2	0	38	37.7	8.23389	-0.6438	Yeji Nsuano
51	8	14	2.2	0	38	39.3	8.23394	-0.6443	Yeji Nsuano
52	8	14	2	0	38	40	8.23389	-0.6444	Yeji Nsuano
53	8	14	2.8	0	38	40.3	8.23411	-0.6445	Yeji Nsuano
54	8	14	3.1	0	38	41.2	8.23419	-0.6448	Yeji Nsuano
55	8	14	2.7	0	38	40.1	8.23408	-0.6445	Yeji Nsuano
56	8	13	49.4	0	38	15.3	8.23039	-0.6376	Jaklai
57	8	13	50.1	0	38	15.5	8.23058	-0.6376	Jaklai
58	8	13	49	0	38	14.7	8.23028	-0.6374	Jaklai
59	8	13	49.1	0	38	14.8	8.23031	-0.6374	Jaklai
60	8	13	39.5	0	38	16.4	8.22764	-0.6379	Jaklai
61	8	13	48.9	0	38	17.2	8.23025	-0.6381	Jaklai
62	8	13	48.8	0	38	16.8	8.23022	-0.638	Jaklai
63	8	13	45.6	0	38	15.6	8.22933	-0.6377	Jaklai
64	8	13	47.8	0	38	16.4	8.22994	-0.6379	Jaklai
65	8	13	58.1	0	40	22.5	8.23281	-0.6729	Kwaeasi
66	8	13	49.5	0	40	18.2	8.23042	-0.6717	Kwaeasi
67	8	13	49	0	40	17.5	8.23028	-0.6715	Kwaeasi
68	8	13	47	0	40	14.6	8.22972	-0.6707	Kwaeasi
69	8	13	40.1	0	40	7.5	8.22781	-0.6688	Kwaeasi
70	8	13	40.1	0	40	7.4	8.22781	-0.6687	Kwaeasi
71	8	13	41.2	0	40	3.9	8.22811	-0.6678	Kwaeasi
72	8	13	42.3	0	40	3	8.22842	-0.6675	Kwaeasi
73	8	13	42.8	0	40	2.9	8.22856	-0.6675	Kwaeasi
74	8	13	42.9	0	40	2.7	8.22858	-0.6674	Kwaeasi
75	8	13	42.7	0	40	2.3	8.22853	-0.6673	Kwaeasi
76	8	13	42.5	0	40	2.4	8.22847	-0.6673	Kwaeasi
77	8	10	14.7	0	44	38.2	8.17075	-0.7439	Kobre
78	8	10	13.5	0	44	37.6	8.17042	-0.7438	Kobre
79	8	10	12.4	0	44	36.9	8.17011	-0.7436	Kobre
80	8	10	12.6	0	44	38.9	8.17017	-0.7441	Kobre
81	8	10	12.8	0	44	40.1	8.17022	-0.7445	Kobre

82	8	10	13.6	0	44	40.3	8.17044	-0.7445	Kobre
83	8	10	15.6	0	44	41.2	8.171	-0.7448	Kobre
84	8	10	16	0	44	42.6	8.17111	-0.7452	Kobre
85	8	10	16.9	0	44	40.6	8.17136	-0.7446	Kobre
86	8	10	15.2	0	44	38.7	8.17089	-0.7441	Kobre
87	8	10	10.6	0	44	48.1	8.16961	-0.7467	Kobre
88	8	7	41.4	0	48	14.5	8.12817	-0.804	Sawaba
89	8	7	42.2	0	48	15.8	8.12839	-0.8044	Sawaba
90	8	7	42.3	0	48	13.6	8.12842	-0.8038	Sawaba
91	8	7	43.2	0	48	13.1	8.12867	-0.8036	Sawaba
92	8	7	44.4	0	48	9.5	8.129	-0.8026	Sawaba
93	8	7	44.2	0	48	7.6	8.12894	-0.8021	Parambo nsuano
94	8	7	45.5	0	48	13.1	8.12931	-0.8036	Parambo nsuano
95	8	7	46.2	0	48	13.5	8.1295	-0.8038	Parambo nsuano
96	8	7	39.4	0	48	14.2	8.12761	-0.8039	Parambo nsuano
97	8	7	39.2	0	48	15.3	8.12756	-0.8043	Parambo nsuano
98	8	7	39.1	0	48	15.6	8.12753	-0.8043	Parambo nsuano
99	8	7	38.8	0	48	19.1	8.12744	-0.8053	Parambo nsuano
100	8	7	38	0	48	19.7	8.12722	-0.8055	Parambo Farmland
101	8	7	37.9	0	48	18.9	8.12719	-0.8053	Parambo Farmland
102	8	7	36.3	0	48	21.8	8.12675	-0.8061	Parambo Farmland
103	8	7	34.1	0	48	20.7	8.12614	-0.8058	Parambo Farmland
104	8	7	33.8	0	48	20.4	8.12606	-0.8057	Parambo Farmland
105	8	7	30.2	0	48	21.2	8.12506	-0.8059	Parambo Farmland
106	8	7	31.5	0	48	20.5	8.12542	-0.8057	Parambo Farmland
107	8	7	32.6	0	48	21.6	8.12572	-0.806	Parambo Farmland
108	8	3	33.6	0	50	49.7	8.05933	-0.8471	Labun Quarters
109	8	3	33	0	50	52.1	8.05917	-0.8478	Labun Quarters
110	8	3	31.3	0	50	54.2	8.05869	-0.8484	Labun Quarters
111	8	3	31	0	50	55.7	8.05861	-0.8488	Labun Quarters
112	8	3	30.7	0	50	57.7	8.05853	-0.8494	Labun Quarters
113	8	3	30.8	0	50	58.3	8.05856	-0.8495	Labun Quarters
114	8	3	32.8	0	50	61.2	8.05911	-0.8503	Labun Quarters
115	8	3	38.1	0	50	63.1	8.06058	-0.8509	Labun Quarters
116	8	3	30.8	0	50	53.8	8.05856	-0.8483	Labun Quarters
117	7	58	42.3	0	53	40.4	7.97842	-0.8946	Prang
118	7	58	42.1	0	53	41.3	7.97836	-0.8948	Prang
119	7	58	41.6	0	53	37	7.97822	-0.8936	Prang
120	7	58	52.8	0	53	35.6	7.98133	-0.8932	Prang
121	7	58	53.6	0	53	34.7	7.98156	-0.893	Prang
122	7	58	54.1	0	53	34.2	7.98169	-0.8928	Prang
123	7	58	54.8	0	53	34.5	7.98189	-0.8929	Prang
124	7	58	53.4	0	53	34.9	7.9815	-0.893	Prang

125	7	58	53.8	0	53	33.8	7.98161	-0.8927	Prang
126	7	58	53.7	0	53	34	7.98158	-0.8928	Prang
127	8	19	34.1	0	45	58.2	8.32614	-0.7662	Kadua
128	8	19	32.8	0	45	57.1	8.32578	-0.7659	Kadua
129	8	19	31.2	0	45	57.6	8.32533	-0.766	Kadua
130	8	19	42.8	0	45	56.9	8.32856	-0.7658	Kadua
131	8	19	58.6	0	45	56.1	8.33294	-0.7656	Kadua
132	8	20	1.2	0	45	14.1	8.33367	-0.7539	Kadua
133	8	20	0.6	0	45	18.7	8.3335	-0.7552	Kadua
134	8	20	0.8	0	45	17.4	8.33356	-0.7548	Kadua
135	8	20	0.8	0	45	17.3	8.33356	-0.7548	Kadua
136	8	20	9.4	0	45	17.3	8.33594	-0.7548	Kadua
137	8	20	6.2	0	45	16.8	8.33506	-0.7547	Kadua

Appendix B1: Household Questionnaire for Household heads

- ✚ Name of Town / Community.....
- ✚ Name of Suburb.....
- ✚ For how long have you been living in this neighbourhood? years, ...months
- ✚ How many people are in your household?

Occurrence of Flood

- ✚ Date of Flood (if available):
- ✚ Last Previous Occurrence:
- ✚ How long did it take?
- ✚ What is/are the cause(s) of the flood?
- ✚ How frequent does it occur?

Effects of flood on Health of Victims

1. Are there any health facilities in your area? Yes [] No []
2. Was there any damage to health facilities due to the floods? Yes [] No []
3. Was there any disruption in access to health services due to the floods? Yes [] No []

4. Before the flood, how would you describe your general health?
- a) Excellent []
 - b) Good []
 - c) Fair []
 - d) Poor []
5. Since the flood, how would you describe your general health?
- a) Excellent []
 - b) Good []
 - c) Fair []
 - d) Poor []
6. Did any of the household members get sick during the floods? Yes [] No []
7. Which of the following diseases were experienced by the household members who got sick?
- a) Diarrhoea []
 - b) Cholera []
 - c) Fever / Malaria []
 - d) Measles []
- e. Others;
Specify.....
8. Were there any death cases due to flooding? Yes [] No []
9. If yes, how many lives were lost in the course of the flood?
.....
10. Did anyone get injured during the flood? Yes [] No []
11. If yes, what were some of the reported injuries?
.....
.....
.....

Effects of Flood on Water and Sanitation

12. What is/are your main source(s) of water in the community?
- a) Protected wells []
 - b) Unprotected wells []
 - c) Boreholes []
 - d) Public taps []
 - e) Rivers []
 - f) Streams []
13. Which of the sources of water got affected by the floods?
- a) Protected wells []
 - b) Unprotected wells []
 - c) Boreholes []
 - d) Public taps []
 - e) Rivers []

- f) Streams []
14. What becomes your source of water during flood situations?
- a) Flood water []
- b) Rivers []
- c) Protected wells []
- d) Unprotected wells []
- e) Streams []
- f) Boreholes []
- g) Public taps []
15. How do you dispose of waste?
- a) Open places []
- b) Public refuse dump []
- c) Landfill site []
16. What kind of sanitary facility do you use?
- a) Free range []
- b) Traditional pit latrine []
- c) Public toilets []
- d) Individual house toilet facility []
17. Which of the sanitary facilities got affected by the flood?
- a) Free range []
- b) Traditional pit latrine []
- c) Public toilets []
- d) Individual house toilet facility []

Effects of Flood on Education

18. Are there any education facilities in your area? Yes [] No []
19. Was there any damage to school infrastructure (classroom blocks, teacher's houses, toilets) due to the floods? Yes [] No []
20. Did any of the school going children in your household experience any disruption in an attendance due to the floods? Yes [] No []
21. If the answer to 3 above is yes, why? [Indicate main reason(s)]
- a) Road Impassable []
- b) Culvert washed away or Submerged []
- c) School submerged / surrounded by water []
22. Which part of the school building got damaged?

.....

.....

Effects of Flood on Infrastructure and Transport

23. Do you own or rent your home?
- a) Own []
- b) Rent []

c) Others, describe

.....

24. What is your home built of?

- a) Clay []
- b) Brick []
- c) Cement block []

25. What was the level of flood on your premises?

- a) Floor / ground level
- b) Between ground and window levels
- c) At window level
- d) Above window level

26. Did your house collapse due to the floods? Yes [] No []

27. Did the collapsing of the house force you to relocate to a new area? Yes [] No []

28. Did the house lose any of the following properties?

- a) Bed Yes [] No []
- b) Television Yes [] No []
- c) Radio Yes [] No []
- d) Clothing Yes [] No []
- e) Chairs Yes [] No []
- f) Books Yes [] No []
- g) Fridge Yes [] No []
- h) Fan Yes [] No []
- i) Computer Yes [] No []
- j) Bicycle Yes [] No []
- k) Others; specify

.....
.....
.....

29. Which of your major means of transport got inundated and hence hindered movement?

- a. Road []
- b. Water []

30. Did the outboard motors, ferry and canoes encounter difficulties due to the inundation of the lake or river? Yes [] No []

31. If yes, describe

.....
.....
.....
.....

32. How did difficulties in transport due to flooding affected businesses and other services?

.....
.....

Effects of Flood on Agriculture and Commercial Activities

33. Do you own a farm? Yes [] No [], **if No, Skip to Que. 40**

34. If yes, what is the size of your farm?
.....

35. List three main staple crops that you grow

- a)
- b)
- c)

36. Did the household experience crop damage during the floods? Yes [] No []

37. Was the main staple crop the one which was damaged? Yes [] No []

38. What size of your farmland got inundated by the flood?
.....

39. Did the household experience any loss of food stocks during the floods? Yes []
No []

40. Do you own any farm animal or bird? Yes [] No [], **if No Skip to Que. 45**

41. What are the types of farm animals you own? List them
.....
.....
.....

42. Were your farm animals affected by the flood? Yes [] No []

43. If yes, what were the numbers of the farm animals or birds before flood?
.....
.....

44. What were the numbers of the farm animals after the flood?
.....
.....

45. Do you fish? Yes [] No [] **if No Skip to Que. 48.**

46. If yes, did the flood in anyway affected the fish catch? Yes [] No []

47. If yes, describe
.....

Economic impact of flood on affected Victims

48. What is your estimate of the total cost of the damage to your home? (in GH¢)

- a) over 250,000 []
- b) between 100,000 and 250,000 []
- c) between 50,000 and 100,000 []
- d) between 10,000 and 50,000 []
- e) between 5000 and 10,000 []
- f) between 1000 and 5000 []
- g) below 1000 []
- h) don't know []

49. Do you have a business? Yes [] No [] **if No Skip to Que. 53**

50. If yes, what is your estimate of the physical damages to your business?

State

business.....

- a) between 50,000 and 100,000 []
- b) between 10,000 and 50,000 []
- c) between 5000 and 10,000 []
- d) between 1000 and 5000 []
- e) below 1000 []
- f) don't know []

51. What is the estimate of your income lost from business due to the flood?

- a) between 50,000 and 100,000 []
- b) between 10,000 and 50,000 []
- c) between 5000 and 10,000 []
- d) between 1000 and 5000 []
- e) below 1000 []
- f) don't know []

Effects of flood on Social and Emotional well – being of Victims

52. Who are the most vulnerable to floods?

- a) The aged (60 years and above)
- b) The adults (18 years – 59 years)
- c) Children (below 18 years)

53. Before the floods did you experience the following problems?

- a) Stress Yes [] No []
- b) Loss of sleep Yes [] No []
- c) Depression Yes [] No []
- d) Difficulty coping with problems Yes [] No []

54. During the flood did you experience the following problems?

- a) Stress Yes [] No []
- b) Loss of sleep Yes [] No []
- c) Depression Yes [] No []
- d) Difficulty coping with problems Yes [] No []

55. After the flood did you experience the following problems?

- a) Stress Yes [] No []
- b) Loss of sleep Yes [] No []
- c) Depression Yes [] No []
- d) Difficulty coping with problems Yes [] No []

56. Before the flood how would you rate your emotional sense of control?

- a) Excellent []
- b) Good []
- c) Fair []
- d) Poor []

57. During the flood how would you rate your emotional sense of control?

- a) Excellent []
 - b) Good []
 - c) Fair []
 - d) Poor []
58. After the flood how would you rate your emotional sense of control?
- a) Excellent []
 - b) Good []
 - c) Fair []
 - d) Poor []
59. Before the flood were you...
- a) Highly confused? []
 - b) Slightly confused? []
 - c) Not confused? []
60. During the flood were you...
- a) Highly confused? []
 - b) Slightly confused? []
 - c) Not confused? []
61. After the flood were you...
- a) Highly confused? []
 - b) Slightly confused? []
 - c) Not confused? []

Evacuation and coping strategies during flooding

62. What was your means of transport or movement from your home to other vicinities at the time of flood?
- a) Canoe []
 - b) Walking through flood water []
 - c) Others, specify
.....
63. Did your immediate family receive an evacuation alert notice? Yes [] No [] **if**
No skip to Que. 68
64. If yes, for how long were you on evacuation alert?.....months.....days
65. Was your immediate family evacuated? Yes [] No []
66. Did you have adequate notice for evacuation? Yes [] No []
67. What are the main coping strategies that you employ during floods? Rank them in order of importance
- a)
 - b)
 - c)
 - d)
68. Are the above strategies effective? Yes [] No []
69. Who did you turn to for support and help during the flood?
.....

.....

.....

72. Was their support effective? Yes [] No []

.....

.....

.....

KNUST

1. Please what are the areas in Pru district that have ever been affected by floods in the past ten years?



.....

.....

.....

.....

.....

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5. If yes, how many lives have ever been lost for the past ten years?
.....
6. Have there been any injuries? Yes [] No []
7. If yes, what are some of the injuries?
.....
.....
.....
8. Are agricultural farmlands affected by floods in the district? Yes [] No []
9. If yes, where are these farms located?
.....
.....
.....
10. Do trading and other businesses get affected by floods in the district? Yes [] No []
11. If yes, how?
.....
.....
.....
12. Have residential buildings ever been affected by floods in the district for the past ten years? Yes [] No []
13. If yes, in which areas are these residential buildings situated?
.....
.....
.....
14. Have buildings ever collapsed due to these floods? Yes No []
15. If yes, why did they collapse? Reasons can be based on the type of building or intensity of flood.
.....
.....
.....
16. Was there any business facility or structure that got affected by flood? Yes [] No []
17. If yes why was it affected?
.....
.....
18. Was there any educational facility that got affected during the flood? Yes [] No []
19. Did the flood interrupt school activities? Yes [] No []
20. Was your Small Towns Water Supply System (STWSS) project affected by flooding? Yes [] No []
21. If yes, why was it affected? Describe
.....

-
-
22. Give an estimate of the physical damage on the STWSS facility due to flood
.....
23. Which agency / organization funded the water supply project?
.....
24. How much was the STWSS project worth?
.....
25. Has there been any effort to rehabilitate or repair the STWSS facility? Yes [] No []
26. If yes, by which organization / agency / department?
.....
27. Which other facility of community importance got affected by the floods?
.....
28. What actually caused the flooding of the STWSS project and other facilities?
.....
.....
.....
29. What then became the source of water for use by the community?
.....
.....
30. Have you been able to identify areas in the district that are prone to flooding?
Yes [] No []
31. If yes, how are you able to identify this/these flood prone area(s)? Please describe...
.....
.....
32. If no to Que. 30 above, what then are the hindering factors?
.....
.....
.....
33. Would you like to suggest any scientific technique that could help in the identification of flood prone areas? Yes [] No []
34. If yes, please describe
.....
.....
35. What measures were taken to control or manage the floods?
.....
.....

.....

.....

36. Which organizations or agencies provided these measures?

.....

.....

.....

37. How effective were these measures?

- a. Very effective
- b. Effective
- c. Ineffective

38. Please provide any other information that can be of interest to this research but have not been captured in this interview

.....

.....

.....

.....

.....

Thank you for your time and assistance

Appendix C: Baseline for Questionnaire administration

Community	Number of houses affected	Estimated number affected	Estimated number still staying
Cherepo	53	461	197
Kwaease	46	354	have relocated but few around
Konkoma	23	146	101
Jindinbisa south	13	107	87
Yeji central	21	105	96
Yeji Nsuano	13	115	have relocated but few around
Kobre	50	463	232
Parambo	24	322	147
Kadua	18	97	97
Total	261	2,172	957

Source: (NADMO, 2010)

Appendix D: Communities and Number of household head questionnaires administered

Community	Number of household heads interviewed	Total number in households
Cherepo	20	122
Banyawaya	14	66
Fante Akura	16	72
Yeji Nsuano	11	41
Jaklai	8	23
Kwaease	23	132
Kobre	28	126
Parambo/ Sawaba	13	46
Labun	7	29
Prang	21	112
Adjantrewa	18	98
Kadua	10	49
Vutideke	17	89
Accra town	5	38
Kade	15	103
Total	226	1,146

Appendix E: Health Problems reported by Flood Victims for 2010

Health Problems	Number of Respondents Mentioning	Percentage of Respondents Mentioning
Diseases		
Malaria	198	87.61
Cholera	9	3.98
Cold	17	7.52
Diarrhoea	188	83.19
Typhoid fever	58	25.66
Headaches	169	74.78
Injuries		
Snake bites	13	5.75
Swollen legs and hands	26	11.5

n = 226 where n = total number of Respondents interviewed