A GEOSPATIAL ASSESSMENT OF AREAS VULNERABLE TO FLOODING WITHIN SOKOTO RIMA RIVER BASIN IN SOKOTO STATE, NIGERIA

BY

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY ZARIA, KADUNA STATE NIGERIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF M.Sc. DEGREE IN REMOTE SENSING AND GIS

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ZARIA, KADUNA STATE

OCTOBER, 2018

DECLARATION

I declare that this dissertation titledgeospatial assessment of areas vulnerable to flood within Sokoto Rima Rivers Basin in Sokoto State Nigeriawas written by me and is a product of my research work in the Department of Geography and Environmental Management faculty of physical sciences Ahmadu Bello University Zaria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. This dissertation has not been presented for any degree or diploma at any other Institution.

Abdulfatai Abiodun BELLO_________________________

Name of Student SignatureDate

CERTIFICATION

This Dissertation titled, "GEOSPATIAL ASSESSMENT OF AREAS VULNERABLE TO FLOOD WITHIN SOKOTO RIMA RIVER BASIN IN SOKOTO STATE NIGERIAmeets the regulations that govern the award of the Degree in Master of Science (Remote Sensing and GIS) of Ahmadu Bello University Zaria, and it is approved for its contribution to knowledge and literacy presentation.

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DEDICATION

This dissertation is dedicated to Almighty Allah for all his care, love, support and mercy. Indeed you are the greatest.

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ABSTRACT

Flood is one of the most harmful natural disasters in the world. Its effect on human existence as well as the environment has been on the increase due to human induced climate change. Farming activities, fishing, and human settlement are seen on the floodplain of the Sokoto Rima river basin. The study area is increasingly been threatened by flood event, and as a result of this, this research tries to identify the vulnerable areas, and the natural factors influencing flooding in the study area, with a view of providing solution to forestall its impact within the Sokoto Rima River Basin. Field survey, Satellite imagery, Global positioning system (GPS), Advanced Space-borneThermal Emission and Reflection Radiometer (ASTER GDEM), rainfall data and questionnaires administration were the materials and dataused. The research uses the AHP method, was used to carry out the pairwise comparison, and ArcGIS was used to analyze the data (elevation, slope, soil data, land use and land cover, drainage density and rainfall) as factor maps to determine which has more influence on the occurrence of flood. The results revealed that, rainfall has the greatest influence on flood occurrence in the study area with a weight of 34%. The results further showed that, 23.36% of the study area is in low vulnerable area, 34.59% of the study area is in moderately vulnerable area, while 42.05 of the study area is in highly vulnerable area. The flood hazard map showed that only one community (Lahodu) is within the very high risk zone. Based on population at risk, the result showed that only Gandi and Giyawa are the communities that are extremely vulnerable to flood with a population of 22182 and 15301 people respectively. On the effect of flood, farmlands suffers the greatest loss (61.25%) to flooding as reveals by the questionnaire. In view of the risk which the people in the area are exposed to, there is great need for settlements that are within or adjacent to the areas liable to flooding to be relocated and future settlements should be discouraged.

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CHAPTER ONE

INTRODUCTION

1.1 Backgroundtothe Study

Vulnerability is a set of prevailing or consequent conditions which adversely affect the community's ability to prevent, mitigate, prepare for or respond to hazard events (Asian Disaster Preparedness Centre (ADPC), (2005). Blaikie, Canon, Davis and Wisner (1994) defined vulnerability as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or in a society. Also, Vulnerability is described by the International Strategy for Disaster Reduction (ISDR) (2004)as the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards. The concept tries to understand which of the factors is more relevant to community vulnerability. Gheorghe (2005) explains vulnerability as a function of susceptibility, resilience, and state of knowledge. Social science's approach to vulnerability focuses on the human's capacity to respond to hazards and to promptly recover from damages and losses. They require little knowledge of the physical system, since their aim is to explain society's behavior. Natural sciences take another point of view to explain vulnerability; they mainly focus on the physical system to defined vulnerability, leaving out socio-economic characteristics of the system.

The aim of vulnerability studies is to recognize correct actions that can be taken to reduce vulnerability before the possible harm is realized. The need for vulnerability analysis is noted in scientific literature, and the concept includes natural vulnerability, social vulnerability and economic vulnerability. In 2005, Veen & Logtmeijer broaden the concept of vulnerability to explain flood vulnerability from an economic point of view. Here the vulnerability is characterized as a function of dependence, redundancy and susceptibility. Susceptibility is the probability and extent of flooding. Dependency is the degree to which an activity relates to other economic activities in the rest of the country. Redundancy is the ability of an economic activity to respond to a disaster by deferring, using substitutes or relocating. Redundancy is measured as the degree of centrality of an economic activity in a network. The more central an activity is, the less it encounters possibilities to transfer production and the more vulnerable it is for flooding.

Flood is a disaster which is among the several types of natural disasters like earthquakes, landslides and droughts. When it happen, it results in threat to human life, and loss of properties. It also affects infrastructure, agriculture and environment. Natural disasters have been a regular occurrence globally right from time immemorial, but their frequencies and intensity have in recent past increased due to human activities(Ladan,1998).

Flooding, especially river flooding is among the most devastating natural disasters in the world, claiming more lives and causing more property damage than any other natural phenomenon (Abubakar, 1993). Although it is said not to be the leading cause of death in Nigeria, but it affects and displaces more people than any other natural disaster (Usman, 2012). Arguably, the rate of flooding in recent times has been unprecedented, with 70 million people globally exposed to flooding every year, and more than 800 million living in flood prone areas (Peduzzi, Dao, Herold and Mouton, 2009). Climate change with more frequent and severe rainfall events, sea level rise, rapid population growth and urbanization, the rate of development on floodplains, the level of awareness of flood risk and the ineffectiveness of efforts towards tackling flooding in many places are factors of concern globally (Raaijmakers, Krywkow and Van der veen, 2008).

The economic consequences of flooding reported in the last two decades amount to tens of billions of US dollars (Guha-sapir, Hoyois and Below, 2013). This event is responsible for hundreds of thousands of deaths mainly in Asia (most notably China, Thailand and Bangladesh) and adversely affected billions of people mostly through homelessness, spread of diseases, physical injuries, mortality (mainly through drowning) and psychological conditions mainly depression, anxiety and post-traumatic stress (Hunter, 2003; Ahern, Kovats, Wilkinson, Few and Matthies, 2005; Tapsel, Tunstall, Green, Floyd and George, 2006). In the US, 32.9% of the total natural disasters in 2012 were hydrological with floods accounting for the most part, affecting more than 9 million people and causing about US$ 0.58 billion worth of damage (EM-DAT, 2015).

In recent years, African countries have also had devastating experiences. For example, between August and September 2007, an estimated 1.5 million people were affected and over 300 killed as a result of floods that swept through 22 countries, from the east to west coast of the continent. The worst hit are Uganda, Sudan, Kenya, Ethiopia, Ghana, and Democratic Republic of Congo (National Geographic News, 2007). Nigeria has experienced similar flood pattern like the rest of the world, as flood events have destroyed lives and properties, polluted the environment, and increased the risk of diseases (Etuonovbe, 2011; Adedeji, Odufuwa, and Adebayo, 2012; Bariweni, Tawari, and Abowei, 2012; Olajuyigbe, Rotowa, and Durojaye, 2012).

Comment [f1]:

In the north-western part of Nigeria, the flood disaster of September, 2010 in Sokoto destroyed roads and bridges including the road linking the Usmanu Danfodiyo University Sokoto. Hence, academic activities was paralyzed for months. It was said to be the most devastating flood event since the University was relocated to its permanent site over thirty years ago (New Nigerian, 10/02/2011:p30). The 2010 flood affected three neighbouring states, where 40 people were killed in Sokoto, 16 people in Kebbi, and 8 people in Zamfara (Shehu, 2010). Besides, 35,000 people were displaced in Sokoto, 150,000 people in Kebbi, and 90,000 people in Zamfara. While in Sokoto, 7,196 houses were destroyed and over 80,000 in Kebbi. The agricultural sector was also affected as 100kg of onions that was sold for ₦4,000 in February 2010 at Aliero market cost ₦40,000 in February 2011 (Shehu, 2010).

Several studies (Olusegun, 2004a; Olusegun, 2004b; Diley et al., 2005; Etuonovbe, 2011; Adedeji et al., 2012) have shown that societies vulnerability to flood have increased due to land use practices employed. With increasing human alteration and development of the catchment area these studies revealed that runoff generation process has changed, especially through decreasing the infiltration capacity of the soil and the change of soil cover. Environmental degradation coupled with uncontrolled urban development in high-risk zones, leads to an increased vulnerability of those communities on the floodplains to catastrophic events (World Meteorological Organization /Global Water Partnership-WMO/GWP, 2007). Adeoye, Ayanlade and Babatimehin (2009) also pointed out that population explosion witnessed in urban centers of developing nations is as a result of rural-urban migration in search of better living conditions has led to occupation of flood vulnerable areas. Climate change as a result of global warming is expected to bring about the increase in the frequency of flood events as temperatures rise, ice melts, sea levels rise with attendant consequences (News Release, 2007). These changes pose a serious threat to human lives, economic development, and the natural world on which much of our prosperity depends. Society therefore needs to take measures to adapt to these unavoidable impacts while taking action to cut the greenhouse gas emissions that are almost certainly causing climate change.

Remote sensing (RS) is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording of reflected or emitted energy and processing, analyzing, and applying that information. In much of remote sensing, the processinvolves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the seven elements (energy source, radiation and atmosphere, interaction with the target, recording of energy by the sensor, transmission-reception and processing, interpretation and then analysis) are involved. However, it is worthy to note that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors. Geographical information system (GIS) can be define as a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes.

Remote Sensing and GIS have been used extensively in Asia and other developing countries for agricultural, aviation and environmental purposes (Ishaya and Ifatimehin, 2009). Remote sensing offers a synoptic view of the spatial distribution and dynamic of hydrological phenomenon such as flood. They are used to measure and monitor the extent of flooded areas, which provide a quantifiable estimate of the land area and infrastructure affected by flooding (Izinyon and Ehiorobo, 2011).

The Sokoto-Rima River basin has witnessed serious river flood events in the past few years which could be attributed to climatic fluctuations. Annually, it displaced thousands of people in the area, and submerged several square kilometers of landed area in general and farmlands in particular. The floods usually occur during the peak of rainy season (June-October) and have attracted the attention of the State and Federal Government (SSG, 2007).

Despite these challenges of flooding, the inhabitant of the study area still produce and cultivate agricultural crops like rice, maize, onions, tomatoes, cabbage, and many more on the flood plain of river Rima and Sokoto, which is an indication of its contribution to their wellbeing.Therefore, an attempt was made in this study to map out and assess the areas vulnerable to flood in the study area (Wamako, Kware, Wurno, Rabah, and Goronyo) using both Geographical Information System and Remote Sensing data, to know the different vulnerable classes of the study area.

1.2 Statementof theResearch Problem

The various ecological zones of Nigeria are associated with different hazards that lead to huge losses of money, lives and properties annually. For example, the southern region is increasingly being affected by coastal floods and severe erosions, while the northern states are continually being threatened by flooding and desertification. However, flood disaster affects virtually all the ecological zones of the country (Nigeria Environment Study/Action Team (NEST), 1991).

The Sokoto flood displaced about 130,000 people in September 2010 and left 6 people dead (Murtala, 2012). The annual rainfall season causes flash flood and massive floods in Nigeria. The torrential rain received in the State in the recent past has resulted in flood at Wamako, Kware, Goronyo, Rabah, Wurno, and some other few places like Silame, with attendant losses of lives and properties(Nigerian Red Cross and NEMA, 2010). The breaking of Lugu dam embankment and over flow of water from Goronyo dam have worsened the flood situation in the State. This is a concern for people who rely on them as a drinking water sources and irrigation (Nigerian Red Cross and NEMA, 2010).

The Sokoto region in Nigeria is one of the major floodplain areas in Nigeria. The plains are seasonally flooded by the Sokoto-Rima River and rainwater run-off during the rainy season. The land area in this location is near flat, making drainage of water on the terrain slow, permitting retention of flooded waters that disperse over large areas during large rain events. The Sokoto plains, in addition to its natural environment and processes, offers important economic benefits such as local large-scale irrigation farming, agriculture, animal grazing, small-scale fishing and flood recession agriculture (Mohammed, 2002). To support these activities and for flood mitigation, the Bakolori and Goronyo dams were built in 1978 and 1984 respectively. The Bakolori dam was built on the River Sokoto, a major water supply tributary of the River Rima, which in turn feeds the Niger River and supplies the Bakolori irrigation project (Mohammed, 2002).

The Goronyo dam was constructed on the Rima River to control flooding and to release water in the dry season to the area and the neighbouring state, Kebbi state, for irrigation purposes (Akane and Jurgen, 2005). Unfortunately, both dams have fallen into disrepair where repeated severe flood events have led to major siltation with the dams, significantly reducing their water holding capacity, along with the collapse of the main wall on both dams. Consequently, the Sokoto plains are now once again subject to considerable flooding resulting in the loss of properties and lives (Akane and Jurgen, 2005). This has been exacerbated by changing rainfall regimes in the region to less frequent but more intense rainfall events. This has resulted in the further reduction and loss of activities such as flood recession grazing, agricultural lands, fishing activities, biodiversity and reduction in vegetation succession (Ekpoh and Ekpenyong, 2011). In particular, the floods of 2010, affected large areas of the state including the Sokoto plains, which serve as clear evidence of their destructive nature and their adverse effect on agricultural products, livestock, property as well as human lives.

Several studies have been carried out on flooding in Nigeria, with the aim of looking at their impact and plans for their abatement across many areas of the country (Akintola 1994; Adeloye and Rustum 2011; Ologunorisa, 2009; Ishaya, Ifatimehin and Abaje, 2009; Egbinola, Olaniran and Amanambu, 2014). However, despite the well-established value of GIS and RS as a critical decision support tool for flood hazard, risk mapping and management, only a few studies can be pointed out incorporating these technologies in Nigeria (Ikusemoran, Anthony, and Maryah, 2013; Muhammad and Iyortim, 2013; Ojigi, Adbulbakiri and Aderoju, 2013; Nwilo, Olayinka and Ayila, 2012). Of these studies, none have focused on the Sokoto region; which is the primary focus of this current study. This is unfortunate because it has increasingly been acknowledged by Egbinola, Olaniran and Amanambu, (2014); Abah, (2013) and Isma'il and Saanyol, (2013) that areas like the floodplains of Sokoto region, which experiences repeated perennial flooding due to its location, topography and recent heavy rainfall, should benefit from these RS and GIS decision support tools.

Like other flood-prone areas in Nigeria, a review of the flood events in Sokoto State shows that flood management and flooding has become one of the primary concerns of people and government decision makers (Amunobi, 2013). With the frequency in flooding likely to increase because of environmental changes (Bhuiyan and Dutta, 2012; Karamouz et al, 2011), there is a growing demand for accurate flood maps for managing disaster risk. Therefore, this study seeks to obtain baseline information on the temporal dynamics of flooding, their extent, and potential risk to human life in the Sokoto Sate region. Information about flooding underscores and justifies the need for this study, in order to help our understanding of flood events in this region that may assist mitigation efforts with the objective of minimizing their destructive power.

Yusuf and Igene (2014) worked on the causes and environmental impacts of flood in Goronyo Local Government Area (LGA) of Sokoto State, applying remote sensing and GIS. Their findings revealed that the main causes of flooding in this area are heavy seasonal rainfall and the failure of Goronyo dam in recent time. The utilization of GIS in their study revealed that more vegetation cover have been converted to other land uses. Despite the loss of farm produce, and buildings in the study area, the situation are still the way they were, as irrigation farmers are seen back to farming along the river channels and the buildings close to the river are still maintaining their stands, with no construction of a concrete embankment along the river as means of protection and guard.

From the aforementioned studies, none has addressed the elements of flood vulnerability in the study area using satellite remote sensing data and GIS techniques to explain the factors enhancing flood vulnerability in the study area, the vulnerable areas, fraction of population affected, as well as flood consequences to the people of the study area, which is the focus of this research. Therefore, this research tries to answer the following questions:

i. What are the factors causing flooding in the study area?
ii. Which areas are vulnerable to flood hazard in the study area?
iii. What proportion of the population is affected in the event of flooding in the study area?
iv. What are the consequences of flooding in the study area?

1.3 Aimand Objectivesofthe Study

The aim of this research is to carry out a flood vulnerability assessment in Sokoto-Rima River Basin in Sokoto State, Nigeria. The specific objectives include to;

i. determinethe contribution of factors causing flooding in the study area;
ii. locate and create a flood hazard map of areas vulnerable to flooding in the study area;
iii. estimate the population at risk in the event of flood in the study area; and
iv. examine the effects of flooding in the study area;

1.4 Scopeofthe Study

The scope of this research work is limited to Wamako, Kware, Wurno, Rabah and Goronyo LGAs of the State. The study tries to assess flood vulnerability in the area, determined the factors causing flooding, the flood risk zones map, and examine the effect of flooding in the study area. The study will cover year 2009 (year before the flood event, so as to know how the area was before the flloding), 2010 (as the base year, this was the flooding year so as to know how the area look like, as it was reported by daily trust 2018, that the state experience a serious devastating event), and year 2011 (year after the flood, so as to see what was left on ground after the flooding event).

1.5 Justification and Significanceofthe Study

Historically, flooding in Nigeria which dates back to the early 1950s can be fluvial, coastal or pluvial in nature and has been a major concern for rural areas and cities within the country.Douglas, Alam, Maghenda, Mcdonnell and McLean, 2008: Jha et al., 2011; Bashir, Oludare, Johnson and Aloysius 2012, believe that the number and scale of the impact of flood events will continue and possibly accelerate in the next 50 years due to two major global themes. The first is the global trend in urbanization especially in the developing countries, to which Nigeria has been identified to belong. The second theme is the environmental change due to global climatic warming.

In view of the aforementioned themes, it is evident that the human race has to live with natural hazards such as floods. It is therefore envisaged that the findings of this research will be beneficial to the government, decision makers, and people of the area in implementation of disaster management response system and strengthening capacities to reduce damages associated with natural hazards such as flood in the study area. The flood event actually resulted in flooding of the roads, farmlands, and submerge of vegetation as can be seen in plate 1.

Plate 1.1: Submerged roads and vegetation in Giyawa area of Goronyo LGA (2010)

CHAPTER TWO

CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Introduction

This chapter reviews the concepts of flood, vulnerability and analytical hierarchical process (AHP). It also reviews related literatures on flood history in Nigeria and flood occurrence in the study area. Finally previous studies on the application of Remote Sensing and Geographical Information Systems (GIS) on flood vulnerability and application of analytic hierarchy process (AHP) are discussed.

2.2 Conceptual Framework

2.2.1 Hazard

The Federal Emergency Management Agency (FEMA, 1997) has defined hazard as an event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructural damage, agricultural loss, and damage to the environment, interruption of business or other types of harm or losses. Meanwhile UNISDR (2009), defined hazard as a dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.According to Coppola (2011) two factors determine whether a hazard becomes a disaster or not: Risk and Vulnerability.

2.2.1.1 Risk

Riskhas been defined by UNISDR (2004) as the potential disaster losses (in terms of lives, health status, livelihoods, assets and services) which could occur to a particular community or a society over some specified future time period. This definition considers the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environmentally damaged) resulting from interactions between natural or human induced hazards and vulnerable conditions. Thus risk can be calculated using the following equation:

Risk = Probability of Hazard x Degree of Vulnerability.

2.2.1.2 Vulnerability

Vulnerability is derived from a latin word 'vulnerabilis' which means to wound (Copolla, 2011). Blaikie et al. (1994) defines vulnerability as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard. It involves a combination of factors that determines the degree to which someone's life and livelihood are put at risk by a discrete and identifiable event in nature or in a society. Blaikie et al.(1994) argues that the most vulnerable groups are those who cannot be able to reconstruct their livelihood after a disaster. Basically, the poor people suffer more from disaster than the rich.This concept has widened over time. The widening of the concept has been described by Birkman (2006) to have started from the definition only related to physical vulnerability to more complex definitions which were influenced by economic, social, and environmental factors. The conceptual differences have arisen from different points of view of different disciplines such as civil engineering, geography and social sciences (Marschavelli, 2008).

Vulnerability denotes exposure to risk and an inability to avoid or absorb potential harm (Pelling, 2003). According to Alexander (1993), human vulnerability is a function of the costs and benefits of inhabiting areas at risk from natural disaster. United Nations International Strategy for Disaster Reduction (UNISDR, 2009), defined vulnerability as the characteristics and circumstances of a community, system or asset that makes it susceptible to the damaging effects of a hazard. Asian Disaster Preparedness Center (ADPC,(2004) outlined four determinants of vulnerability: physical, social, economic, and environmental.

i. Physical vulnerability refers to the potential impact of hazard on the physical environment. It can be estimated through visual evaluation (age, construction material, potential loss of building, assets, infrastructure, lifeline facilities etc.) or through the use of some technology like modelling and simulations. Marschiavelli (2008) observed that physical aspect of vulnerability can answer the questions of what vulnerable and which location is vulnerable. This is part of what this study intends to find out in the study areas.

ii. Environmental vulnerability refers to the potential impact of events on the environment, which brings about natural resource depletion and environmental degradation. Marschiavelli (2008) points out that environmental vulnerability can be influenced by exposure to toxic and hazardous pollutants, reduced access to clean water and sanitation as well as inappropriate forms of waste management.

iii. Economic vulnerability refers to the potential loss of stocks, investment, crops, economic status of individual among others. According to theUnited Nation's International Strategy for Disaster Reduction (UNISDR, 2004), the poor are usually more vulnerable to disasters because they lack the resources to build the damaged structures. Questions such as who is vulnerable and how they have become vulnerable can be answered by the duo of socio-economic vulnerability (Marschavelli, 2008).

iv. Social vulnerability refers to the social component of the society, attitude of population, poverty, age, gender, culture, and institutional vulnerabilities. This may be assessed qualitatively or quantitatively. This implies that some people are more vulnerable than others. For example, the less privileged class in the society, the ethnic minorities, the very young and very old are more likely to be exposed to greater risk.

Having given different definitions of vulnerability, this study adopted that given byUNISDR, (2009) which defines vulnerability as the characteristics and circumstances of a community, system or asset that makes it susceptible to the damaging effects of a hazard.

2.2.2 Flood vulnerability factors

An environment is vulnerable to floods due to three main factors; exposure, susceptibility and resilience. The vulnerability of any system (at any scale) is reflective of (or a function of) the exposure and susceptibility of that system to hazardous conditions and the ability, capacity or resilience of the system to cope, adapt and/or recover from the effects of those conditions (Smit, 2006). Understanding each concept and considering certain indicators may help to characterize the vulnerability of different systems, by which certain actions can be identified to decrease it.

2.2.2.1 Exposure

Exposure is defined as the predisposition of a system to be disrupted by a flooding event due to its location in the same area of influence. The disruptions in the systems can be interpreted as damage and losses. They are categorizedas direct, resulting from the physical contact of flood water with damageable property, or indirect, resulting from the interruption or disruption of social and economic activities. Damage and losses from floods can also be classified as tangible, for which a monetary value can be easily assigned, or intangible, for which a monetary value cannot be easily assigned

2.2.2.2Susceptibility

For Di Mauro (2006), susceptibility combines the likelihood of a hazardous event, the differential exposure and the potential sensitivity of a target. I.e. the degree to which a target could be potentially damaged or affected by a given hazard and the existing capacity of this target that could potentially reduce this level of damages (e.g. existing measures of prevention, mitigation, etc.) In this study susceptibility will be defined as the elements exposed within the system, which influence the probabilities of being harmed at times of hazardous floods.

2.2.2.3 Resilience

Originally, resilience was defined by Holling in 1973 as "a measure of persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations and state variables", definition more in tune with social sciences, but still remarkably useful for this study. Equally, Walker, Holling and Kinziq(2004) argued that resilience is the capacity of a system to absorb disturbance and reorganized while undergoing change, so as to still retain essentially the same function, structure, identity and feedbacks.

2.2.3 Methods of determine flood vulnerability

Three main methods exist in computing the direct economic losses from floods (Penning-Rowsel and Chatterton, 1979; Smith and Ward, 1998; Aglan et al., 2004). The first method is done by conducting an experiment to measure the flood damage by exposing building and its contents to floodwater. Aglan et al., (2004) conducted an experiment by inundating building to assess the damage that would happen to building structures and its contents before and after flood. The effect of floodwater to wall, floor, doors, and windows for different flood duration were assessed. Subsequently, the vulnerability curves of the relationship between duration and damage were created.

The second method is based on assessing the potential losses as the expected result from the flood events on a specific severity based on generalized relationship between certain flood characteristics and physical damage (Smith and Ward, 1998). The disadvantage is, however, that results tend to be synthetic rather than actual. It is important to realize that the unmodified synthetic losses can be higher than actual recorded losses simply because the assessment ignores the damage, reducing actions that the floodplain residents take in a flood event.

The third method is based on the collection of actual flood damage information which is reported after the event (Penning-Rowsell and Chatterton, 1979; Smith and Ward, 1998; Dutta and Tingsanchalli, 2003). This method was applied by Saut (2006)in the cases of Naga City, the Philippines, and the United Kingdom, respectively. The advantage of this method is that it deals with real event. It is based on field interview and questionnaire on damage to properties and level of injuries to people due to flood. The results is very much dependent on the responses of the respondents. However, it has disadvantages as there might be exaggerated data from the respondents.

The later (which is the third method) is most appropriate for this study since it is achievable and applicable in a relatively short time. The other reason is that, this research deals with community damage information and peoples flood experiences over the past few years due to flood. Moreover, community can provide the actual details on losses for vulnerability, risk, and damage assessment.

2.2.4 Vulnerability mapping

A vulnerability map is a map that has been drawn to show the precise locations of sites where people, the natural environment or property are at risk due to a potentially catastrophic event (Edwards, Gustafsson, and Naslund-Landenmark, 2007). They further opined that these maps can show the housing areas that are vulnerable to a chemical spill at a nearby factory, or delineate the commercial, tourist, and residential zones that would be damaged in case of a 100 year flood or more devastation. These maps as noted by the authors are most often created with the assistance of Geographic Information System (GIS), digital land survey equipment designed for use in the field and can also be created manually using background maps such as satellite imagery, property boundaries, roadmaps, or topographic maps.

2.2.4.1Advantages of vulnerability maps

According to Edwards et al. (2007), vulnerability maps have the following advantages

i. They allow better visual presentation and understanding of the risks and vulnerabilities so that decision makers can see where resources are needed for protection of these areas.
ii. They also allow for improved communication about risk and what is being threatened.
iii. The vulnerability maps will help concerned agencies to decide on mitigating measures to prevent or reduce loss of life, injury and environmental consequences before a disaster occurs.

iv. These maps also helps to determine which properties and buildings are at risk. Subsequently land owners can be properly informed ahead of time about impending danger and available measures that would protect their homes from potential damage either through inundation or slope failure.

2.2.5 Flood hazard

Without human being and their natural environment, there would be no hazard or disaster. Hazard is the probability of an occurrence within a specified period of time and within a given area of a potentially damaging phenomenon (Alexander, 1993). Nwafor (2006) defined flood as a natural hazard which occurs as a result of an extreme hydrological (runoff) event. However, Abam (2006) defined it as a large volume of water which arrives and occupies the stream channel and its floodplain in a time too short to prevent damage to economic activities including homes. Adeoye *et al*.,(2009) defined flood as an extreme weather event naturally caused by rising global temperature which results in heavy downpour, thermal expansion of the ocean and glacier melt, which in turn result in the rise in sea level, thereby causing salt water to inundate coastal lands. Despite the slight differences in these definitions, they all point to the facts that floods occur when lands that are known to be usually dry get inundated as a result of the presence of excess water due to hydrological events, leading to destruction of properties and disruption of human daily activities

Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75 million people world-wide (Smith, 1996). The reason lies in the widespread geographical distribution of river floodplains and low-lying coasts, together with their long standing attractions for human settlement (Ologunorisa and Abawua, 2005).

2.2.6 Types of Floods

Flooding can be categorized based on their occurrences and durations, or based on their locations (Action Aid, 2006).

Floodingbased on their occurrence and duration:

i. Slow-onset Floods:

These usually last for long periods. They may last for one or more weeks, or even months. As this kind of flood last for a long period, it can lead to loss of stock, damage to agricultural products, roads and rail links (Jeb, 2013).

ii. Rapid-onset Floods:

They last for short period; they usually last for one or two days only. Although this kind of flood lasts for a shorter period, it can cause more damage and pose a greater risk to life and property as people usually have less time to take preventative actions during rapid-onset floods (Jeb, 2013).

iii. Flash Floods:

They may occur within minutes or a few hours after heavy rainfall, tropical storm, failure of dams or levees or releases of ice jams, and they cause the greatest damage to societies. Dam failures in the case of Bagauda in Kano state and the Goronyo Dam failure in Sokoto state in 2010 led to serious flash floods that washed away farmlands and led to loss of several lives (Jeb, 2013).

Flooding based on their locations:

i. Coastal Floods

Coastal Floods usually occur along coastal areas. When there are hurricanes and tropical storms which will produce heavy rains, or giant tidal waves created by volcanoes or earthquakes, ocean water may be driven onto the coastal areas and cause coastal floods. These types of floods occur in the coastal regions of Nigeria especially in cities like Calabar, Port Harcourt, Warri, Lagos and other smaller rural communities along the coast (Adeoye *et al*.,2009)

ii. River Floods

This is the commonest type of flooding. When the actual amount of river flow is larger than the amount that the channel can hold, river will overflow its banks and flood the areas alongside the river. This may be caused by reasons like snow melt or heavy spring rain. This is common in most riverine areas of Nigeria, especially in the rainy season and particularly from June to October every year (Adeoye et al.,2009).

iii. Urban floods

In most of the urban areas, roads are usually paved. With heavy rain, the large amount of rain water cannot be absorbed into the ground and this leads to urban floods. Urban floods in Nigeria result from human activities such as unplanned urbanization, poor refuse disposal, blocked drainages and siltation of waterways (Jeb, 2013).

iv. Arroyo floods

An arroyo is a river which is normally dry. When there are storms approaching these areas, fast moving river will normally form along the gully and cause damages. These types of floods occur in the northern semi-arid regions of Nigeria like Sokoto, Katsina, Borno and Jigawa states (Jeb, 2013).

2.2.7Causes of flood

According to Olanrewaju and Fadairo (2003), flood disaster are anthropogenic activities influenced by deforestation, climate change, population growth and economic assets in river plains has led to alterations in the natural drainage and river basin patterns. Thus, most floods result from two major causes: Climatic and Non-climatic activities (Jeb, 2013).

2.2.7.1 The climatic causes are

Heavy rainfall**;** flooding occurs from heavy rainfall when natural water courses do not have the capacity to convey excess water. This is the dominant cause of flooding in Nigeria. Each time it rains and the volume is much for the drainage system to take, it can lead to flooding.

Also, Coastal storm surgeare caused by coastal storm surge, particularly in coastal areas where inundation can be caused by a storm surge associated with a tropical cyclone. On the other hand, Snowmelt like in many cold regions, snows melt when the temperature rises and then can result in massive movement of water into places that are usually dry. This is worse when the subsoil is still frozen reducing the infiltration capacity of the soil.Climate change is expected to cause accelerated sea-level rise with elevated tidal inundation, increased flood frequency, accelerated erosion, increasing storm surges and increasing frequency of cyclones (Fenster and Dolan, 1996). Such storms bring heavy rainfall and storm surges along the coastline of countries lying in their paths.

2.2.7.2 The non-climatic causes are

Earthquakes, Volcanic eruption and Landslide; Floods can also be caused by earthquake, volcanic eruption, and landslide which can disorganize river flow patterns and often makes them to flood the surrounding flood plains. Dam collapse**;** Dams are man-made blocks mounted to hold water flowing down from a high land. Dam break can be triggered by earthquake, volcanic eruption and landslide, which can lead to flooding of the downstream area, even in dry weather condition. Also, Blocked drainages; Drainage consists of largely impermeable concrete which take water quickly and directly to the river channel. The drainage system is an important physical factor that greatly contributes to flood disaster. If the drainage systems are blocked it can cause flooding especially in urban areas. Reliefof an area plays a very significant role in the occurrence of flood disaster in a particular area. Since water responds to slope, a hilly area will discharge its water to lower elevation areas. This terrain pattern justifies why highly prone areas to flood are areas with relatively low elevation.

v. Deforestation; Trees and plants normally help in absorbing too much water. When forests are cut or burned down, water from rainfall flows down barren land and can lead to flooding.

2.2.8Consequences of flooding

Flooding is one of the major environmental disasters one has to contend with, it has both positive and negative consequences. These consequences vary greatly depending on location, duration, depth and speed, as well as the vulnerability and value of the affected natural and constructed environments they affect.

(i) Positive consequences of flooding:

The good thing about water overflowing its banks is that, as water flows into the surrounding, sand, silt and debris are deposited into the surrounding land (Abowei and Sikoki, 2005). Floods are not always destructive natural events; flood brings along nutrients and make the land around the rivers fertile.

(i) Negative consequences of flooding:

Floods can have devastating negative effects on the economy, environment and people.During floods (especially flash floods), roads, bridges, farms and houses are destroyed. Additionally, the government deploys police and other emergency apparatuses to help the affected people. All these come at a heavy cost to people and the government. It usually takes years for affected communities to be re-built and business to come back to normalcy (Ologunorisa,2006; Etuonovbe, 2011).

2.2.9 Remote Sensing and Vulnerability mapping

Nowadays, satellite imagery and information derived from them are used in models to predict runoff and river discharge, and subsequent likelihoods of floods, and area at risk to flood (Shrestha, 2008). With the improvements in the resolutions of imageries and possibility of stereo capability and digital image processing methods, the use of satellite imageries has become increasingly important for hazard and risk assessment. The emerging trend of researches on natural hazards by applying modern remote sensing techniques is a testimony (Bikram, 2010). Remote sensing provides synoptic data of the area either in real-time or near real-time in different spatial or temporal resolutions for different magnitudes of flood (Jeb, 2013).

For planning the flood control and related works, reliable and timely information about flooded areas, river behavior and configuration prior to floods, during the floods and after the floods are required.Such information are very difficult to acquire through conventional ground surveys. Advent of satellite remote sensing technology has helped in solving the problems of mapping flood vulnerable areas, monitoring and management of floods.

2.2.10 GIS and Vulnerability Mapping

GIS is defined as a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information (United State Geological Survey (USGS), 1998). In the context of flood vulnerability mapping, GIS can be used to create interactive map overlays, which clearly and quickly illustrate which areas of a community are in danger of flooding. Such maps can then be used to coordinate mitigation efforts before flood event and recovery after flood event (Awal, 2003). On the other hand, GIS also provides the environment for the integration of remote sensing data and different spatial and attribute datasets to delineate the flood affected areas under different magnitudes of floods or flood scenarios (Sharma, 2004; Forku, 2011).

2.2.11 Analytical Hierarchy Process

Analytic Hierarchy Process (AHP) is a theory of measurement through pair-wise comparisons and relies on the judgments of experts to derive priority scales. The pair-wise comparisons were developed by Saaty (1980) in the context of a decision making process known as the Analytic Hierarchy Process (AHP). Saaty (1987) also defined it as a general theory of measurement that can be used to derive ratio scales from both discrete and continuous paired comparisons. The comparisons are made using the scale of absolute judgments that represents how one element dominates another with respect to a given attribute.

Pair-wise comparison involves the comparison of the criteria and allows the comparison of only two criteria at once which often results in a ratio matrix (Saaty, 1980). This method can convert subjective assessments of relative importance into a linear set of weights (Heywood, Oliver and Tomlinson, 1993). It takes pair-wise comparison as inputs and produces relative weights as outputs. This technique has found its widest applications in multi criteria decision. According to Figuera, Greco and Ehrgott (2005), processes for which we evaluate different factors have become mathematical science. This decision making involves many criteria and sub-criteria used to rank the alternatives with respect to the criteria or sub-criteria in terms of which they need to be evaluated.

In identifying the factors influencing flood in the study area, the six flood causative thematic maps produced (land-use and land-cover, slope, elevation, soil, rainfall and drainage) were weighted according to the estimated significance towards causing flooding using the three steps involved in pair-wise comparison (Saaty, 1980). The steps involved are:

i. Development of pair-wise comparison which uses the Saaty’s scale of preference with values ranging from 1 to 9.

ii. Computation of the weights

iii. Estimating the consistency ratio (CR) to determine if the comparison are consistent or not. The formula for calculating CR is = CI/RI

Where CI = Converting Index and RI= Random Index

If CR is less than 0.1, the ratio indicates a consistency in the pairwise comparison (PC) and the result is accepted. However, if CR is greater than or equal to 0.1, it is said to be inconsistent and has to be revisited (Saaty, 1980).

2.3 Literature Review

2.3.1 Flood Disasters in Nigeria

Flooding has always been a part of human history. The fact that many settlements developed along waterways because of the economic benefits makes people and infrastructure vulnerable. In Nigeria, flood accounts for the highest occurring natural hazards, with great consequences on the life and property (Aderogba, 2012). This flood hazard is becoming a yearly event: it occurs in the form of river flood, flash floods, urban floods and coastal floods (Akinola, Suleiman and Francis, 2015). Despite the fact that several studies have been conducted on flooding across the country, flooding is still an annual event in many Nigerian communities. Table 2.1 presents a review of some recent flood disaster in Nigeria.

Table 2.1 shows the review of some recent flood disaster in Nigeria

Table 2.1: A Review of Some Recent Flood Disaster in Nigeria

Year	Location	Cause	Recorded Effects/Estimated Damage	Source
2012	22 states	Overflowing of River Niger	Over 431 deaths, millions of people displaced, properties worth billions of naira destroyed.	Adebayo and Oruonye(2013)
2015	Zamfara	Rainfall	10 deaths, 46,200 people displaced, 6,450 hectares of farmland destroyed.	PremiumTimes 20/09/2015
2016	Calabar	Rainfall	30 housing units submerged, 200 people displaced.	PremiumTimes 11/04/2016
2016	Ebonyi	Overflowing of Iyi-Udele River	About 5,000 people displaced, over 100 houses destroyed.	Floodlist 12/06/2016
2016	Sokoto		635 houses destroyed and over 5000 people displaced.	Daily Trust 23/07/2016
2016	Kano	Blocked drainages Rainfall	18 deaths, properties worth 700 million naira destroyed	TodayNewsletter 26/07/2016

Source: Modified from Jeb (2013).

2.3.2Flood occurrence in the study area

Sokoto State is not known for flooding before, but in recent times the situation is changing at interval with some recorded flood event in the State. Sokoto State environment is characterized by high evapotranspiration rate greater than precipitation in two folds. On the average, eight months is dry season and four months is wet season. This problem is further exacerbated by climate change. Besides that of drought, the case of flooding due to intensity and extended concentration of the rains after the already known cessation of the rainfall destroyed crops and livestock, loss of human lives and property. Those worst hit are mostly small farm holders, fishermen and herders. Flooding has been occurring in the flood plains of the rivers Sokoto and Rima for years due principally to the release of water from the Goronyo and Bakolori dams. The most destructive flood was in 2010 when two-thirds of the state was affected.

Table 2.2 shows the review of some flood disaster in the study area

Table 2.2:A Review of Some Flood Disaster in the Study Area

Year	Cause	Recorded Effects/ Estimate of Damage	Source
1999	Heavy Rainfall	32 communities were submerged with lots of farmlands destroyed	Dartmouth flood observatory (DFO, 2004)
2001	Heavy Rainfall	Houses and farmlands worth millions of naira destroyed with over 16, 000 people affected	Etuoanovbe, 2011
2003	Heavy Rainfall	7 death were recorded with several buildings submerged	DFO (2006)
2010	Heavy rainfall/dam breakage	About 40 people were recorded dead, many buildings destroyed with farm produce worth millions of naira	DFO (2010)

2012	Heavy rainfall	Lots of people were displaced, and damages was done to farmlands	Vanguard Newspaper (2012)

Source: Modified from Jinadu (2016)

2.3.3GIS and vulnerabilitymapping

GIS was first introduced and used in the 1960's and since then, the technique has developed into a useful means of gathering and analyzing different kinds of spatial data related to unique geographical locations (Lowry, Miller and Hepner, 1995). A GIS facilitates the input, storage, management, analysis, integration, and output of spatial data which can aid real time decision making and strategic planning for effective risk management and hazard preparedness (Smith, 1996). It is thus a key tool to map vulnerability (Edwards et al., 2007) because it can be used to improve warning, evacuation and emergency response facilities (Lowryet al., 1995; Smith, 1996). Spatial data such as soil and geology, urban infrastructure, and socio-economic data, can be input and stored in a GIS and then analyzed to identify areas prone to hazards, identifyvulnerable populations, monitor hazards and forecast disasters, and aid in land use zoning decisions to improve disaster mitigation and management (Smith, 1996; Roy, Leconte, Brissetteand Marche, 2011).

2.3.4 Application of Remote Sensing and GIS in Flood Vulnerability Assessment

This section reviews research works that employed Remote Sensing and GIS to assess flood Vulnerability both locally and internationally. Remote Sensing is the technology that is used in gathering spatial information used for identifying, classifying, mapping, monitoring, planning, mitigation and management of natural disasters (Jeyaseelan, 1999; Ishaya and Ifatimehin, 2009). This technology has been used extensively in Asian and developing countries for agricultural, aviation and environmental purposes (Ishaya and Ifatimehin, 2009).

Sreyesi (2007) employed Remote Sensing and GIS in his study conducted in Orissa India on flood vulnerability assessment and flood risk calculation.Thestudy considered the depth, duration and damage of the flood event. The results shows similarity with flood modelling from the research done by Lesslie (2007) in the same area. Also two structural types of buildings and four agricultural cropping patterns were found in the study area. Vulnerability curves were made for these two structural types and four cropping patterns by plotting the relationships between flood depth and vulnerability for each structural type and each cropping pattern. The results indicate that, the structural type with mud walls-floors and straw of paddy roofs is the most vulnerable buildings to flooding, while the structural type with Reinforced Cement Concrete(RCC) wall-floors and RCC roofs are the least vulnerable.

Dukiya and Vimal (2013) carried out a research in Lokoja using Remote Sensing and GIS based techniques for assessing the flood vulnerability zones of the town using the minimum and maximum water level bench mark from the year 1995 to 2005. The ortho-photo map and the image drape generated clearly shows that development along the marine road and the new Filele mini-dual carriage road are within the floodable areas of the river confluence. The study recommended an integrated approach in managing the confluence zone. In addition, major development activities should be concentrated on the South-western part of Lokoja.

Ilesanmi (2014) carried out a research on assessment of urban vulnerability towards flood: a case study of Kosofe Local Government area, Lagos State. The approach uses a comprehensiveIntegrated Flood Vulnerability Index (IFVI) concept adapted specifically for the purpose of the study. From the study, 6 wards out of the 21 wards were discovered to have high vulnerability towards flood after conducting the IFVI and GIS analysis. These 6 wards have high level of vulnerability. The areas very close to the river (the flood plain) are the most vulnerable. Also, 2 wards have medium vulnerability towards flood. These wards are Orile Oworo and Isheri /Olowora. The study also shows there are about 1400 buildings are within the high vulnerable areas. This implies that if there is a flood hazard along River Ogun and River Agboyi in future all the 1400 buildings will be flooded and properties worth millions of naira will be destroyed.

Warghat, Das, Doad, Mali, and Moon (2012) considered the contribution of annual rainfall, size of the watershed, slope, drainage density of natural channels and land use in analyzing flood vulnerability in Karad region, Satara district, Maharashtra India, using Remote Sensing and GIS techniques. The analysis revealed four classes of vulnerability in the area: very high, high, moderate, and low. Out of 27 villages in the area, four (4) were found to be of very high vulnerability to flood , another 4 were in high vulnerability zone, 6 are of moderate vulnerability, and the last 6 were of low vulnerability.

Ismail and Sanyol (2013) applied Remote Sensing and GIS techniques to produce flood map of the middle course of River Kaduna, Nigeria. Using high resolution imagery, a Digital Elevation Model (DEM) was developed with ArcGIS to identify flood prone areas along the middle course of the river. A flow accumulation model was created using the DEM and the DEM was reclassified into high risk, moderate risk, and low risk zones using equal interval of separation based on elevation. This was overlaid on the map of the area to produce a vulnerability map of the area. The study discovered that a flood map can be used effectively in public enlightenment, disaster response planning and flood risk management

2.3.5Application of GIS Based AHP in Flood Vulnerability

This section presents a review of works that employed the use of MCE to access flood vulnerability globally and locally. According to Meyer, Schever and Haase (2009), the application of MCE in flood risk assessment is a recent development as it has been employed predominantly in past years for Site Suitability Analysis.

Ozcan and Musaogu (2010), in a study conducted in River Ayamama basin in Turkey, discovered that elevation, slope, aspect, landuse landcover and Geology had the greatest influence in flood occurences. The authors employed AHP to carry out the analysis and came up with four (4) flood vulnerability zones of high, moderate, low, and no risk.

Atiku (2015) carried out flood vulnerability assessment in Jalingo town Taraba state, Nigeria. The study produced thematic maps of six flood causative factors (elevation, slope, soil, drainage density, rainfall, land-use and land-cover) and employed AHP to determine the influence of the flood causative factors on flood vulnerability in Jalingo. The study revealed that elevation had the greatest influence on flood occurrence in Jalingo followed by slope, soil, landuse, drainage density and rainfall in that other.

Yahaya, Ahmad and Abdalla (2010) conducted a Study in the Hadejia-Jama'are River Basin in Nigeria. The Study analyzed the contribution of annual rainfall, the basin slope, drainage network, land cover and the type of soil to vulnerability in Hadejia-

Jama'are. A combination of pairwise comparison (PC) and ranking methods were used to calculate the weights of these attributes. After the PC calculations had been done, the weights were found to be: 0.339, 0.255, 0.197, 0.152, and 0.057 for annual rainfall, the drainage network in the river basin, the basin slope, and the soil type and land cover respectively. Thus, the highest contributors to risk vulnerability in the region were found to be annual rainfall, the drainage network in the river basin and the basin slope.

Lawal, Matori, Hashim, Yusuf and Chandio (2012) detected flood susceptibility areas in Perlis, Malaysia, using GIS based AHP. The flood causative factors considered were rainfall, capacity of existing drainage, size of the watershed, landuse, soil type and slope. The weights derived showed that annual rainfall and capacity of existing drainage contributed most to flood.

Siddayo, Valdez and Fernandez (2014) employed GIS based analytical hierarchy process to identify the level of contribution of each of the flood causative factors in Enrile in the province of Cagayan, northern Philippines. Distance from river bank was discovered to contribute most to flood events in the area followed by site elevation and population density. Using the Quantum GIS software, the factor weights from the AHP were incorporated to produce a map representing five levels of estimated flood risk: very low risk, low risk, moderate risk, high risk and very high risk.

In identifying the gap, the work of Atiku 2015; Lawal, Matori, Hashim,Yusuf, and Chandio (2012) didn't focused on river flooding but rather on urban flood which is different from the researchers work, and those found to be carried out on a river system are conducted outside the scope of the researcher study area, as most of the condition or variables been looked into varies from one region to another.To the best of the researcher knowledge, no nature of this study has been carried out on the river Rima and Sokoto basin. Other studies uses GIS and AHP alone, but the researcher tries to incorporate the use of questionnaires too in other to seek for people's opinion about flood in the study area.

The literature reviewed established that flooding is a major environmental concern in all parts of the world. Human activities and climate change continue to increase the rate of flood occurrence all over the world with increasing threat, therefore the need arises to mitigate the effects of flooding. Vulnerability assessment give an information about how vulnerable an area is, what makes it vulnerable, and the factors causing flood in a particular area. Several method of flood vulnerability assessment such as Remote Sensing and GIS, minimum and maximum water level bench, pairwise comparison and ranking, GIS based AHP have been used by different scholars for flood vulnerability assessment. All these methods have their advantages and limitations. In remote sensing, issues like scan lines in some Landsat imagery, few expert to interpret imagery,powerful active remote sensing systems such as radars that emit their own electromagnetic radiation can be intrusive and affect the phenomenon being investigated. However, combining the Remote Sensing and GIS with the GIS based AHP is very good as it will give the possible best result. All disasters have a spatial component and therefore adequate geographic information on hazardsand areas vulnerable to hazards is required in order to be able to prepare for disasters.

Multi-criteria evaluation (MCE) methods have been applied in several studies since 80% of data used by decision makers is related to geography (Malczewski, 1999). GIS may provide more and better information about decision making situations as it allows the decision maker to identify and list a predefined set of criteria with the overlay process.

Multi-criteria decision analysis within GIS may be used to develop and evaluate alternative plans that may facilitate compromise among interested parties (Malczewski, 1999).

The main advantage of using GIS for flood analyses is that it not only generates a visualization of flooding, but also creates potential to further analyze these events to estimate probable damage due to floods. Compared to traditional mapping, GIS enables the comparisons across spatial units; comparison across different themes by category of hazards and disasters; merging of qualitative with qualitative assessment and spatial database, based on which logical and/or numerical operations can be dynamically performed. These are grounds for concluding that GIS has an important function to play in natural hazards analyses because natural hazards are multi-dimensional phenomena, which have a spatial component (Coppock, 1995).

Most conventional GIS based methods for flood risk mapping (Yalcin, 2002) are based on ground surveys and aerial observations, but when the phenomenon is widespread, such methods are time consuming and expensive. Furthermore, timely aerial observations may be impossible due to prohibitive weather conditions. This study therefore proposes a multi-parametric approach for delineating flood vulnerability in a growing urban area through the integration of Analytical Hierarchical Process (AHP) as a multi-criteria decision making (MCDM) technique within a GIS mapping environment. The effectiveness of AHP in evaluating problems involving multiple and diverse criteria and the measurement of trade-offs—sometimes using limited available data—has led to its recognition across different fields of application (Yalcin, 2002)The AHP gives room for dividing the problem into issues which are later considered in tackling the problem. This hierarchical order help to simplify the problem and bring it to a condition which is more easily understood.

CHAPTER THREE
STUDY AREA AND METHODOLOGY

3.1 Introduction

This chapter consists of two parts. The first part describes the study area in terms of location, climate, geology, relief,drainage, soil, vegetation, population and socio-economic activities. The second section discusses the materials and methods that were used to carry out this research work.

3.2 The Study Area

3.2.1 Location and size

The study areas which coversWamako, Kware, Wurno, Goronyo, and Rabah Local Government Areas of Sokoto State Nigeria, lies between Latitudes $12^0 45$`N and $13^0$ 35`N and Longitudes $4^0 55$`E and $6^0 00$`E. It is bordered to the North by Gada Local Government Area, to the South by Dange shuni, East by Sabon Birnin and Isa Local Government Areas (LGA) respectively whileit is bordered by Tangaza and Binji to the west. The study area has an area coverage of $6009.8km^2$ as shown in Fig. 3.1.

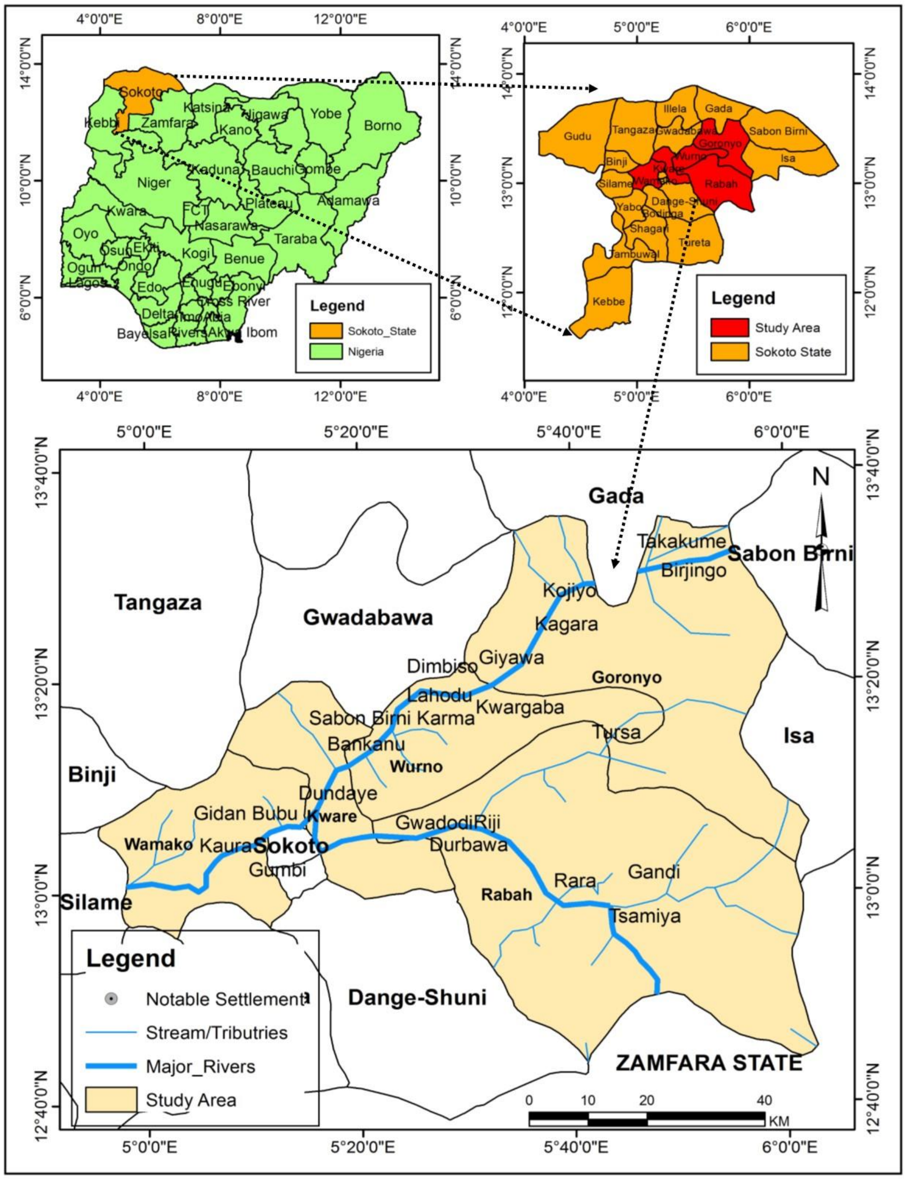

Figure 3.1: The Study Area
Source: Adapted from Sokoto State Government, 2014.

3.2.2 Climate

The area lies in the Sudano-Sahelian ecological zone which is semi-arid. It is characterized by three seasons – the cool and dry, the hot and dry and the hot and wet (Alagbe, 2006). The area is influenced by the Tropical Continental air mass (cT) during the months of November to February. The cT is a south moving cold air mass that is associated with cool and dry, dusty winds. This period is referred to as the harmattan season. Temperature during this period could be as low as 22^o Celcius or below. The hot season is experienced in the months of March to May, and it is associated with high temperature of up to 38^oC to 45^oC. The hot and wet seasonon the other hand usually starts from the month of May and lasts for about four months only. The Maritime Tropical air mass (mT) which is a moist, northward moving West African monsoon influences the area from May to October. An annual rainfall of 500mm-800mm (Nigeria Meteorological Agency (NIMET), 2011). With the state recording a temperature as high as 45^OC, the area is expected to be frequently heated up, and high evaporation, enhancing intense rainfall in the months of July to Septemberwhich can easily lead to flash flood in the study area.

3.2.3 Drainage

The study area is drained by the Sokoto and Rima rivers. The Sokoto River formerly known as (Gulbin Kebbi) is a river in north - west Nigeria, and a tributary of the River Niger. The river source is near Funtua in the south of Katsina state, some 275 kilometers in length (Akane and Jurgen, 2005). The tributaries of the Rima River take their source from the basement complex region and flow in the north western direction. Their valleys are narrow and restricted until they enter and flow through where their valleys are broader. The Rima River takes a gradual turn at Sokoto and then flows southwards to join the river Niger. Most of the tributaries of the Sokoto Riverare not perennial streams. Seasonal springs, due mostly to interflow are common along the valley slopes of the Sokoto-Rima river basin (Kogbe, 1979). With the Rima and Sokoto rivers channels and its tributaries found in the study area, this means that, when the river channels is filled up, the water will eventually over flow its boundary and cause flooding, which can result in different level of damage.

3.2.4 Geology and relief of the study area.

The study area is located within the illumeden basin, which is surrounded to the east and south by the Precambrian basement complex. Within the state, there is no outcrop of basement complex, rather it is covered by a series of sedimentary rocks which have been deposited over the basement complex. These sediment were laid down under varied environmental situations ranging from continental to marine events.According to Obaje (2009), Sokoto's relief is a monotomy of low land interrupted by isolated flat-topped hills (mesas) and escarpments. The hills and escarpment rise up to488m. The land is a gentle rolling to undulating plane. This makes it easy for water to flow freely and easily into different directions without any hindrance causing serious havoc in the case of flooding.

3.2.5 Soils and vegetation

Sandy topsoil with clayey subsoil is common, except along the flood plains of the river valleys where alluvial soil predominate. To the north of the state especially along the border with Niger Republic, the undulating plains are covered by Aeolian deposits of variable depth. Due to the geographical location, the state suffers from the scourge of desertification and occasional drought. The whole state falls within the Sudan savanna, and the soils are highly susceptible to wind and water erosion (Driessen and Dydal, 1989). The vegetation consists of mostly short feathery grasses and some scattered trees most of which are deciduous in character, the vegetation is characterized by thorny species with a scatter of Acacia specie (Abdu et al 1982). The tree species are mostly those that can adapt to dry conditions and are fire resistant (Sokoto Agriculture and Rural Development Authority (SARDA), 1992). The soils in the study area is sandy topsoil and clayey. This implies that the level of water infiltration into the soil will be slow especially for areas that has clay soil, and area with sandy topsoil can be easily washed away with water, as the tree species in the study area are short, few leaves, and not a broad base. So it cannot hold back water effectively in case of heavy rainfall, thereby resulting in erosion or flooding.

3.2.6 People and socio-economic activities.

The study area has a total population of 59,340 people as at 1991 (NPC, 1991). Using the exponential projection method as recommended by the National Population Commission (NPC) with a growth rate of 3%, the projected population of the study area for year 2016 is 124,245 people. The people in the study area are mainly the Hausa and the Fulani.

Mortimore (2009) confirmed that greater proportion of the population in the semi-arid zone including the study area are agrarian and depend on land for their livelihood. The major crops cultivated in these areas are millet, rice, guinea corn, beans and some vegetables such as onions, lettuce, cabbage, spinach. The use of camels and donkeys are common in these areas for the transportation of goods locally from one place to the other. The area has been a center of learning since the Jihad period and a predominantly Muslim dominated community (Murtala, 2013). Along the stretch of the Sokoto and the Rima

Rivers, fishing is practice and provides a means of additional income to farmers(Sani, 2005).

3.2.7 Land-use

The land-use types in the study area are built-up areas, farmlands, bare surface, vegetation and water bodies. The people live in mud houses and very few bricks houses, with tarred and un-tarred roads linking settlements. The built-up environment is characterized by residential, agricultural, academic, commercial, religious, open spaces, among others.

3.3 **Methodology**

3.3.1 Reconnaissance

A reconnaissance survey was carried outin other to get acquainted with the study area and help in preliminary field data collection techniques. It was observed that most of the irrigation farming activities going on in the area are along the river floodplains which makes it so easy for serious destruction of farmland whenever there is a flood event. Meanwhile, few houses are seen on the floodplains too, mainly owned by the farmer and the fishermen around the area.

3.3.2 Materials

3.3.2.1 Thematerials used

The materials used for the research study are

I. Satellite imagery (Landsat ETM imagery of the study area with a spatial resolution of 30m)
II. Advanced Space-borne Thermal Emission and Reflection Radiometer(ASTER)global digital elevation model (GDEM-30m) of the study area

III. Soil map of the study area.

IV. Rainfall data of the study area.

V. Global Positioning System (GPS)

VI. Questionnaire administration to the study area

Both primary and secondary data were used in this study to achieve the aim and objectives earlier outlined. The data name, types, resolution, dateand sources of data required for this study are summarized in Table 3.1.

S/NO	**Data Name**	**Data Type**	**Resolution**	**Data**	**Sources**
1	Questionnaire	Primary data	-	2017	Field
2	GPS	Primary data	-	2016	Field
3	Landsat ETM	Secondary data	30m	2009-2011	USGS
4	ASTER DEM	Secondary data	30m	2007	USGS
5	Soil Map	Secondary data	-	2016	IAR ABU
6	Rainfall data	Secondary data	-	1985-2016	NIMET ABUJA

Table 3.1: Types and Source of Data

Source:Author's compilation, 2017

3.3.4 Sampling Size and Sampling Technique

The study area comprises five local government areas: Wamako, Kware, Wurno, Rabah and Goronyo, (Table 3.1). Questionnaire was administered to the residents of the study area from 18 years and above. In order to obtain the population of wards as at 2016, the 1991 population figures of each wards was projected to 2016 and the projection was done using the population growth rate of 3% (National Population Commission (NPC), 2006). The reason for using the 1991 population figures for the study and projecting it is because the 2006 population census does not capture data down to rural communities.

$P_n = P_i \left(1 +\right.$

Where: pi= population at the base year

r= growth rate

n= interval years

$$P_n = P_i \left(1 + {}^{r}/_{100} \right)^{en}$$

$$P_n = P_i \left(1 + {}^{r}/_{100} \right)^{en} = 59340(1+3/100)^{e25}$$

P_n = 124245

In order to get the sample size of the population for the study area, Yamane (1967) formula was used. Yamane formula was used because it calculates sample size with 95% confidence level.

$$n = {}^{N}/_{1} + N(e)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3.2$$

Where n = sample size, N = population of the area, e = error margin (at 0.05).

n = 124245/ 1 + 124245 (0.05) ^{2}

n = 124245/ 1+ 124245 (0.0025)

n = 124245/ 310.61

n = 400.00

Based on this calculation, 400 copies of the questionnaire were administered for the study (Appendix I). Data were collected on the issues relating to the socio economy and demographic status of the people, their perceptions on the effects of flooding and their opinions on how subsequent flood can be prevented or managed in the study area using questionnaires. The proportion of questionnaire administered in each ward is shown in Appendix II

3.3.4.1 Sampling techniques

For the sampling techniques, the local governments in the study areas consist of eleven wards each. Purposive sampling technique was used in selecting the wards under consideration based on the flood event of year 2010 .This was because these are the wards that are highly affected by the flood as documented by the Sokoto Rima River Basin Development Authority(SRRBDA) and the state National Emergency Management Agency. In selecting the households, purposive sampling was employed too, as only those living close to or along the river banks were considered, and the questionnaire was distributed ramdomly to these households. See Appendix iii

3.3.5 Data Processing

3.3.6.1 Image processing

The satellite imagery of the study area was enhanced to improve its visual interpretation of features using ERDAS IMAGINE 9.2. Geo-referencing was also carried out to translate the images into real world coordinate. The imagery was assigned Universal Transverse Mercator (UTM, Zone 31) using the ArcGIS 10.2. The UTM system was adopted because of its high reliability since its measurement are cited in linear, decimal units rather than in angular, non-decimal units (Wilford, 1977).

3.3.6.2 land-use and land-cover classification mapping

ETM Satellite imagery of the study area with (30m resolution) was georeferenced using the Universal Transverse Mercator (UTM) Zone 31 North with datum WGS 1984. The study area fall into two scenes that is (Path 191 and 190, with Row 51). The area of interest was clipped out of the imagery and was mosaic Using Erdas Imagine 9.1. The Landsat imagery was overlaid on the study area. Unsupervised classification was carried out due to the large area of the study areato produce six classes (Waterbody, Wetland,Forest, Agriculture, bare surface, and Built-up areas)

3.3.6.3 Generation of Slope Map and Elevation

The digital elevation model (DEM)creation was done using ArcGIS 10.2 was used to subset elevation model (DEM) of the study area from digital elevation dataset of Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER GDEM) with 30m resolution. The slope map and elevation map of the study area was generated from the DEM using spatial analysis tools on ArcGIS 10.2.

3.3.6.4 Generation of drainage density

The drainage density of the study area was generated by overlaying the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER GDEM) data on the study area.. The Arctol box was open and the spatial analyst tools on ArcGIS 10.2 software was selected, and the following procedures was taken: hydrology > fill > flow direction >

flow accumulation. The next step taken was the generation of stream raster using the raster calculator. This procedure was followed by the stream ordering > stream to feature. This generate the drainage density of the study area as the final output.

3.3.6.5 Generation of rainfall map

The mean annual rainfall for 30 years was used to create rainfall map of the study area by interpolating from three meteorologicalstations (Sokoto, Kebbi and Zamfara) that are close to the study area due to lack of rainfall data for the wards or communities under study. The Kriging method on the spatial analysis tool of ArcGIS 10.2 was used for the interpolation. It is a method of interpolation which predicts unknown values from data observed at known locations. This method uses variogram to express the spatial variation and it minimizes the error of predicted values which are established by spatial distribution of the predicted values.

3.3.7 Steps Used in Deriving Criterion Weight Using AHP

The relationship between the six causative thematic map and their attributes were derived using Analytic Hierarchy Process (AHP). The methodology used for deriving their weights involved the following steps:

Step 1: defining the problem clearly and decomposing it into various thematic layers containing the different features or classes of the individual themes so that they form a network of the model (Saaty, 1980).

Step 2: Generating the pair-wise comparison matrices. The relative important values are determined with Saaty's 1-9 scale (Table 3.2) where a score of 1 represents equal importance between the two attributes, and a score of 9 indicates the extreme importance of an attributes compared to the other one (Saaty, 1980).

Table 3.2: Fundamental Scale for Pair-wise Comparison

Intensity of importance	Definition	Explanation
1	Equal importance	Two elements contributes equally to the objective
3	Moderate importance	Experience and judgement slightly favour one element over another
5	Strong importance	Experience and judgement strongly favour one element over another
7	Verystrong importance	One element is favored very strongly over another; its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation.
	2,4,6, and 8 are intermediate values	

Source: Adapted from Saaty (1980)

Based on the thematic layers used for delineating flood vulnerable areas, pair-wise comparison matrix was derived using Saaty's nine point importance scales. The AHP captures the idea of uncertainty in judgements through the consistency index (Saaty, 1987).

Consistency Ratio (CR) is a measure of consistency of judgement among the criteria.

The measure of consistency given by Saaty (1980) is as follows.

i. The rule of thumb states that the consistency ratio (CR) should be less than or equal to 0.1. Thus a value of 0-0.1 is acceptable in practice.
ii. Higher values indicate that the judgement needs to be re-visited.
iii. It is evaluated as follows: CR=CI/RI

Where CI= Consistency index which reflects the consistency of one's judgement.

And CI= CI=λmax-n/1-n.

λ is calculated by averaging the value of the consistency vector (calculated factor weight)

RI- denotes Random Inconsistency index that is dependent on the sample size (Table 3.4).

Table 3.3: RI= Random Inconsistency Index that is Dependent on the Sample Size

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.89	1.12	1.24	1,32	1.41	1.45	1.49

Source: Saaty (1980)

3.3.8 Data Analysis

Objective i: To determine the contribution of factors causing flooding in the study area**.**The factors influencing flood in the study area was identified on the basis that they are factors concerning mostly hydrological, geological and physio-geographical characteristics of the study area which can be measured and evaluated (Zelenakova and Ganova, 2011). These factors include: land-use/land-cover, slope, elevation, drainage, soil and rainfall. The factors were weighted according to the estimated significance towards influencing flooding using AHP. The thematic maps of these factors land-use/land-cover, slope, elevation, drainage, soil and rainfall were subsequently reclassified into appropriate classes depending on the factor's perceived contribution to flood occurrence using the Reclass> Spatial analysis tools>Arc toolbox on ArcGIS 10.2.

Objective ii: Locate and map out areas vulnerable to floodingin the study area as well as generate the flood hazard zones map. To achieve this, the weights generated from the flood causative analysis using the AHPwere overlaid using the weighted sum in ArcGIS 10.2 spatial analysis tools, which lead to the production of the vulnerability areas into three classes of low, moderate and high vulnerable areas.

Objective iii: Estimate the population at risk in the event of flood in the study area

The settlement map was overlaid on the flood vulnerability map. This is done in other to get a clear picture of communities/settlement that falls within different vulnerability category or classes and consequently project the population at risk in the study area with the help of the Exponential method given as:

$Po = Pte^{m}$, where

Po= Expected population

Pt=Population of previous year

e= Exponential

r=Growth rate (in this case 0.003)

n= Number of years interval (in this case 25 years)

Objectives iv: to examine the effect of flooding in the study area. Thisobjective was achieved through the use of questionnaire survey. Respondent's responses to questionnaires were analyzed using descriptive statistics such as tables and pie charts.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

Inthis chapter, results are presented and discussed. The first segment is on the production of thematic maps of the factors under consideration that influence flood. Priority scale was assigned to the factor attributes, and consequently generating the weights. The second segment of this work deals with generating the flood vulnerability maps. The third segment estimates the population at risk of flood. The fourth part of the work examines the effect of flooding to the people in each community. The results are presented in the form of maps, tables, and pie charts.

4.2 Factors Contributing to Floods in the Study Area

This section analyzes factors that are influencing flood in the study area. The factors considered are rainfall, drainage density, elevation, land-use/Land-cover, soil type, and slope. The classes of the factors were further weighed using pair-wise comparison in Analytical Hierarchical Process and reclassified using reclass tool on ArcGIS 10.2.

4.2.1 Rainfall

Due to the lack of rainfall data for the wards or communities under study, the rainfall pattern of the study area was generated from the interpolation of average annual rainfall from three meteorological stations: Zamfara, Sokoto, and Birnin-kebbi (Appendix ii) which lie around Sokoto State. Rainfall data for a period of 30 years (1986-2015) was collected and interpolated using the spatial analysis tool of ArcGIS 10.2. In order to come up with a single rainfall map of the study area, the mean of the rainfall data was derived and interpolated. The analysis reveals that rainfall amount in the study area ranges from 644mm to 877mm per annum (Figure 4.1).

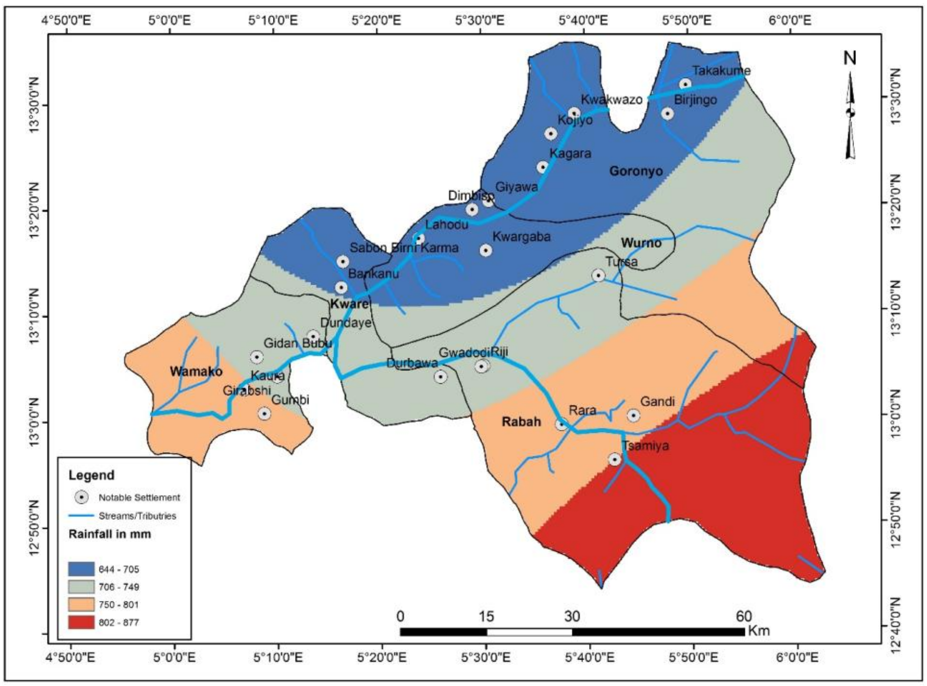

Figure 4.1: Mean Annual Rainfall Map of Sokoto-Rima River Basin

Figure 4.1 shows the distribution of rainfall in the study areas in Sokoto State by ranking in four classes (very low, low, Moderate and High), 1= very low, 3= low, 5= moderate, 6=high.The classification was based on Atiku (2015) study and it showed that the rainfall increases southwards. This can be attributed to the rainfall distribution pattern of Nigeria, as the amount of rainfall received in the North decreases northward and increases southward.

4.2.1.1 Weights for Reclassified Rainfall Pattern of the Study Area.

To understand the contributing pattern of rainfall as a factor influencing flood in the study area, the four classes were further reclassified. The reclassification was done based on the rainfall pattern observed in the study area, with rainfall amount between 644mm - 705mm per annum as very low, 706mm to 749mm as low, 750mm to 801mm as moderate while 802mm to 877mm are considered as high. The pairwise comparison was based on the facts that higher rainfall amounts will results in greater flood risk and vice versa. The results of the weights derived from the pair-wise comparison for the four classes (very low, low, moderate and high) are 6 for very low, 16 for low, 33 for moderate, and 45 for high. (Table 4.1).

The weight generated for the rainfall classes is presented in table 4.1

Table 4.1: Weights for Rainfall Classes

	644-705	706-749	750-801	802-877	Weight	Class
644-705	1	3	5	6	6	Very low
706-749	1/3	1	3	5	16	Low
750-801	1/5	1/3	1	3	33	Moderate
802-877	1/6	1/5	1/3	1	45	High

Consistency Ratio = 0.013

With a consistency ratio (CR) of 0.013, the judgement was seen to be consistent.

The reclassified map of the rainfall was generated based on the rainfall weight and is presented in Figure 4.2.

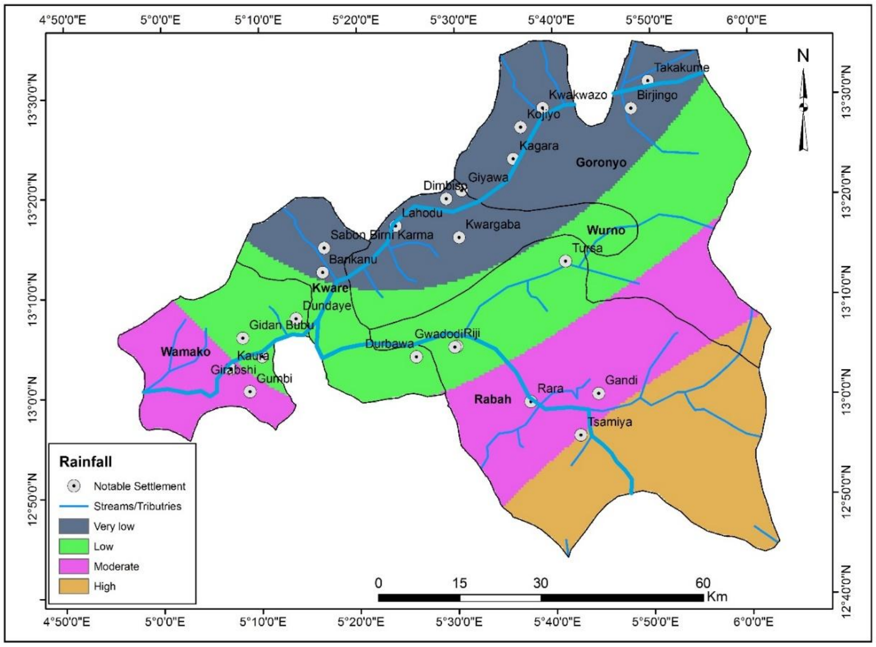

Figure 4.2: Reclassified Rainfall Pattern of Sokoto Rima River Basin.

Figure 4.2 shows the reclassified rainfall pattern based on the rainfall weights. Four classes were obtained which are very low, low, moderate, and high. The rainfall pattern is such that some communities (Tsamiya, Gandi, Gumbi, Girabshi, and Rara) receive high to moderate rainfall than others, which means that there is high tendency for these communities to be more liable to flooding than those that receive less rainfall. The rainfall is generally high towards the southern part of the study area, but very low towards the northern part. This can be attributed to the rainfall distribution pattern of Nigeria, as the amount of rainfall received in the North decreases northward and increases southward. This result agrees with Atiku (2015) that communities that receive higher rainfall are more liable to flooding than those that receive less rainfall.

4.2.2 Elevation

Elevation is used to assess the spatial distribution of potentially endangered flood areas. According to Siddayao, Valdez and Fernandez (2015), areas on low elevations, lying adjacent to the rivers are prone to flooding while those on high elevations are less prone to flood. This terrain pattern justifies why a highly prone area to flood are areas with relatively low elevation as this allow easy flow of water. The elevation of the study area was obtained from the digital elevation model (DEM) of the study area which was windowed from the ASTER DEM with a 30m resolution. The DEM reveals that the elevation of the study area ranges from 236m to 401m above the sea level (Figure 4.3).

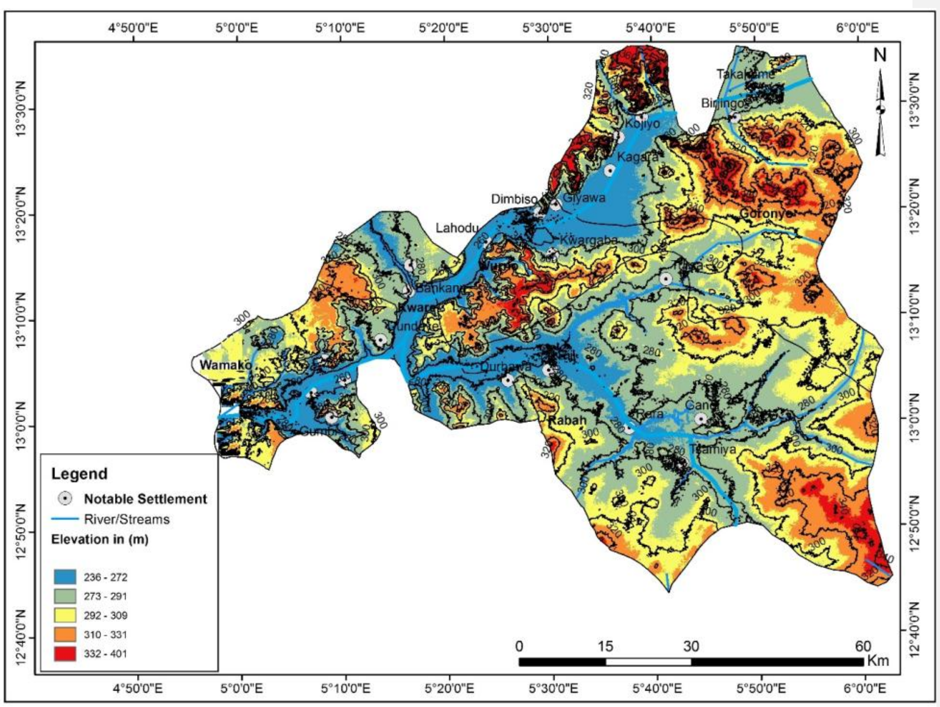

Figure 4.3: Elevation Map of Sokoto-Rima River Basin

Figure 4.3 is an elevation map of the study area, showing the contours lines and the overlaid rivers and tributaries. This is to enable a better analysis of areas vulnerable to flooding in the study area. The communities affected were listed out in the reclassified elevation pattern of the study area based on the different level of elevation position in each community. High elevations are found in patches to the north and east while lower elevations exist in the western and around the southern areas, with low elevation generally seen along the river banks.

4.2.2.1 Weights for Reclassified Elevation Pattern of the Study Area

To ascertain the contribution of elevation as a factor influencing flood in the study area, the five classes (very low, low, moderate, high, and very high) were selected to serve as the category of elevation in the study area. The reclassification was done based on the elevation pattern in the study area. Areas with elevation ranging from 236-291 were considered as very low to low elevation range. Communities that fall in this category are (Gumbi, Kaura, Gidan-bubu, Dundaye, Bankanu, Lahodu, Dimbiso, Giyawa, Kagara, Kojiyo, Kwakwazo, Birjingo, Takakume, Durbawa, Gwadodi, Riji, Rara, Gandi, Tsamiya, and Tursa), these communities did not have high elevation which makes them vulnerable to flooding in the study area. Areas with elevation range of 292-331 were considered moderate to high elevation, which none of the selected communities in the study areas fall into. Elevation range of 332 and 401m were considered as very high elevation areas, which equally none of the communities selected in the study area falls into this category. The pair-wise comparison for elevation (Table 4.3) was done based on the facts that areas on low elevation, lying adjacent to the rivers are prone to the flood while areas on high elevations are less prone to flood. The results of the weights derived from the pair-wise comparison for the five classes is shown in the table below.

Table 4.2: Weights for Elevation

Elevation (m)	**236-272**	**273-291**	**292-309**	**310-331**	**332-401**	**Weight**	**Class**
236-272	1	3	5	7	9	51	Very low
273-291	1/3	1	3	5	7	26	LOW
292-309	1/5	1/3	1	3	7	14	Moderate
310-331	1/7	1/5	1/3	1	3	6	High
332-401	1/9	1/7	1/7	1/3	1	3	Very High

Consistency Ratio: 0.06

The reclassified elevation map was derived based on the weights generated from the elevation and is presented in Figure 4.3

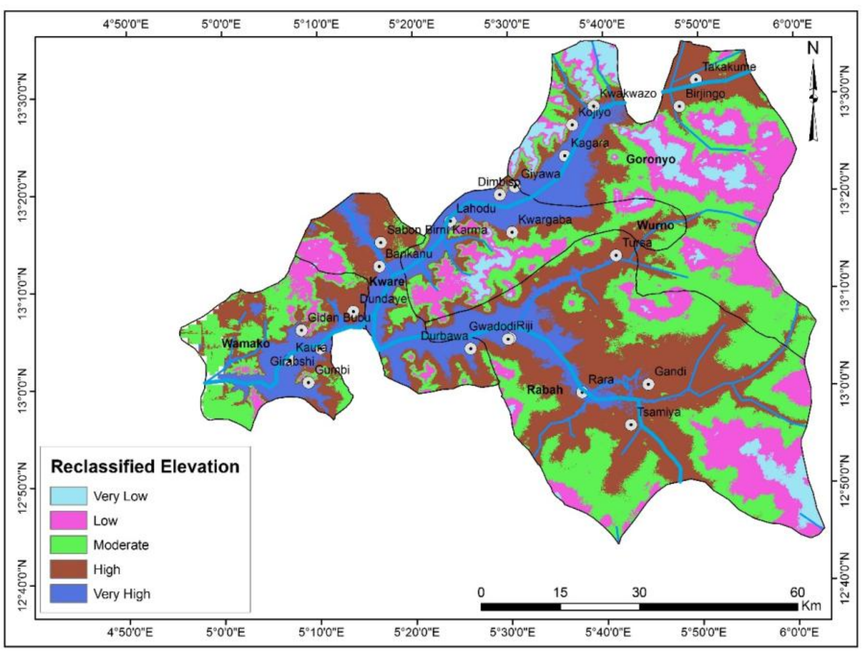

Figure 4.3: Reclassified Elevation Map of Sokoto-Rima River Basin

Figure 4.3 shows the reclassified elevation pattern using reclass tool on spatial analysis tools of ArcGIS 10.2. As a result of the reclassification, it can be seen that communities like (Tsamiya, Gandi, Tursa, Bankanu, Sabon-birnin karma, Dundaye, Kwargaba, Birjingo, and Takakume) are found within the high vulnerability areas and communities like (Gumbi, Girabshi, Kaura, Gidan bubu, Durbawa, Lahodu, Dimbiso, Giyawa, Gwadodi, Riji, Rara, Kagara, Kojiyo, and Kwakwazo) are found in the very high vulnerable area of the study area. This is because, this areas lies with a very low elevation level above the mean sea level, which permits easy flow of water through it. What this simply means is that there is high tendency for those communities to be more vulnerable to flooding since run-off does not easily take place on lower elevation compared to places of higher elevation which experiences easy run-off and flow to the lower area, leaving the area to be flooded in situations of heavy rainfall or water spill.

4.2.3 Slope

Slope is a surface of which one end or side is at a higher level than another. It is an inclination to the ground level. The gentle the topography (low slope angle), the greater the chances for water to accumulate on the surface of the area. In order words, gentle slope will result in greater flood risk and vice versa. A study carried out by Lindsay-Walters (2015) revealed that; the steeper the basin, the more quickly it drains and the gentle the basin, the greater the chances for water to accumulate on the surface. The slope mapwas generated from the ASTER DEM. Figure 4.3 shows that the slope of the study area ranges from 0 to 18.3 degree.

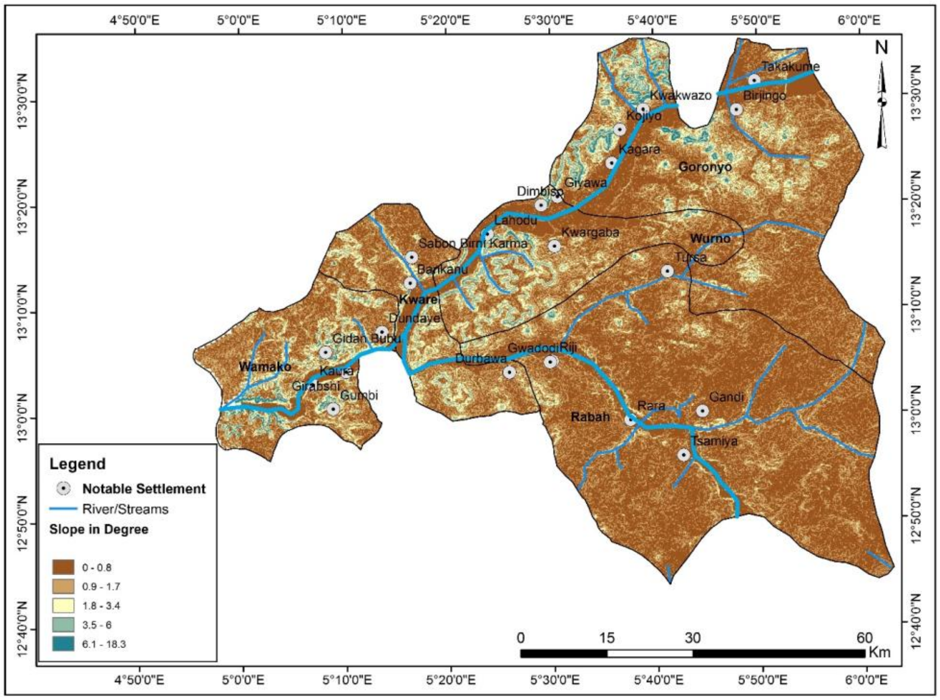

Figure 4.4: Slope Map of Sokoto-Rima River Basin

Figure 4.4was classified based on natural breaks to produce the slope map of the study area. From the map, it can be seen that the area generally has a low slope. The data on Figure 4.4 showed the slope characteristics of the study area which ranges from 0-18 degree and was classified based on the nature of the slopes. In relation to the study, gentle areas where the slope amount is low are more vulnerable to flooding since they facilitate accumulation of water on the surface. However, areas with steep slopes where the slope amounts are high encourage high run-off and low accumulation of water on the surface.

4.2.3.1 Weights for Reclassified Slope Pattern of the Study Area.

To ascertain the role of slope as a factor influencing flood in the study area, five classes of slope (flat, gentle, moderate, steep and very steep) were further reclassified. The reclassification was done based on the slope pattern in the study area. Areas with 0-0.8 were considered as flat slope, 0.9-1.7 were considered as gentle slope, 1.8-3.4 were considered as moderate slope, 3.5-6.0 were considered as steep slope, while areas with 6.1-18.3 were considered as very steep slope. The pair-wise comparison was based on the fact that the gentle the topography (flat/low slope angle), the greater the chances of water accumulation on the surface and vice-visa. In other words, gentle slope will result in greater flood risk and vice-versa. This is because previous study by Lindsay-Walters (2015) revealed that; topography of the drainage basin can affect the speed with which the precipitation flows: the steeper the basin, the more quickly it drains, and the gentle the basin, the greater the chances for water to accumulate. Table 4.2, shows the result of the weights derived from the pair-wise comparison for the five classes:flat, gentle, moderate, steep, and very steep respectively.

Table 4.3: Weights for Slope

Slope in degree	**0-0.8**	**0.9-1.7**	**1.8-3.4**	**3.5-6.0**	**6.1-18.3**	**Weight**	**Class**
0-0.8	1	2	4	6	1	47	Flat
0.9-1.7	½	1	2	4	6	27	Gentle
1.8-3.4	¼	½	1	2	4	14	Moderate
3.5-6.0	1/6	¼	1/2	1	2	8	Steep
6.1-18.3	1	1/6	¼	½	1	4	Very Steep

Consistency Ratio = 0.03

The reclassified slope map of the study area was derived based on the weights generated, and five classes of slope pattern was considered as seen in figure 4.4

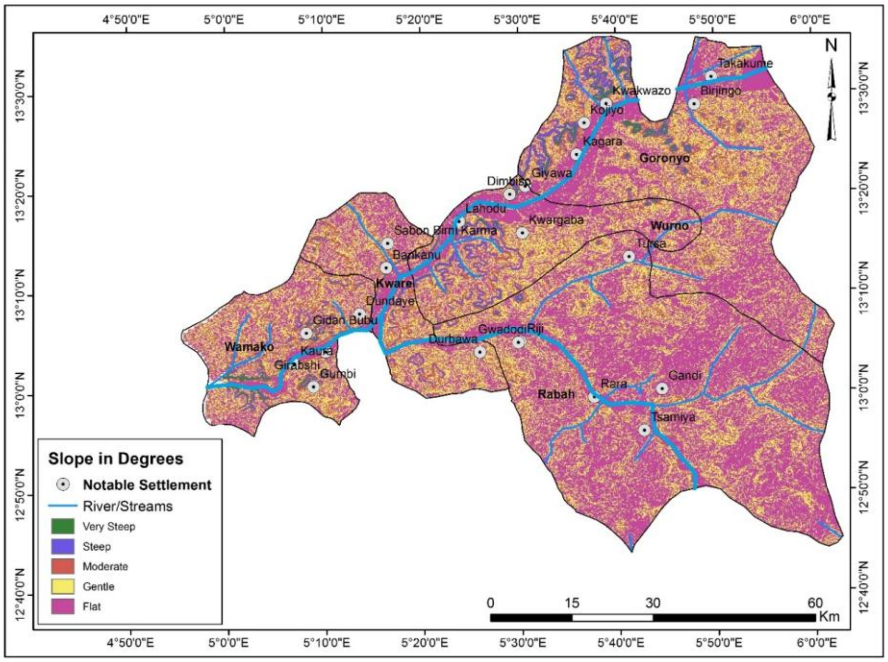

Figure 4.4: Reclassified slope map of Sokoto-Rima River Basin

Figure 4.4 shows the reclassified slope map. The essence of the reclassification is to clearly show the pattern of slope in the study area. The classes of flat and gentle means the slope coverage in this area is less steep, and this is found along the rivers banks and its nearby areas which support easy water flow.As a result, when there is excess water, these areas can easily be inundated compared to places with steep and very steep slope which means that the slope in the area is high. That is, thestudy area is dominantly a flat area which means that there is high tendency for water to accumulate in the area and communities in such areas are more liable to flooding than those in areas with steep slopes. This is justified by the fact that a low land area will beflooded by water easily without any obstruction. This result testifies the study by Mumammed (2017), who observed that the slope pattern of Ibaji local government area of Kogi State is dominantly a flat land area which means that there is high tendency for water to accumulate in the area and communities in such areas are more liable to flooding than those in areas with steep slopes.

4.2.4 Drainage Density

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. The drainage density of the study area was generated from the ASTER data. The major rivers in the study area are rivers Rima and Sokoto which are fed by many streams in the area that drains directly into the river channel. Five classes of drainage density have been identified in the study area ranging from 0 to 57.8km^2(Figure 4.5)

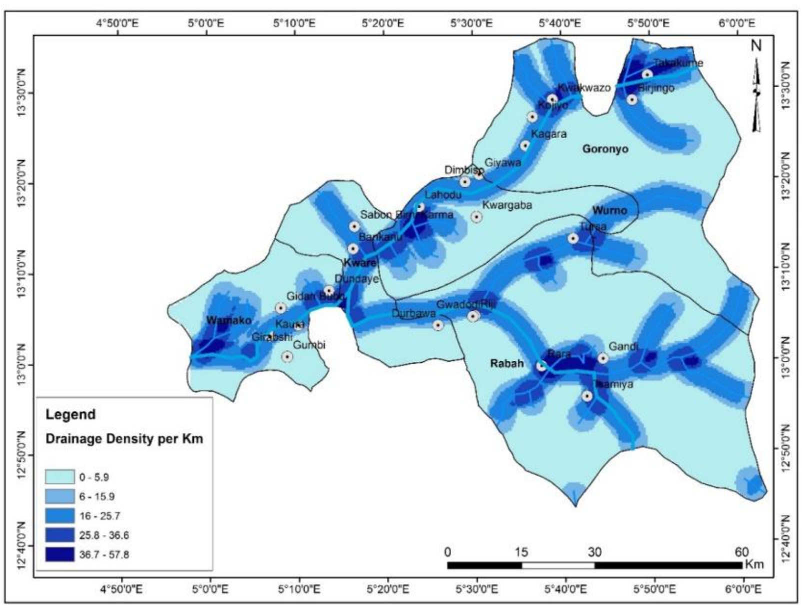

Figure 4.5: Drainage Density Map of Sokoto-Rima River Basin

From Figure 4.5, it can be seen that high, to very high drainage density (25.8-36.6, and 36.7-57.8) occurs more in patches along the river banks of the study area, while low density (0-5.9) is found farther away from the rivers in the study area. To understand the contribution of drainage density as a factor influencing flood in the study area, the five classes (very low, low, moderate, high and very high) were further reclassified. According to Pallard, Castellarin and Montanari (2009), high drainage densities can indicate a greater flood risk, while a decreasing drainage density generally implies decreasing flood volumes. Thus, the five classes of drainage density generated (figure 4.) were compared against each other as shown on Table 4.4.

4.2.4.1 Weights for Reclassified Drainage Pattern of the Study Area.

Drainage density has been recognized by authors such as Gardiner and Gregory (1982) and Pallard, Castellarinand Montanari (2009) tobe significantly effective on the formation of flood flows. According to the authors, high densities can indicate a greater flood risk, while a decreasing density generally implies decreasing flood volumes. To understand the contribution of drainage density as a factor influencing flood in the study area, the five classes (very low, low, moderate, high, and very high) were further reclassified.

Thus the five classes of drainage density generated (figure 4.6) were compared against one another (Table 4.4). The results of the weights derived from the pair-wise comparison for the five classes: very high, high, moderate, low, and very low was found to be 36, 32, 19, 9 and 4 respectively (Table 4.4).

Table 4.4: Weights for Drainage Density

Drainage Density (km^2)	0-5.9	6.0-15.9	16.0-25.7	25.8-36.6	36.7-57.8	Weight	Class
0-5.9	1	1/9	1/7	1/5	1/3	4	Very low
6.0-15.9	9	1	1/7	1/5	1/3	9	Low
16.0-25.7	7	7	1	1/5	1/3	19	Moderate
25.8-36.6	5	5	5	1	1/3	32	High
36.7-57.8	3	3	3	3	1	36	Very high

Consistency Ratio = 0.014

The reclassified drainage density map of the study area was produced based on the weights generated from the drainage density in table 4.4, and is presented in Figure 4.6

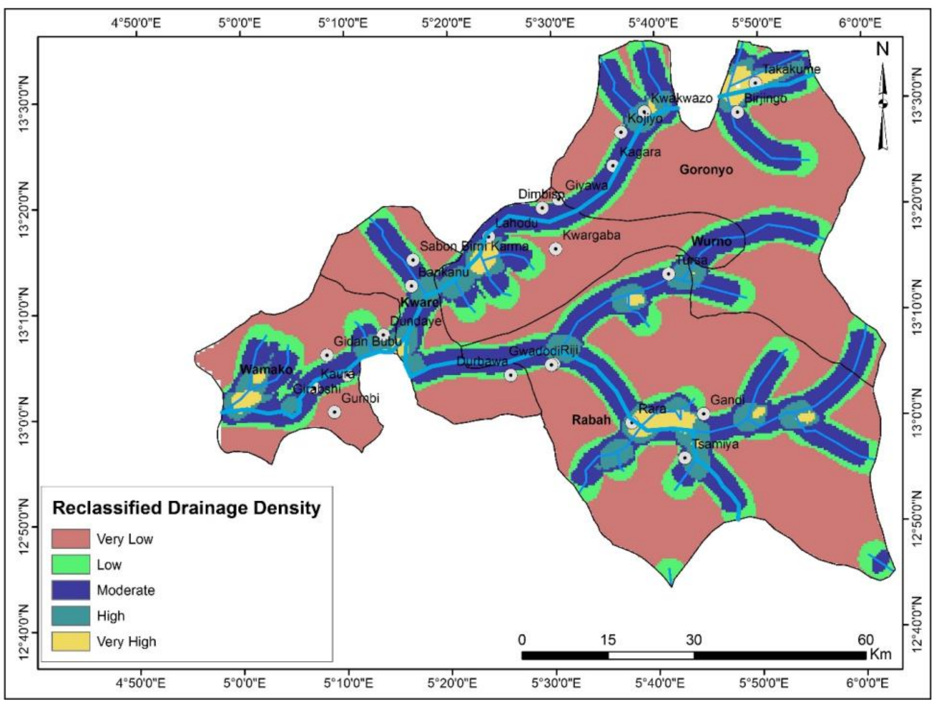

Figure 4.6: Reclassified Drainage Density Map of Sokoto-Rima River Basin

Figure 4.6reveals that communities like (Kwakwazo, Takakume, Tsamiya, Tursa and Rara) are in a very high to high drainage density, which implies that these communities are more exposed to flood.While communities like (Girabshi,Kaura, Dundaye, Bankanu, Sabon-birnin karma, Lahodu, Dimbiso, Kagara, Birjingo, Gwadodi, and Riji) are in the moderate drainage density area. Gumbi, Gidan-bubu, Kwargaba, Kojiyo, Giyawa, Gandi, Durbawa, and Kojiyo has a low to very low drainage density which implies that they will be less affected with flood. This result reflect the results obtained by Gardner and Gregory in (1982) who worked on drainage density in rainfall run-off modelling: rainfall run-off relationships. The results of the study showed that, high densities indicate a greater flood risk, while a decreasing density generally implies decreasing flood volumes.

4.2.5 Soil

The soil types in an area is important as they control the amount of water that can infiltrate into the soil, and hence the amount of water which becomes flow (Nicholls & Wong, 1990). The soil type of the river basin was used based on Henry and William (1973), who identified the soil type of the study area as sandy, clay and loamy. The Soil map was classified on the basis of infiltration capacity. The soil types found in the basin include; poorly drained, moderately drained, and well drained. The structure and infiltration capacity of soils will also have an important impact on the efficiency of the soil to act as a sponge and soak up water. Different types of soils have differing capacities. The chance of flood hazard increases with decrease in soil infiltration capacity, which causes increase in surface runoff. When water is supplied at a rate that exceeds the soil's infiltration capacity, it moves down slope as runoff on sloping land, and can lead to flooding (Lowery, et al, 1996).The soil map was generated by digitizing the existing map of the study area. Three categories of soil were identified clay, loamy and sandy soil (Figure 4.9).

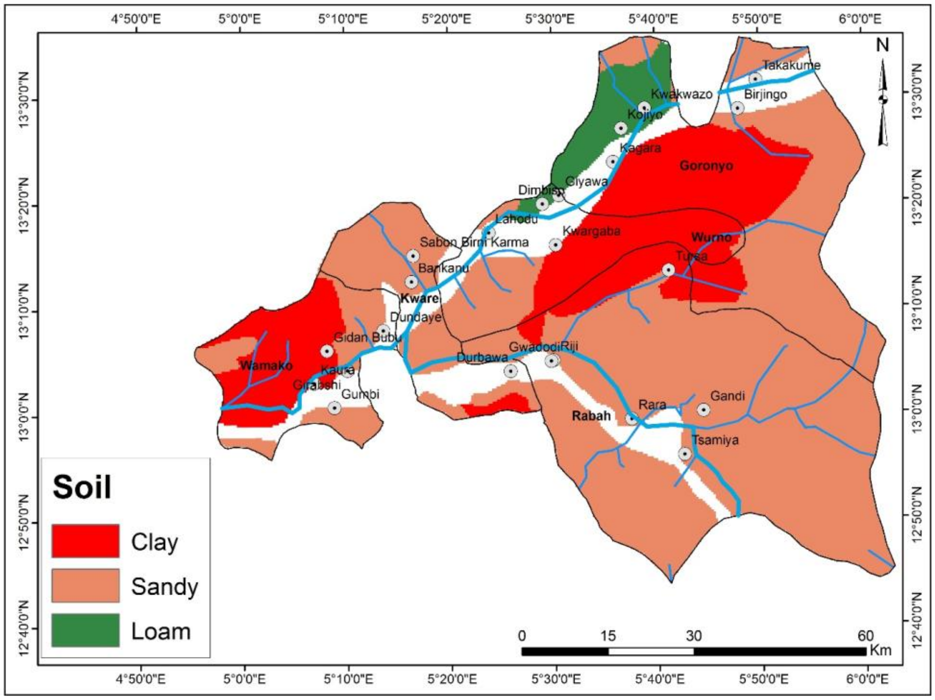

Figure 4.9: Soil map of Sokoto-Rima River Basin

Figure 4.9 shows that clay soil are found towards the north and western part of the study area along the rivers channel, the loamy soil is found at the extreme north west of the study area, while the sandy soil dominates other parts of the study area. The implication of this result to the study is that, areas with clay soil will tend to drain water slowly due to the sticky and less pervious nature of the soil, thereby enhancing water lodge in the areas, rendering houses or farming activities around this areas more vulnerable. The loamy area is moderately drained, and its area coverage is less, meaning its negative impact in the study area is expected to be moderately. The sandy soil in the area permits quick and easy water infiltration into the soil, rendering areas under this coverage less vulnerable.

4.2.5.1 Weights for Reclassified Soil Pattern of the Study Area

To understand the influence of soil as a causative factor to flood in the study area, the three classes (clay, loamy, and sandy) were further renamed. Classification of soil types for analysis was done based on their ability to allow water to infiltrate into the ground and to hold water in the ground thereby reducing run-off or vice versa as recognized by the Federal Department of Agricultural Land Resources Abuja (FDALR, 1990). FDALR designated clay as being poorly drained, loamy soil as being moderately drained and sand soil as well drained, since clay soil absorb less water at a slower rate than sandy or loamy soil. This therefore implies that areas dominated by clay soils are more prone to flood than areas covered by loamy or sandy soils. To facilitate comparison, sandy has been designated well drained, clay as poorly drained and loamy as moderately drained. The pair-wise comparison done was carried out for the three categories of soil type (Table 4.5)

Table 4.5: Weights for Soil

Soil	**Clay**	**Loam**	**Sandy**	**Weight**	**Class**
Clay	1	5	9	74	Poorly Drained
Loam	1/5	1	5	20	Moderately Drained
Sandy	1/9	1/5	1	6	Well Drained

Consistency Ratio = 0.02

.

Table 4.5 shows the weights generated after pair-wise comparison. Clay has 74, while Loam has 21 and Sandy soil has

The reclassified soil map of the study area was produced based on the weights generated from the soil types in table 4.5, and is presented in Figure 4.10

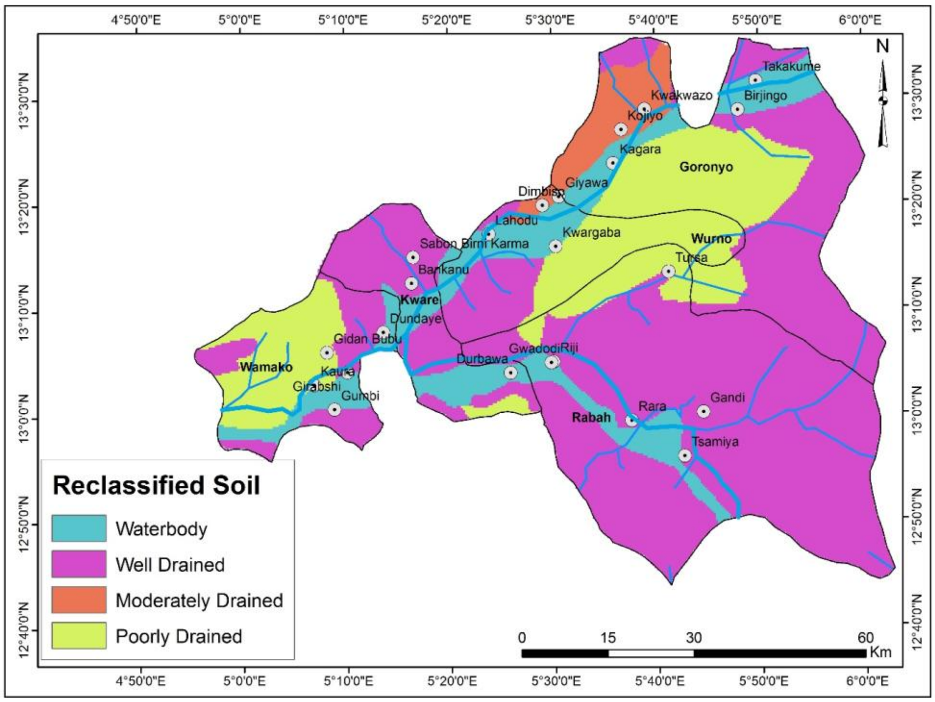

Figure 4.10: Reclassified Soil Map of Sokoto-Rima River Basin

Figure 4.10 shows the reclassified soil pattern. As a result of the reclassification, three classes were obtained which are well drained, moderately drained and poorly drained. Looking at the classes of soil pattern of the study area, it shows that some communities (Gidan Bubu, Girabshi, and Tursa) lie within the clay soil which means that there is high tendency for these communities to be more liable to flooding than other communities with different soil type in the study area. Communities like Dimbiso, Giyawa, Kojiyo, and Kwakwazo are moderately drained, which means that this areas also contribute to flooding effect. This result is in disagreement with the study of Muhammed (2017) whose soil classification of Ibaji reveals that the sandy soilis more vulnerable to flooding, which means that there is high tendency for those communities to be more liable to flooding than other communities with different soil type in the study area.

4.2.6. Land-Use and Land-Cover (LULC)

The land-use and land-cover class (LULC) of the study area for three years (2009, 2010 and 2011) was obtained from Landsat ETM via unsupervised classification using ERDAS IMAGINE 9.2. The classes are: Waterbody, Wetland, Built-up Areas, Agriculture, Vegetationand Bare surface.Figure (4.11, 4.12 and 4.13) represents the land use and land cover maps of the study area and Table 4.6 represents the area coverage of the land cover in percentage for the three years.

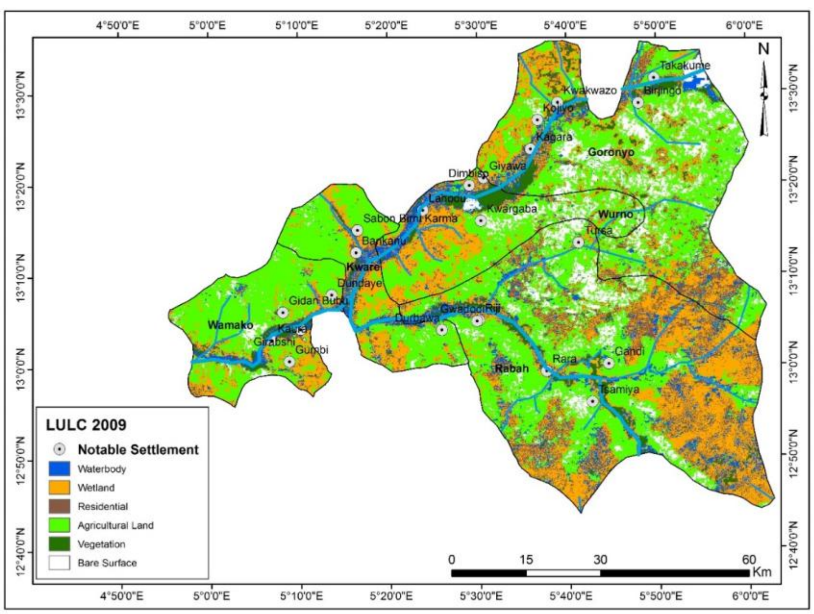

Figure 4.11: Land-Use and Land-Cover Map of the Study Area for (2009)

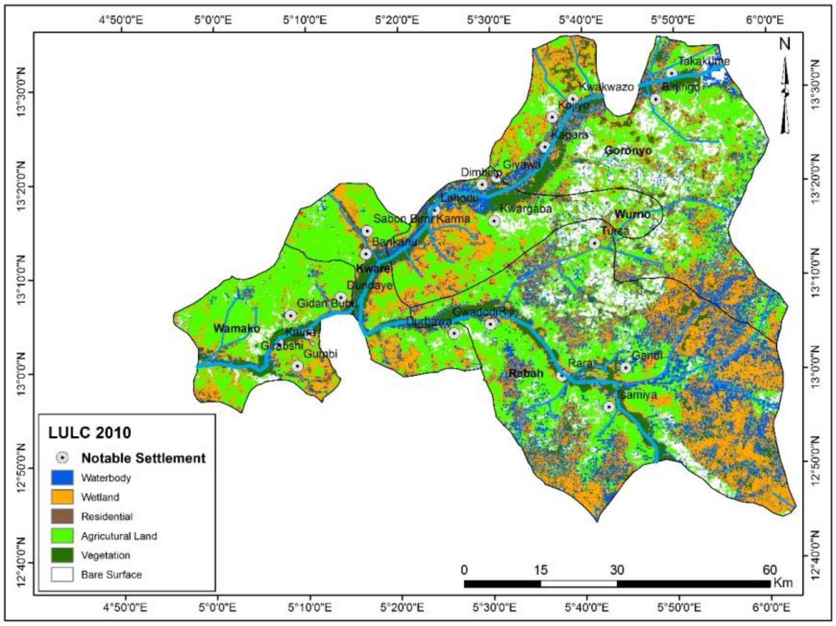

Figure 4.12: Land-Use/Land-Cover Map of the Study Area (2010)

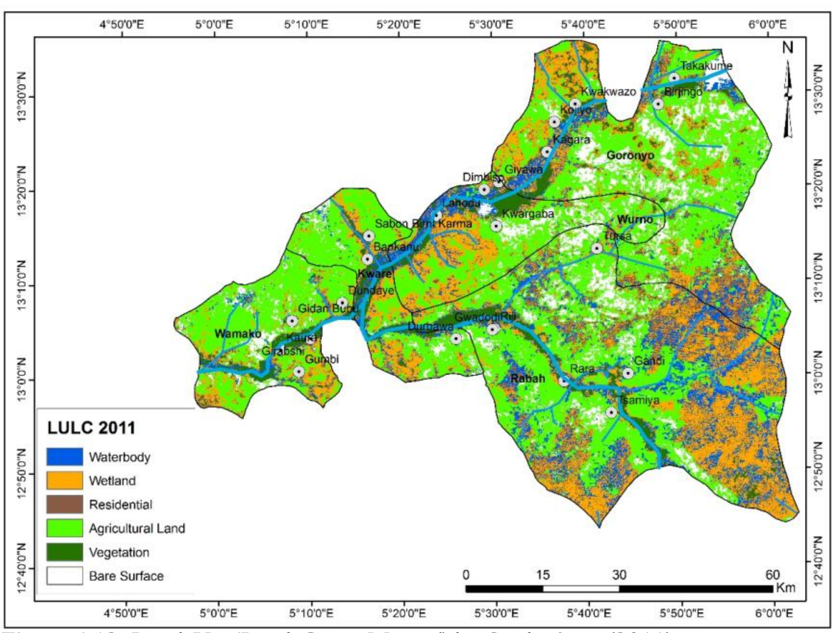

Figure 4.13: Land-Use/Land-Cover Map of the Study Area (2011**)**

Table 4.6: Area Coverage of the Land use and Land cover

Landcover/ Landuse	2009 Area in Sq. Km	%	2010 Area in Sq. Km	%	2011 Area in Sq. Km	%
Waterbody	469.64	7.81	913.89	15.20	701.63	11.67
Wetland	1577.87	26.25	1482	24.65	1377.6	22.92
Built-up Areas	501.2	8.33	327.02	5.44	353.87	5.88
Agriculture	2670.47	44.43	2228.27	37.07	2689.23	44.74
Vegetation	244.68	4.07	429.07	7.13	338.69	5.63
Bare surface	545.94	9.08	629.55	10.47	548.78	9.13
Total	6009.8	100	6009.8	100	6009.8	100

Source: Authors GIS Analysis (2017)

The total extent of the study area is 6009.8 Km^2. looking at (table 4.6), it can be seen that the percentage of waterbody in year 2010 was higher (15.20%) than that of 2009 and 2011, this indicates that there was high level of water inundation in the study area for year 2010. The built-up areas was much in the year before the flooding (that is 2009) with a percentage of 8.33%, which later reduce to 5.44% in the year of the flooding event (2010) as part of the damage been done to the study area. An increase of 5.88% in thebuilt-up areas after the flood event (2011) was recorded indicating that some people in the study area have gradually erect new building back at a very slow rate, this may be as a result of lack of money to erect the collapsed building back, or as a result of fear of continue living in the flood plain. In terms of the agricultural land 44.43%, 37.07%, and 44.74% was recorded for the year 2009, 2010 and 2011 respectively. This indicates that there was a loss of agricultural land which is as a result of the flooding event as farmlands were been washed away during the flood event, this implies that farmers will record high loss of financial benefit as there farm is been inundated by water and damaged this is justifiable by the results obtained from the questionnaire regarding farm loss. Percentage of Forest was

7.13 in 2010, 4.07 in 2009, and 5.63 in 2011. Open land was high in the year of the flood event, which signifies that more land areas has been washed off through flood, except for wetland which has higher value in the year before the flooding.

4.2.6.1 Weights for Land use Land cover of the Study Area.

To understand the influence of land cover as a flood causative factor in the study area, six classes (Water body, Wetland, Built-up Areas, Agriculture, Vegetation and Bare surface) were further reclassified. The pair-wise comparison carried out and weights calculated for land-cover (Table 4.7) was based on the fact that built-up areas and open landgenerate more surface runoff since they do not allow infiltration, while others like forest comprising of vegetation and farmlands on the other hand permit interception of precipitation which can either evaporate and return to the hydrological cycle or flow down the stem of plants and trees (stem flow) and then flow into the ground to infiltrate or percolate deeply into the ground, thereby reducing the surface runoff and consequently the flood magnitude (Lindsay-Walter, 2015). To facilitate the comparison, water body has been designated as very low, wetland as high, Built-up areas as very high, agriculture as high, vegetation as moderate, and bare surface as low. See table 4.7 for the pairwise comparison of the six categories.

Table 4.7: Weights for Land-Cover and Land use

LULC	Water body	Wet-land	Built-up	Agriculture	Vegeta tion	Baresurface	Weight	Class
Waterbody	1	1/7	1/9	1/7	1/5	1/5	3	Very low.
Wetland	7	1	1/3	1	3	5	20	High.
Built-up	9	3	1	3	5	7	42	Very high.
Agriculture	7	1	1/3	1	3	5	20	High.
Vegetation	5	1/3	1/5	1/3	1	3	10	Moderate
Baresurface	3	1/3	1/7	1/5	1/3	1	5	Low

Consistency Ratio: 0.035
With a consistency ratio of 0.035, the judgement is consistent and the result is accepted.

The pair-wise comparison carried out and weights calculated for land-cover (Table 4.7) was based on the fact that built-up areas, agriculture, and wetland are the most important here based on the ranking order, since the major concern of any flood event is the people and the infrastructure, followed by the agricultural setting and wetlands areas, the forest is of importance too, the bare surface and the waterbody are less important here based on the ranking order definition.Alhough, forest, and grasslands permits interception of precipitation which can either evaporate and return to the hydrological cycle or flow down the stem of plants and trees (stem flow) and then flow along the ground or infiltrate and percolate into the ground, thereby reducing the surface runoff and consequently the flood magnitude (Lindsay-Walters, 2015). This is not the case in the study area, as the vegetation in the place are not thick enough like those in the rainforest region of Nigeria, and trees in the study area are scanty and scattered, thereby making it difficult to reduce or stop the effect of flooding in the study area.

The reclassified land-use and land-cover map of the study area was produced based on the weights generated from table 4.7, and is presented in figure 4.14

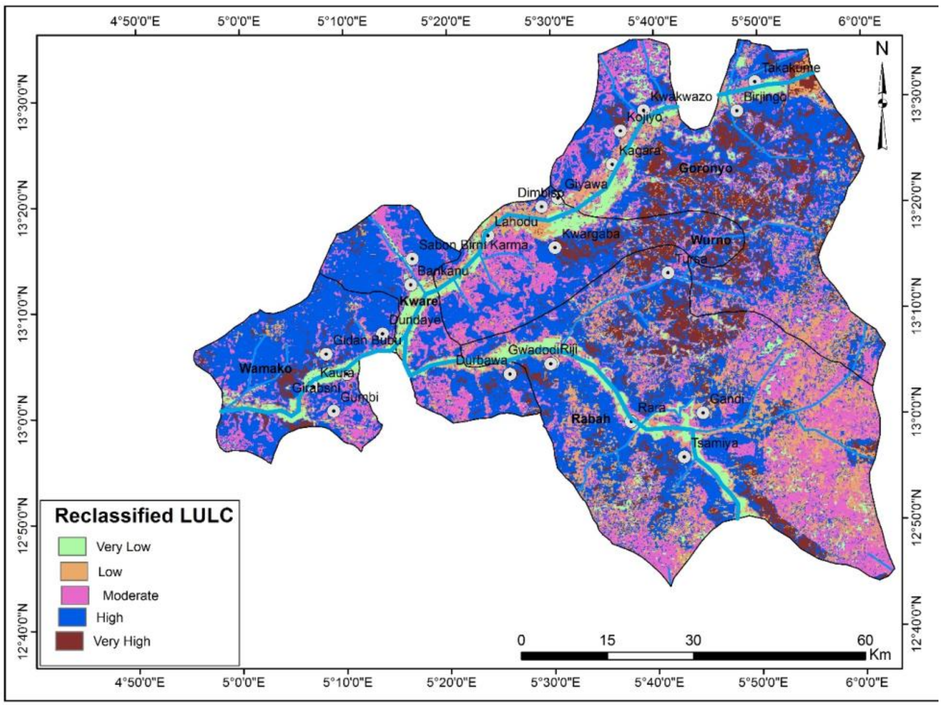

Figure 4.14: Reclassified Land-use and Land-cover Map of Sokoto-Rima River Basin

The results in Table 4.7 shows the reclassified land cover map. The reclassification, reveals that waterbody is very low to flooding with a weight of 3, agriculture and the wetland areas are both high vulnerable to flooding with a weight of 20, the built up areas are very high with a weight of 42, the vegetation areas are moderate with a weight of 10, while the bare surface areas are low with a weight of 5. The result is similar to the result obtained from the work of Atiku (2015) whose work was based on flood vulnerability assessment in Jalingo town, Taraba State, Ngeria.

Table 4.8 shows the combined weights of all the flood causative factors using pair-wise comparison

Table 4.8: Combined Weights for all the Causative Factors

Factor	Rainfall	Slope	Elevation	Drainage Density	LULC	Soil	Weight
Rainfall	1	3	3	7	9	1	34
Slope	1/3	1	3	5	7	9	30
Elevation	1/3	1/3	1	3	5	7	18
Drainage density	1/7	1/5	1/3	1	3	5	9
LULC	1/9	1/7	1/5	1/3	1	3	5
Soil	1	1/9	1/7	1/5	1/3	1	4

Consistency ratio: 0.068

The result reveals that rainfall has the greatest influence on flood occurrence in the study area with 34 as its weight, followed by slope with a weight of 30, elevation with a weight of 18, drainage density and land-use/land-cover accounted for 9 and 5 respectively, while soil has 4. This result reflects the results obtained by Lawal, Matori, Hasim, Yusof and Chandi (2012) whose study on detecting flood susceptible areas in Perlis, Malaysia identified mean annual rainfall as the major factor causing flooding. Also, Eguaroje *et al*.(2015 who worked on flood vulnerability assessment of Ibadan city, Oyo State revealed that mean annual rainfall contributed to flooding than any other factor considered in the model.Atiku 2015 observed that the weights generated reveal that elevation has the greatestinfluence on flood occurence.

4.3 Areas Vulnerable to Flood in the Study Area

This section used the result of the pair-wise comparison carried out for the six flood causative factors (Table 4.8) based on Saaty's Fundamental scale of Pair-wise comparison and generated flood vulnerability map. To determine vulnerability level of communities, these factors (rainfall, slope, elevation, drainage density, LULC and soil)weight from the Analytical Hierarchy Process (AHP) were overlaid using the weighted sum tool of the ArcGIS 10.2 to produce the flood vulnerability map of the study area in three different vulnerability classes. That is: (low, moderate, and high vulnerability) as shown in Figure 4.15

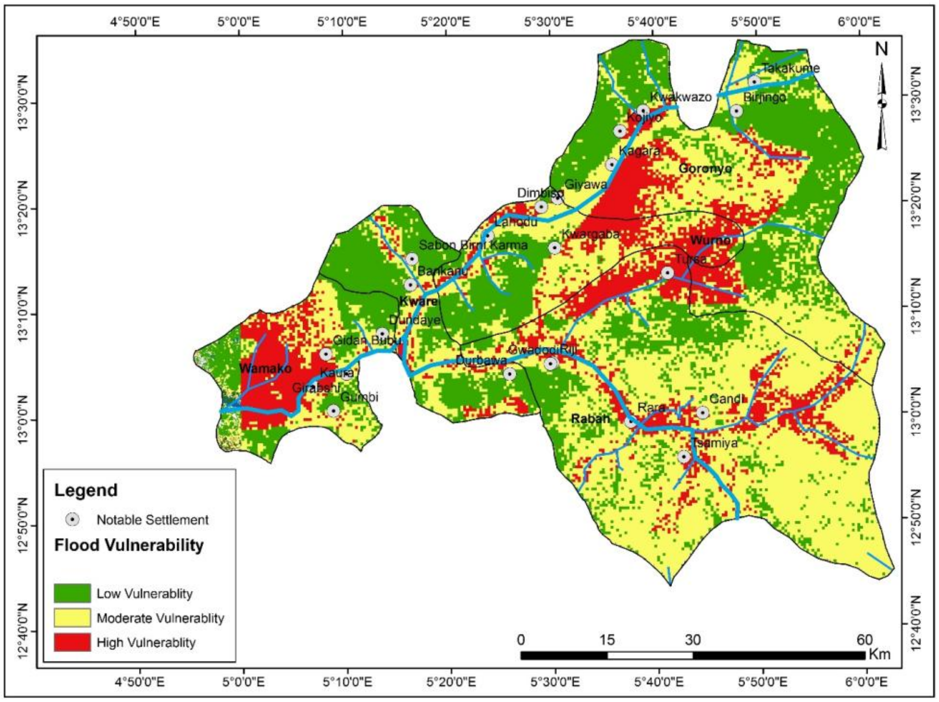

Figure 4.15: Flood Vulnerability map of the study area

Results reveals that communitieslike Birjingo, Gumbi, Dundaye, Kwargaba, and Durbawa are found in the low vulnerable categorywith an area coverage of141755 hectares of the land area making 23.36% of the study area. Communities in the moderately vulnerable area are: Kaura, Bankanu, Sabon birnin karma, Lahodu, Dimbiso, Riji, Gwadodi, Gandi, Takakume, and Kagara, which cover a total land area of 209864 hectares making 34.59% of the study area. Tsamiya, Rara, Tursa, Giyawa, Girabshi, Gidan bubu, Kwakwazo, Kojiyo are found in the high vulnerable area covering 255163 hectares of the land, making up 42.05% of the study area.

From the result, it's evident that most of the communities that are vulnerable to flooding are those that are close to the banks of rivers Rima and Sokoto which are characterized by low elevation and slope. Muhammed and Iyortim (2013) affirmed that areas that lie beside a river may not be liable to flood if it is at a great height while areas that lie far away may experience floods if the intervening land is flat, or if the area lies in a depression of low slope areas.

4.4 Flood Hazard Zones of the Study Area

The flood hazard map was generated within the ArcGis 10.2 environment. In order to generate the map, buffers werecreated with specified distances of 100m, 500m, 1500m, 2000m, and 2500m to serve as areas of very high risk, high risk, minimal risk, low risk, and very low risk respectively, which was later processed accordingly. This is done so as to know the proximity of each settlement to the river (Figure 4.16)

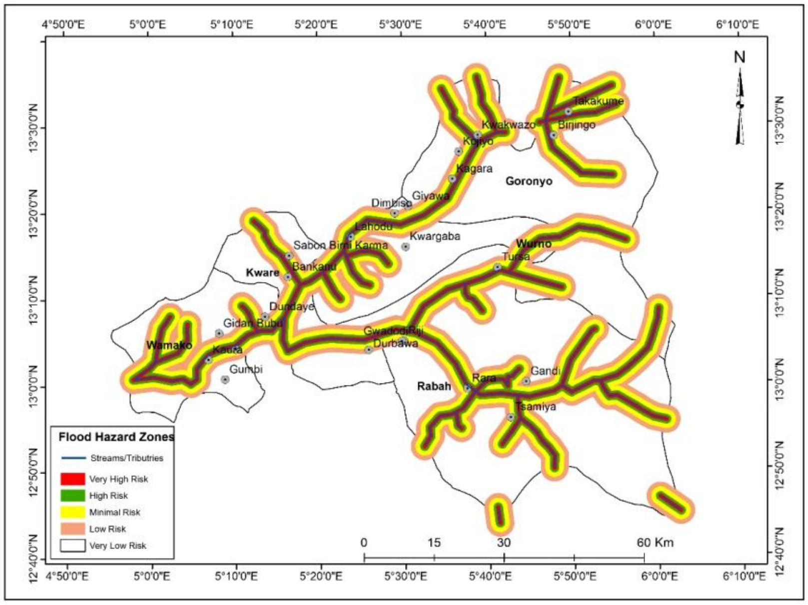

Figure 4.16: Flood Hazard Zones of the Study Area**.**

From the map in Figure 4.16, Lahodu is the only settlement that falls into a very high risk area. Settlements like Kaura, Rara, Tursa, Birjingo, Takakume, Kwakwazo and Kagara,fall into the high risk area. The minimal risk settlement areas are: Tsamiya, Bankanu, and Sabon birnin karma. The low risk area in the hazard map are: Dundaye, Durbawa, Gwadodi, Riji, Gandi, Giyawa, Dimbiso, Gidan bubu, and Kojiyo, while the very low risk settlements areas in the hazard map are; Gumbi, and Kwargaba.The result of this analysis reflect the work of Emmanuel, Ojinaka, Baywood and Gift (2015), who worked on flood hazard and damage analysis in Anambra. The result of there study shows that, areas closer to river are highly vulnerable to flood hazard with hazard intensity decreasing away from the river as the distance increases.

4.5 Estimating the Population at Risk in the Event of Flood in the Study Area

In order to determine the population at risk of flood in the study area, point location of communities affected in the study area were overlaid on the flood vulnerability map as recommended by the United Nations Environment Programme (UNEP, 1998) and localities that fall within the zones were noted and their 1991 population figures was projected to the year 2016. This method was adopted because population data by wards that would have given detailed information was unavailable as at the time of this research. This information is shown in Table 4.9

Table 4.9: Population at Risk

Vulnerable communities	Previous pop. (1991)	Projected pop. (2016)
Gumbi	1413	2959
Kaura	513	1074
Gidan Bubu	859	1799
Girabshi	2087	4369
Dundaye	1754	3673
Durbawa	1598	3346
Sabon Birnin Karma	527	1103
Lahodu	1213	2539
Kwargaba	1732	3626
Tursa	1169	2448
Birjingo	1536	3216
Tsamiya	683	1430
	15084	**31582**

Table 4.9 Continued

More Vulnerable		
Gwaddodi	3358	7031
Riji	1786	3739
Kagara	2920	6114
Kojiyo	2845	5957
Kwakwazo	2114	4426
Takakume	2878	6026
Bankanu	2455	5140
	18356	**38433**
Very Vulnerable		

Dimbiso	**2985**	**6249**
Highly Vulnerable		
Rara	**4849**	**10153**
Extremely Vulnerable		
Gandi	10594	22182
Giyawa	7372	15301
	17966	**37483**

Source: NPC, 1991

The estimated population figures generated were based on projection that assumed the population of the communities with a population increase rate of 3% per annum. From the results, it was revealed that an estimated population of about 31582people are vulnerable to flooding, 38433 people are more vulnerable to flooding, 6249 people are very vulnerable to flooding, 10153 people are highly vulnerable to flood, while 37483 peopleare extremelyvulnerable to flood. The field study carried out revealed that the residents of the communities have a long history of settlement along the river banks in the study area with most of the resident engaging majorly in farming and fishing along the rivers. Mud houses are seen constructed on these lands and occupied by the resident, and in recent years few houses have been replaced by concrete bricks in the study area.

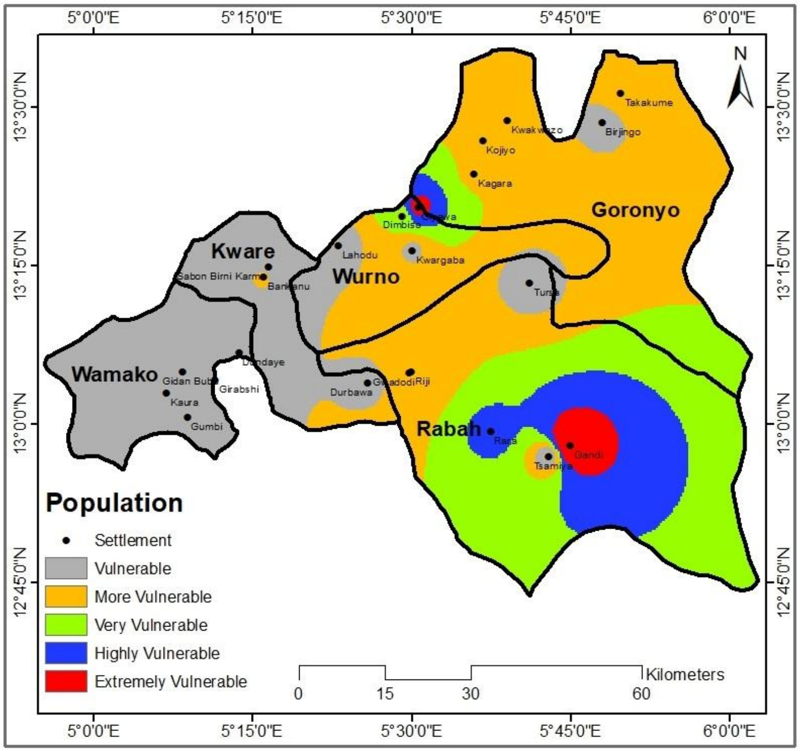

Figure 4.17: Vulnerability Population of Localities in Rima River Basin

Figure 4.17 reveals that, almost all the localities fall within the vulnerable to more vulnerable zones, while Dimbiso and Rara fall under very vulnerable to highly vulnerable areas respectively, except for Gandi and Giyawa which falls in the extremely vulnerable areas.The projected population at risk of flood for the communities at different levels are presented in Table 4.9

4.6 Effect of Flooding in the Study Area

This section uses the perception of residents on effect of flood (Appendix) to examine the effects of flood on the livelihoods of the residents in the study area. Table 4.10 and figure 4.19 showed the summary of damage and property losses caused by flood as perceived by the people in the study area.

Table 4.10: Effect of Flood in the Study Area as Perceived by the Respondents

	Frequency	**Percentage**
Loss of lives	9	2%
Damage to farmland	245	61.25%
Damage to building	81	20.2%
Restriction of movement	65	16.25%
Outbreak of diseases	0	0%
Total	400	100

Table 4.10 shows that flood hazard had also impacted on human causalities. Thus majority (61.25) of the respondents believed that the effects of flood in the study area leads to damages of farmland, 20.2 % of the respondents results to damages to buildings, this is because most of the houses in the study area are built with mud bricks and aluminium zinc. 16.2% and 2% believed that the occurrence of flooding in the study area lead to restriction of movement and loss of life respectively. During the flood event, some people had to look for an alternative route to go out of their houses or get to their various offices or shops. The findings of this study is in harmony with that of Emmanuel, Ojinnaka, Baywood and Gift (2015) who work on flood hazard analysis and drainage assessment of 2012 flood in Anambra.The results revealed that the major effects of flood were disruption of public and personal properties. Also this result is in conformity with the work of Mohammed and David (2014) who worked on the analysis of flood risk inundation hazard in Birnin Kebbi town, Kebbi State Nigeria.It was discovered that farmland, wetland and agriculture were

the most affected consisting 87.78% of the total area. Even though the built up area affected was only 0.13%, yet it is very significant because it constitute human residences.

Information from the respondent about what they lose during the flooding was analysed and presented in Figure 4.18.

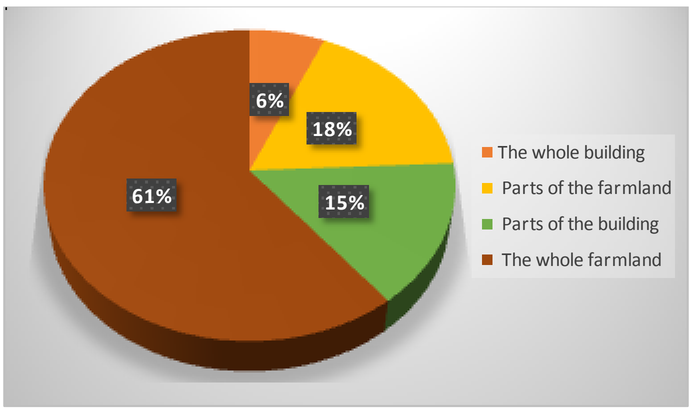

Figure4.18: Responses on Losses to Flood by the Respondents.

The result in Figure 4.18 revealed that most of the items been damaged by the flood event is between farmlands and buildings. It shows that 15% and 18% of the respondents lost parts of their building and farmland to flooding, while 6% and 61% lost their whole buildings and farmlands to flooding. What this simply means is that the farmers are the most vulnerable to flooding in the study area and this implies that there is high possibility of financial loss by the farmers, which may take them longer period before they could recover from the loss, while the inhabitant of the study area are rendered homeless especially by those who are affected and they are left with option of vacating the area or sourcing for money to erect a new building for a better shelter.

The socio-economic characteristics of the respondents in the study area considered include; sex, age, educational qualification, occupation and household size as presented in Table 4.11. The essence of this is to give an information about the flood victim, so as to know the type of people living in the study area, which can tell how they handle the flood situation. The Socio-Economic characteristic of the respondents is presented in Figure 4.11

Table 4.11: Respondents Socio-Economic Characteristics

Sex	**Frequency**	**Percentage %**
Male	400	100
Female	0	0
Total	400	100
Age	**Frequency**	**Percentage**
18-22	0	0
23-27	13	3.25
28-32	25	6.25
33-37	81	20.25
38-42	179	44.75
43 and above	102	25.5
Total	400	100
Education	**Frequency**	**Percentage**
Primary	101	25.75
Secondary	66	16.5
Tertiary	50	12.5
No formal education	181	45.25
Total	400	100
Occupation	**Frequency**	**Percentage**
Civil servant	105	26.25
Business/petty trader	11	2.75
Farmer	284	71
Unemployed	0	0
Others	0	0
Total	400	100
Household size	**Frequency**	**Percentage**
1-5	115	28.75
6-10	182	45.5
11-15	103	25.75
16 above	0	0
Total	400	100

From the questionnaire analysis, it is clear that 100% of the respondent are males, this is traceable to the fact that the study area is in the northern Nigeria where Islamic practice dominates. This practice restricts majority of the women from participating in activities outside their houses, as most of the outdoor services are being carried out by the men, while the women take care of the indoor chores.

Table 4.11 reveals that most of the respondents (44.75%) are between 38 and 42 years old.This is because most of the respondents encountered were full grown up adult men who were engaged in outdoor economic activities during the survey period. However, 70.25% of the respondent were between 38 and 43 years above.

Table 4.11 shows that farming constitutes the major occupation (71%) of the people of the study area. This implies that majority of the respondent in the study area are agrarian and using the advantage of the river for irrigation farming during the dry season. About 26.25% of the respondents are civil servants as their major occupation, while 2.75% were traders. The implication is that, since most of the people in the study area are engaged in farming activities, there is high tendency of loss of farm produce if there should be any flood event, since much of their farmland is closer to the rivers.

Table 4.11indicates that 45.25% of the respondents have no formal education. Some of them said their parents never bothered in enrolling them in the western education during their time, but instead they would rather go to the Islamic learning centre popularly called 'karatun allo' on how to write and recite in Arabic and further support their parent in farming. Nevertheless, 12.5% of the respondents in the study area attain tertiary education with most of them working at the local government level and are equally actively engaging in farming activities in the study area. 16.5% had secondary education, while 25.75% had primary education. Since 29% of the respondents attended secondary and post-secondary education, this shows that a little portion of the respondent are educated and know the implication of living in a flood vulnerable areas or engaging in farming activities there. Most of the respondents had no formal education which implies that, they may not see flood as a threat to them, even though they are being affected.

This result was expected for the household size. This is because Islam encourages polygamy, hence the large number of children per household. Children are required to help in carrying the farm produce when harvested to the house or market so as to minimize transport cost. This relatively large household size was also prevalent among the farmers. This provided a good pool for the supply of household labour to assist in the farm work. There is need to also emphasize the fact that large families are of high cultural value in the area under study. The implication of this to the study is that, more people will be living and farming in the river basin flood plain, and the effect of any flood hazard occurrence in this area will definitely means more damage of lives and property.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary of findings, conclusions drawn from the findings and recommendations made. It highlights issues that were revealed during the research with regards to factors influencing flood, areas vulnerable to flood, the population at risk, the consequences of flooding in the study area, and the strategies of averting flood in the study area.

5.2 Summary of Findings

The Geo-spatial analysis of flood vulnerability in the local government under study (Wamako, Kware, Wurno, Rabah, and Goronyo) was carried out using analytical hierarchy process (AHP) and GIS technique. Landsat ETM of 30m resolution, elevation, slope, soil type, land-use and land-cover, drainage density, and rainfall data were inputted into GIS environment as factor maps to determine which has more influence on the occurrence of flood in the study area. The study revealed that;

- Rainfall plays the greatest role on the occurrence of flood among the factors considered in the study area. This may be part of a climate change pattern, with rising temperatures and more intense rainfall in the rainy season, resulting into intense rainfall duration with heavy downpour.
- The study also generated a flood vulnerability map of the study area and the results showed the vulnerability level of communities in three classes that is; low, moderate and highvulnerable areas as: 23.36%, 34.59%, and 42.05% respectively.

- The flood hazard map created shows five classes of hazard levels as very high risk, high risk, minimal risk, low risk, and very low risk. Lahodu is the only community that falls into the very high risk area. Kaura, Rara, Tursa, Birjingo, Takakume, Kwakwazo, and Kagara are the communities in the high risk zones. Tsamiya, Bankanu, and Sabon birnin karma are the communities that falls into the minimal risk zones. Dundaye, Durbawa, Gwadodi, Riji, Gandi, Giyawa, Dimbiso, and Kojiyo falls under the low risk zones, while Gumbi, Kwargaba, and Gidan-Bubu are communities that falls into the very low risk zones.
- The study also revealed that an estimated population of about 31582people are vulnerable to flooding, 38433 people are more vulnerable to flooding, 6249 people are very vulnerable to flooding, 10153 people are highly vulnerable to flood, while 37483 peopleare extremelyvulnerable to flood.
- The land use and land cover of the study area confirms that the study area is actually exposed to flood in 2010. Considering the six classes.Water which have 15.20% coverage of the study area in year 2010, as against 7.81% for 2009, and 11.67% for 2011. The agricultural coverage of the area reduced to 37.07% as against 44.43% of 2009, and 44.74% in year 2011. There was a reduction in the built-up areas in year 2010 to 5.44% as against 8.33% for year 2009, and 5.88% for 2011. There was an increment in the bare surface area for year 2010 with 10.47% as against the value of 9.08% for 2009, and 9.13 for 2011. There was an increment in the vegetation area for 2010 and the wetland area was moderate.
- The consequences of the flood event showed that, flood hazard had also impacted on human causalities. Thus majority (61.25) of the respondents believed that the

impact of flood in the study area leads to damages of farmland, 20.2% of the respondents results to damages to buildings. 16.2% and 2% believed that the occurrence of flooding in the study area lead to restriction of movement and loss of life respectively.

- The study also reveals that agriculture is the most affected by flooding in the study area.From the satellite imagery of the study area, it is seen that only those communities that are very close to the river banks falls into the high risk zones. The areas vulnerable to flooding in the study areas was displayed through the satellite imagery into different vulnerability category.

5.3 Conclusions

The study analyzed areas vulnerable to flood in the study area. The integrated approach of Remote Sensing and GIS techniques provide the major tool in the determination of the factors influencing flood in the study area, the generation of thematic maps for each factors been considered, the areas vulnerable to flood and the determination of the population at risk. The findings showed that the communities that lie along the river banks with low elevation are all prone to flood hazard. This means that all the buildings, populace, the farming and planting activities and other facilities found within the area are at great risk of flood hazard.

As a result of the large inter-annual variability of rainfall in the arid and semi-arid zones of Nigeria, the area are subjected to frequent floods and drought. According to (Abaje and Giwa, 2010), severe flooding have become an almost annual occurrences in this zones. The storm that caused the flooding in the study area may be part of a climate change pattern, with rising temperatures and more intense rainfall in the rainy season. This seriously affect the Goronyo dam in the study area that results in its inability to hold the water capacity and the failure of the water run-way which triggered the flood effect in the year 2010, resulting to damage to farmland, houses, loss of life and restriction of movement within the study area.. Thus it can be concluded from this study that although flood is a natural disaster, man contributes significantly to its occurrence due to his involvement in activities that disrupt the environment like encroachment of human activities on floodplains and violations of building regulations

5.4 Recommendations

Based on the findings of this study, the following recommendations are hereby made;

i. Settlements that are within or adjacent to the areas vulnerable to flooding should be relocated far away from the rivers bank or around it. Where possible, the state government should set aside plots of land for the re-settlement of people vulnerable to flood.

ii. Farmers in the study area should be enlightened about the danger involved in raining season farming along the river banks, so that they can take precautions.

iii. Timely information about the weather condition of the study area should be notified to the people of the area, so as to take necessary measures.

5.5 Suggestion for Further Studies

i. From the result of the analysis carried out on the causative factors of flooding in the study area, it reveals that rainfall is the major causative factors causing flood in the study area, it is therefore suggested that research should be carried out in order to determine the return period of flooding in the area.

ii. There is need for further research on the mitigation measures so that the menace of flooding can be minimized in the study area.

5.6 Contribution to Knowledge

i. Produced information/ maps of areas vulnerable to flooding in the study area from integrated techniques of AHP, GIS and Remote Sensing.

ii. Estimated the Population Figures at Risk in the event of Flooding in the Study area.

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APPENDIX I

DEPARTMENT OF GEOGRAPHY

FACULTY OF PHYSICAL SCIENCE, AHMADU BELLO UNIVERSITY, ZARIA.

QUESTIONNAIRE

Dear respondent,

I am a postgraduate student of Geography Department, Ahmadu Bello University Zaria, Kaduna State Currently studying M.Sc. in Remote Sensing and GIS. I am undertaking a research title geospatial assessment of areas vulnerable to flood along Sokoto Rima River Basin in Sokoto State Nigeria, using Remotely Sensed Data.

Your co-operation in completing this questionnaire will be appreciated. All information supplied would be treated confidentially and strictly for academic purpose.

Thank you very much.

PERSONAL DATA AND ECONOMIC CHARACTERISTICS OF RESPONDENT.

Name of LGA/Ward ……………………………………

1. Sex:Male [ ], Female, [ ]

2. Age: 18-22 years [ ], 23-27 years [ ], 28-32 years [ ], 33-37 years [ ], 38-42 years [ ],
   43 and above [ ]

3. Highest level of Education
   No formal Education [ ], Primary School [ ], Secondary School [ ], Tertiary Institution
   [ ]

4. What is your occupation?
   Civil servant [ ], Business /petty trader [ ], Farmer [ ], Unemployed [ ]
   Others (Specify) ______________________________

5. What is your monthly income?
   ₦ 5,000- ₦ 10, 000 [ ], ₦10,000- ₦ 20,000 [ ], ₦ 20,000 - ₦ 30,000 [ ],
   ₦ 30,000 - ₦ 40,000 [ ], Above ₦ 40, 000[ ]

6. How long have you been in this area?
   Less than 5 years [ ], 5 – 10 years [ ], 10 - 15 years [ ], 15 – 20 years [ ]
   Over 20 years [ ]

HOUSING CHARACTERISTICS

7. Type of House.

   Compound type [ ], Bungalow [ ], Story Building [ ], Terrace [ ]

8. Building material
   Mud [ ], Bricks and Cement House[ ], Wooden House [ ], Zinc house [ ], Thatch house []
   Others (Specify) ________________________________

9. What is the distance of your house from the flood plain?
   10 – 20 m [ ], 20 – 30 m [ ], 30 – 40 m [ ], 40 – 50 m [ ], Above 50m [ ]

10. Is there any drainage around your habitat? (a) Yes (b) No

11. If yes, which type of drainage system is it?
    Concrete with slab [ ], Concrete without slab [ ], Ordinary drainage with no concrete [ ]

12. Did you experience flooding over the years? (a) Yes (b) No
13. If yes, which year specifically ______________________

14. Did you lost anything during the flood? (a) Yes (b) No

15. If yes, what did you lost?
    a) Parts of the house, (b) The whole house including all my belongings
    b) Parts of my farm land, (d)The whole farm land
16. What is the estimate in (₦) of what you lost?
    a) Less than ₦ 10, 000, (b) 10,000 - ₦20,000, (c) 20,000 - ₦30,000
    b) 30,000 - ₦40,000, (e) above ₦40,000.

17. What are the causes of flooding in this area?

Causes	Agree	Disagree	Undecided
Low lying areas			
Built in a floodplain			
No river and dam management by the government			
Absence of good drainage channels			
Excessive rainfall			
Built next to a dam with a low storage capacity			
Blockage of drainage channel by refuse dumps			

18. What do you consider as the consequence of flooding in your area?

Consequence	Agree	Disagree	undecided
Loss of life and properties			
Outbreak of sickness and diseases			
Loss of business			
Loss of farmland			
Damages of building			
Restriction of movement			

19. Did the authorities assisted you in cash or kind?
    (a) Yes (b) No

20. If yes, what sort of assistance have you received from the authorities? Specify

    ____

    ____

21. What is the population size of your house hold? [ ]

22. Was there any lost of life in your household? (a) Yes (b) No

23. If yes, how many lives were lost? Specify

    ____

    ____

24. Did the authorities made any attempt to relocate you from your habitat due to the flood you experience in your area? (a) Yes, (b) No

25. If yes, specify the area that you are being relocated to.

    ____

    ____

26. Do you have any intention of leaving your current place of habitat?

    (a) Yes. (b) No.

27. If no, why did you want to remain here? Give your reasons

    ____

    ____

28. In your own best opinion, what are the strategies that can be taken to avert flood vulnerability in your area? Specify.

____

____

APPENDIX II:

Population Distribution and the Proportion of Questionnaire Administered by Wards

S/NO	**Goronyo LGA**	**Wards**	**Ward-pop. (1991)**	**Pop. Projection (2016)**	**No-of Respondent**
1	"	Giyawa	7372	15301	49
2	"	Kagara	2920	6114	20
3	"	Kwakwazo	2114	4426	14
4	"	Kojiyo	2845	5957	19
5	"	Birjingo	1536	3216	10
6	"	Takakume	2878	6026	19
Total		6	19765	41040	131

S/N	Kware LGA	Wards	Ward pop. (1991)	Pop. Projection 2016	No.of Respondents
1	"	Bankanu	2455	5140	17
2	"	Sabon Birnin Karma	527	1103	4
3	"	Durbawa	1598	3346	11
Total		3	4580	9589	32

S/NO	Rabah LGA				
1	"	Riji	1786	3739	12
2	"	Rara	4849	10153	33
3	"	Gwaddodi	3358	7031	23
4	"	Gandi	10594	22182	71
5	"	Tsamiya	683	1430	5
6	"	Tursa	1169	2448	8
Total		6	22439	46983	152

S/NO	WamakoLGA				
1	"	Kaura	513	1074	3
2	"	Gumbi	1413	2959	10
3	"	Girabshi	2087	4369	14
4	"	Gidan Bubu	859	1799	6
5	"	Dundaye	1754	3673	12
Total		5	6626	13874	45

S/NO	Wurno LGA				
1	"	Lahodu	1213	2539	8
2	"	Dimbiso	2985	6249	20
3	"	Kwargada	1732	3626	12

Total	3	5930	12414	40
Total	23	59,340	124,245	400

Source: National Population Commission (1991)

APPENDIX III:

Sampling Technique

Wamako Wards	Selected communities
Arkilla	
Bado	
Dundaye	Dundaye
Gidan Bubu	Gidan Bubu
Gidan kaya	
Gumbi	Gumbi
Gwamatse	
Gedewa	
Girabshi	Girabshi
Kammata	
Kaura	Kaura
Wurno Wards	
Achida	
Alkammu	
Chacho	
Dankenu	
Dimbiso	Dimbiso
Dinawa	
Kwargaba	Kwargaba
Kwasere	
Lahodu	Lahodu
Magarya	
Marafa	
Kware Wards	
Bankenu	Bankanu
Basansan	
Durbawa	Durbawa
Gidan rugga	
Gidan modibbo	
Marabawa	
Kabange	
Kware	
Sabon birnin karma	Sabon birnin karma
Tsaki	
Mallamawa	

Rabah Wards	
Gandi	Gandi
Gawakuke	
Gwaddodi	Gwaddodi
Kurya	
Rabah	
Rara	Rara
Riji	Riji
Tsamiya	Tsamiya
Tursa	Tursa

Goronyo Wards	
Birjingo	Birjingo
Boyekai	
Giyawa	Giyawa
Goronyo	
Kagara	Kagara
Kojiyo	Kojiyo
Kwakwazo	Kwakwazo
Rimawa	
Tasakko	
Shinaka	
Takakume	Takakume

Location	Long.	Lat.	Average Annual Rainfall
Zamfara	12.5538	6.123364	888
Sokoto	13.6424	5.370264	629
B/Kebbi	12.96068	4.620734	800

APPENDIX IV:

Computed Average Annual Rainfall of the study area

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APPENDIX V:

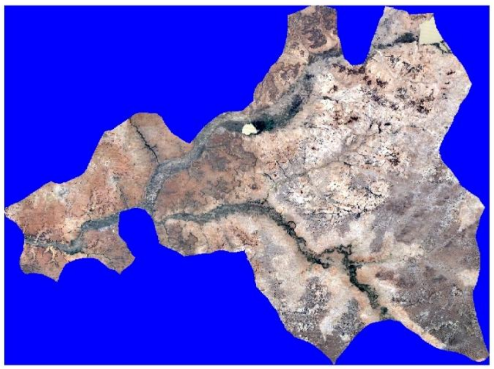
Coordinates of Localities of the Local Government Communities

Location/Localities	Lat	Long
Giyawa	5.5107	13.34301
Kagara	5.59882	13.39489
Kwakwazo	5.64999	13.47921
Kojiyo	5.61207	13.4477
Birjingo	5.80021	13.47731
Takakume	5.82961	13.52275
Bankanu	5.266667	13.23333
S/Birnin karma	5.2754	13.2494
Durbawa	5.43097	13.06626
Riji	5.5	13.08333
Rara	5.6248	12.98979
Gwadodi	5.49652	13.0821
Gandi	5.75	12.96667
Tsamiya	5.716667	12.95
Tursa	5.68627	13.22354
Kaura	5.11451	13.04922
Gumbi	5.1471	13.01087
Girabshi	5.19101	13.07024
Gidan Bubu	5.13925	13.08352
Dundaye	5.22779	13.11376
Lahodu	5.3422	13.33609

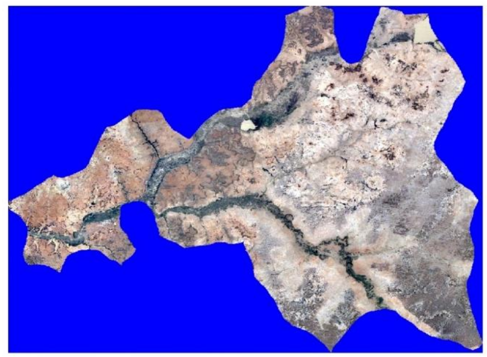
Dimbiso	5.48426	13.32936
Kwargaba	5.50157	13.2743

APPENDIX VI:

Landsat Imagery of the Study Area for year 2009, 2010, and 2011 Respectively



2009 Satellite Imagery of the Stuy Area.



2010 Satellite Imagery of the Study Area

2011 Satellite Imagery of the Study Area