MODELLING SEASONAL FLOOD IN THE DOWNSTREAM OF SHIRORO DAM, NIGER STATE, NIGERIA

BY

HASSAN, Aishatu Bello

PhD/SPS/2015/698

DEPARTMENT OF GEOGRAPHY, SCHOOL OF
PHYSICAL SCIENCES, FEDERAL UNIVERSITY OF
TECHNOLOGY MINNA.

AUGUST, 2021.

MODELLING SEASONAL FLOOD IN THE DOWNSTREAM OF SHIRORO DAM, NIGER STATE, NIGERIA

BY

HASSAN, Aishatu Bello

PhD/SPS/2015/698

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILMENT OF REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHOLOSOPHY IN ENVIRONMENTAL MANAGEMENT.

AUGUST, 2021

ABSTRACT

The highest occurring natural disasters in Nigeria are attributed to flood with its attendant consequences on lives and properties. Nigeria witnessed an increased number of dam construction between 1970 and 1995 as an aftermath of the Sahelian drought of 1970-1972. Communities located downstream of these dams, are traditional areas of special importance for rural communities. The resulting population growth and degradation of natural resources in these areas, aggravates flooding and vulnerability. This study assessed the vulnerability and level of risk through flood modelling of these communities downstream of Shiroro dam, Niger State, Nigeria. The specific objectives include extraction of hydrologic layers from Digital elevation model (DEM), estimation of surface runoff and analysis of satellite imageries of the area from (1990-2016) and flood simulation of the study area. Meteorologic data (rainfall, temperature, relative humidity and evaporation), hydrologic data (inflow, reservoir elevation, average discharge and storage) satellite images for the period of 26 years (1990 – 2016), DEM were acquired. The Hydrologic Engineering Center (HEC) Hydrologic Modelling System (HMS) and River Analysis System (RAS), ARCGIS 10.3, ERDAS IIMAGINE and IDRIS Selva were employed for data analysis. Results revealed variation in hight in the analysis of the DEM of the study area from 48 m to 723 m, where 44.21% of the area is on lower elevation, 32.19% are moderate risk areas while 23.60% are low risk areas based on elevation. The surface runoff analysis reveals that the sub-basins actually aggravate the flooding in the study area with a discharge of 2459.3 (m3/s). The analysis of satellite images revealed a trade-off between vegetation and agricultural land. As the agricultural land increases vegetation decreases. Between 1990 - 2016 vegetation drastically decreased from 62.84% in 1990 to 28.34%, on the contrary, agricultural land shows significant increase during the said period from 22.43% to 50.98%. Built-up areas and bare ground /rock outcrops shows a slight increase from 3.77% to 6.37% and 8.93% to 12.34% respectively. Water body on the contrary continue to shrink from 2.03% to 1.87%. The analysis of the flood simulation revealed that at an altitude of 50 meter above sea level 1.787616 km2 (0.01%) of land area was inundated, similarly, at 100 meter above sea level 2729.162657 km2 (14.47%) of land area was inundated, furthermore, at 150m 6647.622904 km2 (35%) was inundated while, at 200m 9486.40261km2 (50.29%) was inundated. Generally, the result indicates the study area is vulnerable and at risk of seasonal flood. It is recommended that these findings should influence rational decision making with respect to resettlement and compensation and facilitate realistic flood sensitisation campaign on sustainable flood plain management for disaster risk reduction in the study area. The result should serve as a further knowledge that improve our understanding of the flood plain and its attendant advantages and disadvantages to the communities.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

The environment is literally defined by Singh (2010) as the "surrounding and everything that affects an organism during its lifetime ". It further describes the environment as the sum total of water (hydrosphere), air (atmosphere) and land (lithosphere) interrelationships among themselves and also with the other living organisms (biosphere) that exist on, and in, (land, air, and water), and property. Among all these constituents of the environment, man is the most active agent of change. Man modifies his environment to suit him or the situation at a given time. In this quest to satisfy his needs, man built dams to solve problems of municipal water supply, flood control, irrigation, navigation, sedimentation control, and for hydro-electric power generation. Uyigue (2006), defined a dam as " a barrier constructed across a stream or river to impound water and raise its level for various purposes such as; generating electricity, directing water from rivers into canals for irrigation and water supply systems, increase river depths for navigational purposes, to control water flow during times of flood and droughts and to create artificial lakes for fisheries and recreational use." In doing this, surface waters (streams, rivers, and lakes) are being interfered with. Hydroelectric dams are established all over the world for the generation of environment-friendly energy and are often regarded as developmental projects (Salami and Sule, 2010).

Flooding is a global phenomenon that affects both developed nations such as USA, China, Germany, Italy and Poland, and developing nations (Cosgrave, 2014). Parker and Silke (2010) reported that in October 2010, Burkina Faso, Cameroon, Guinea, Chad, Cote d’Ivoire, The Gambia, Ghana, Guinea Bissau, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo, Sudan and Benin were all affected by floods with Benin recording the highest number of 360,000 affected persons followed by Nigeria with 300,000 affected persons. While the developed nations are not unaffected in terms of natural disasters, disasters cause severe consequences for the continued existence, self-esteem and livelihoods of all communities, predominantly the poor in developing countries (Parker and Silke, 2010). Consequently, increasing disaster risk is hindering sustainable development (UNISDR, 2011).

The United Nation's World Water Assessment Programme (WWAP), reported that global trends in natural disasters confirmed that floods, droughts and windstorms have been the most frequently occurring disaster events since 1900 (UN-Water, 2006). The report further revealed that the three accounted for 88.5% of the most catastrophic natural events with more than 83% of flood-related disasters occurring in Asia. The number of casualties per decade has shown a continuous decrease from nearly two million people in the 1960s to half a million in the 1990s

Adikari and Yoshitani (2009) have disclosed that a comprehensive analysis of global and regional water-related disasters between 1980 and 2006 indicated a decline in the universal water-associated casualties while the figures of the affected people and estimated economic damages have increased. Asia is the most vulnerable region to water-related disasters, accounting for more than 45% of fatalities with more than 90% of the people affected by disasters. However, as a result of water related disasters in 1990, Africa recorded the highest number of fatalities accounting for more than 46% of the world's total (Takara, 2014).

In Nigeria, an upsurge of dam construction was observed between 1970 and 1995 due to the effect of Sahelian drought of 1970-1972 (Uyigue, 2006). Shiroro Gorge Dam is one of the three hydro-electric power dams constructed in Niger State in 1990. Others are the Kainji, Jebba and dams constructed in 1969, 1984 and 2013 respectively. Communities located downstream of the dams

often referred to as floodplains, are traditional areas of special importance for rural communities that present favourable conditions for human settlement, economic development, and assets for sustainable livelihood support (Patrick, 2009). In Nigeria, as in other developing nations such India and Zambia, these floodplains continued to attract human populations, particularly in recent times due to a southward migration in the northern regions in response to climate change, land degradation and security challenges (Abdulkadir, 2011). The resulting population growth and degradation of natural resources (land, vegetation and water) in these areas, aggravates flooding and vulnerability of communities resulting to varying levels of disaster during the seasonal rains.

Floods can occur in rivers when the capacity of the river bank can no longer contain the inflow, water flows out of the river channel, particularly at bends and meanders. This often causes damage to lives and property. While flood damage can be virtually eliminated by moving away from the river banks, people have lived and worked by the water to seek sustenance and capitalise on the gains of cheap and easy travel and commerce by being near water as it is apparent in the riverine areas across the world (Adikari and Yoshitani, 2009). Thus, humans' continuous persistence to live in and around areas threatened by flood is an evidence that the perceived value of living near the water exceeds the cost of repeated seasonal flooding Richter *et al*., (2010).

According to Reynaud *et al. (*2013) and Tawari-Fufeyin *et al.* (2015), flooding cannot be completely prevented, but the incidence of a flood needs not be considered a failure and, on the contrary, minimisation of losses may constitute a success. There are lessons to be learned from every flood and it is important to use them in preparing for the next flood. Once we accept that no flood protection measures can guarantee complete safety, a general change of concept is needed to reduce human vulnerability to floods. The attitude of living in areas prone to flooding and accepting the flood in decision making seems more sustainable than totally striving to eradicate them (Reynaud *et al.*, 2013). Despite all these, the hazard of, and damage caused by, flooding cannot be overemphasized in terms of loss of life, property, displacement of people and disruption of socio-economic activities as well as the loss of valuable agricultural land due to the attendant inundation of flood plains. Thus, there is the need for a proactive approach in dealing with this disaster.

In Nigeria for instance, four predominant flood types were observed by Salihu (2014) as Urban flooding (41%); Flash flooding (11%); River flooding (43%); and Dam flooding (5%) with the menace gradually becoming a serious environmental problem. The country recorded series of catastrophic flooding events during the past years (Abia in July 2001, Adamawa in April 2001, Akwa Ibom in March 2001 and in Niger 1999 and 2000 to mention but a few). According to Etuonovbe (2011) Lagos and Ogun States experience seasonal floods as a result of the release of excess water from Oyan dam. Also more than 5000 people were affected in two communities of Sagbama and Kokoluma Local Government Areas of Bayelsa State, due to the over flow of River Nun (Ogba and Utang, 2008). Similarly, several areas along the coast of the along major river valleys are also affected by floods every year.

In the North Central region however, Rivers Benue and Niger account for major river flooding (Salihu, 2014). Seasonal floods occur on many rivers, forming adjoining regions known as floodplains *(*Tawari-Fufeyin *et al.*, 2015). In 2012 the region experienced the most devastating flood catastrophe by inundating larger parts of the flood plains with the confluence town of Lokoja and its surrounding communities as the most widely affected (James *et al*., 2013). In Niger State, the flood plains of Rivers Niger and Kaduna, have been identified by Jinadu (2014) as a permanent dwelling of over 350 smaller communities. The downstream communities of Nupeko, Gurmana, Ketso, Akare, Wuyakede, Muye, Mawogi, Dutsen, Gusoro, Lenfa-Kuso, Jiffu, Gusoro, Gbogifu and Sonlafi have a long record of seasonal riverine flooding as a result of river banks overflowing due to the release of water from the three hydroelectric dams in the State (Ikusemoran, *et.al* 2014; Jinadu, 2014; Musa *et al*., 2016).

An essential requirement for a substantial reduction of communities' vulnerability to natural hazard noted by ISDR (2005) is flood modelling. Flood modelling, estimation, prediction, and forecasting became noticeable in the 1930's and 40's after the work of Sharman and Horton (1932) cited in (Ramirez, 2000). These led to the understanding of laws governing the hydrological processes and behaviour of floodwaters following improvements in observational capability based on progressively higher computational power. With the break-through in science and technology that brought about the development of computers, programmes and GIS, these models began to be tested and calibrated. Ramírez (2000) defined flood modelling and prediction as "a process of transformation of rainfall into a flood hydrograph, and to the translation of that hydrograph throughout a watershed or any hydrologic system". This process generally involves the approximate description of rainfall-runoff transformation, based on the representation of the physical process involved. Thus, the need for flood modelling as a decision support system for sustainability of floodplains and other relevant socio-economic sectors such as agriculture is long overdue. Consequently, this work will incorporate GIS and remote sensing technology, that will integrate runoff from land use land cover map, slope and height to develop a flood modelling and forecasting scheme that will provide sustainable mitigation measures.

1.2 Statement of the Research Problem

In Nigeria, like other parts of the world, floods have often rendered millions of people homeless, injured several others and caused many losses in lives and property (Salami and Sule, 2010). In his address to the 18th session of the Conference of the Parties (COP18) to the United Nations Framework Convention on Climate Change (UNFCCC) 2012, in Doha, Qatar, the Director General, Nigerian Emergency Management Agency (NEMA) stated that, "the 2012 flood in the Country affected a total of 7.7 million people during which over 300 people were killed and 2.1 million others were displaced. Sources of livelihood worth billions of (Nigerian) Naira were destroyed due to the floods (UN, 2012)". A classic example of this is the fate of communities downstream of the Shiroro hydropower dam, including Muregi, Gurmana, Jiffu, Gbara and Akare, which experience annual floods with submergence of farmlands as well as residential and institutional buildings Olukanni and Salami, (2012), Salami and Sule, (2010).

The highest stirring natural hazards in Nigeria is attributed to flooding, with great consequences on the lives and properties (Aderogba, 2012) cited in (Komolafe *et al.* 2015). Numerous Studies have been carried out in the study area on; hazard and vulnerability assessment using questionnaire, oral interview and direct field work (Jinadu, 2014), operational and environmental impact Usman and Ifabiyi (2012), Salami and Sule (2010)), Wahab and Adeola (1999), Olajuyigbe *et al*. (2012) and Olukanni and Salami (2012), river analysis and hazard mapping (Musa *et al*., 2016) and numerous others. Despite the fact that flood modelling approaches are crucial components of flood disaster risk reduction, because of its flexibility and data update capability (Nkwunonwo *et al.* 2015), none of these researches have been carried out on flood modelling and forecasting in the study area.

In addition, the absence of flood data and additional supplementary record for example, the absence of available record on discharge from the catchment sub basins of River Kaduna is a major setback in tackling flood menace in the study areaa. This is due to the fact that the discharge figures from the dam have not been taking into cognisance, the contribution of these catchments. The absence of a geospatial database for flood phenomena and the absence of flood models for Disaster Risk Reduction (DRR) and sustainable livelihoods particularly on the floodplains, despite annual frantic activities by the National Emergency Management Agency (NEMA), Nigerian Meteorological Agency (NIMET), Nigerian Hydrological Services Agency (NHSA) and other related agencies and parastatals.

Therefore, this research work seeks to fill this subsisting void by developing a flood modelling scheme that will integrate the use of geospatial technology (to analyse the impact of land use and land cover dynamics, geospatial database development such as flow direction, flow accumulation, stream definition and segmentation, catchment grid delineation and polygon processing, drainage line and slope) hydro-meteorological variables and discharge from catchment sub-basins of River Kaduna, as a proactive approach towards DRR to ensure livelihoods protection and guarantee sustainable development. Consequently, these have lead to series of questions such as;

1.3 Research Questions

1. What hydrological layers are relevant for hydrologic modelling?

2. What are the possible impacts of land use and land cover on surface runoff coefficients?
3. What is the contribution of sub-basin on flood downstream?
4. What will be the intensity of future flood?

This research effort therefore seeks to answer these questions

1.4 Aim and Objectives of the Study

The aim of this research is to employ geospatial technique in modelling flooding activities in the downstream of Shiroro dam in furtherance of disaster risk reduction in Niger State. To enhance this, the following specic objectives are being processed as follows:

i. Extract hydrologic features (layers) for input into flood modelling from Digital Elevetion Model (DEM)
ii. Analyse Land use and land cover (LULC) map of the study area from 1990 to 2016
iii. Estimate surface runoff coefficient of the area using (LULC) map
iv. Produce a model simulating river flood in the study area.

1.5 Justification of the Study

We cannot stop natural calamities, but we can and must better equip individuals and communities to withstand them. Former UN Secretary General, Kofi Annan (UN-HFA, 2005).

Despite the efforts of various researchers on the scale of inundation and impacts of flood in Nigeria particularly across the study area (mostly during the 1999 and 2012 floods) such as (Ojigi, *et al.* (2013), Ejemma *et. al*. (2014), Ejikeme *et.al*. (2015), Suleiman and Ifabiyi (2014), Musa *et. al*. (2016), Jinadu, (2014), Usman and Ifabiyi (2012), Salami and Sule (2010), Wahab and Adeola (1999), Olajuyigbe *et al*. (2012) and Olukanni and Salami (2012), one vital question that still remains unanswered is "what is the solution to the persistent flooding in the study area?"

The answer could be attributed to either the approaches employed by the researchers are grossly inadequate, lacking in data integration and update capability from the researchers or lack of will to implement the recemmondations of the research findings by the Government. This work attempt to answer the reasons from the researchers perspective.

Similarly, (de Almeida *et al.,* 2012; de Moel *et al.*, 2009; Merz *et al.,* 2007) argued that a range of flood modelling approaches are fundamental constituents of flood risk reduction since they are capable of speedy, constant and routine simulation of flood data needed for flood hazard and risk assessment.

Additionally, the fact that Nigeria is one of the most populated countries of the world with population size projected at over 180 million people in 2016, 286 milllion by 2030 and 300 milllion people by 2035 (World Bank, 2016), coupllled with the assertion by the Global Network for Disaster Risk Reduction (GFDRR, 2016) that, the future population increase will drive future flood risk further emphasises the urgency in seeking for ways of preparing human population in the country to adapt to floods.

In many countries with similar issues of rapid population increase, outstanding among them like China, India, Bangladesh and Vietnam, even though some of them having ‘not too well' instituted flood management systems and flood modelling approaches for flood risk appraisal and mitigation (Huong and Pathirana, 2011; Renyi and Nan, 2002; Sayers *et al*., 2013). It will therefore be a developmental achievement for Nigeria to execute flood modelling given that in other parts of the world such a technique is demonstrated towards flood hazard and risk mapping. Thus, this study provide new approach towards adapting to flooding and to support other stakeholders' attempts towards flood disaster risk reduction in Nigeria.

1.6 Scope of the Study

The scope of the study was limited to the application of geospatial techniques for modelling river flood and its associated impacts in the downstream of Shiroro Dam, Niger State, Nigeria encompassing selected communities from the downstream of Shiroro Dam, in Niger State, Nigeria.

The study did not cover all the communities downstream of the dam. Rather, since flood vulnerability of the communities downstream of Shiroro dam declines with increasing distance from the river channel and elevation (Ismail and Saanyol 2013) cited in (Komolafe *et al.*, 2015), a community each located within 4-10km from the river channel such as Akare, Ketso, Gurmana and Nupeko were selected. These communities were affected by recent floods and classified by Ikusemoran *et al.* (2014) as highly vulnerable to floods.

The LULC classes were grouped into five main groups, namely, agriculture, vegetation, water body bareground/rock outcrops and built-up areas because of their different effect on river discharge Kabanda and Palamuleni (2013). Thus, there was a need to distinguish agriculture from the general vegetation.

1.7 Description of the Study Area

This sub section described the study area under the following themes; location, climate, rainfall, relief and drainage, hydrology, economic activities, vegetation and land use.

1.7.1 Geographical location of the study area

The study area are the vulnerable communities located between Longitude $5^{0}20^{'}E$ to$7^{'}10^{'}E$ and Latitude $8^{0}45^{'}N$ to $10^{0}15^{'}N$ downstream of Shiroro Dam, Niger State, Nigeria. Figure 1 show the map of the study area. With a population of over 4 million people, Niger State has a total land area of 72,200.14km^{2}. The Niger valley terrain covers 18,007.38km^{2} (24.94%), the plains cover 24,181.04km^{2} (33.49%), upland is 20616.09km^{2} (28.55%) while the remaining 9593.3km^{2} (13.01%) are made up of highlands (Mayomi *et al,*. 2014). Shiroro dam is situated 550 metres downstream of the confluence of Kaduna River with River Dinya its main tributary. The dam is built on River Kaduna that takes its origin around the west and North-West of the Jos Plateau in North-Central Nigeria from where it flows westward and southwest-ward. Rivers Koriga, Maarigna and Durimi are main tributaries of River Kaduna, (Ikusemoran *et al*., 2014).

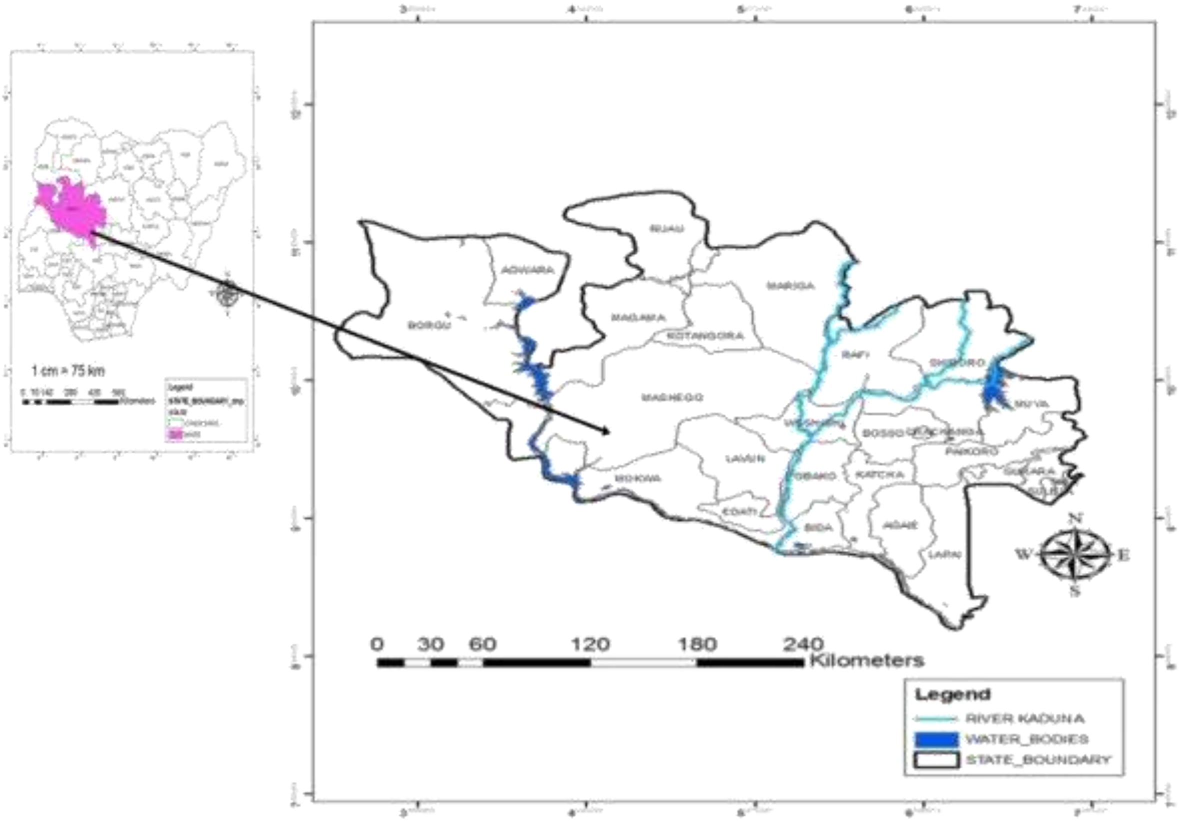


Figure 1.1 Nigeria showing Niger State

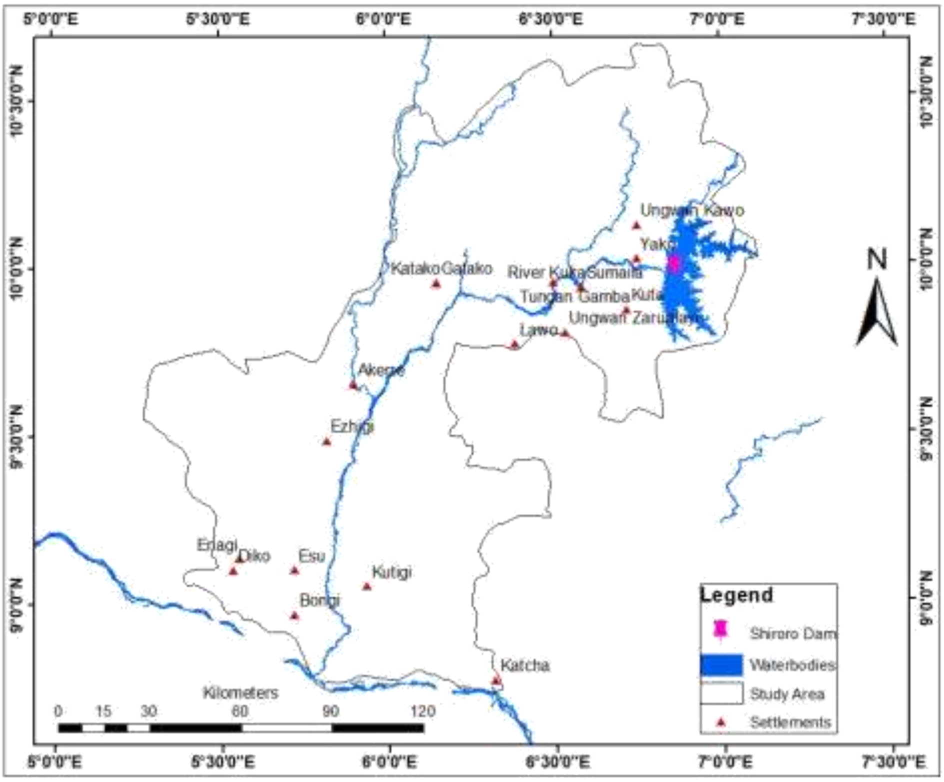


Figure 1.2 The study area

1.7.2 Climate of the study area

Niger State experiences distinct dry and wet seasons with annual rainfall varying from 1,100mm in the northern parts to 1,600mm in the southern parts. The maximum temperature (usually not more than 35^{0}C) is recorded between March and June, while the minimum is usually between December and January (Niger State, 2012). The climate of the area is tropical and belongs to the tropical wet and dry (AW) of the Koppen's climatic classification (Garnier, 1967) cited in (Eze, 2004). However, the creation of Shiroro lake has lea to a change in climatic conditions in and around the lake area (Eze, 2004).

1.7.2.1 Rainfall of the study area

Adefolalu, (1992) cited in (Yakubu, 2012) studied and summarized the rainfall patterns in Northern Nigeria into four periods within a year (January – March, May – July, August

– September and November – December). Rainfall in January to March is very low ranging from 5mm in January to about 40mm in the extreme Southwest in March, by April rainfall of 70mm or more covers the North Central part which is the study area while the lowest value is 40mm in the extreme Northwest. Between May and July, the Shiroro lake watershed receives in excess of 100mm with peak value of about 280 – 300mm in July. There is no part of the North Central watershed that receives less than 180 – 200mm of rainfall in July, August and September, constituting the peak of rainy season within the study area. Rainfall amount is in excess of 300mm in the western half of the area. The highest rainfall receipt of over 400mm is to be expected in September during normal rainy year but can drop sharply to a maximum of 130 – 150mm during a low rainfall year. The onset of the seasonal rainfall is between 20 – 30th April and the Length of Rainy Season (LRS) is between 161 – 200 days.

1.7.3 Drainage pattern and relief in the study area

Shiroro Lake has about eight smaller tributaries contributing to its sum total capacity of about (8 x $10m^3$) inflow with Kaduna river being the major contributory of almost 70% of the total capacity (Eze, 2004). Rivers Muye, Sarkin Pawa, Guni, koriga, Durumi and Mariga are the major tributaries in the study area that feed the main river Kaduna. However, unlike most rivers in northern Nigeria, the river is a perennial river. The river flows in a moderately straight course in the upper and middle stages with some consisting of a number of steep gradient valley steps, which are separated by elongation of others with low gradient. Its course is interrupted where it crosses hard rocks, and deep gorges have been cut across the area of more pronounced steeps in the valley, figure 1.3 showa the drainage map of the study area.

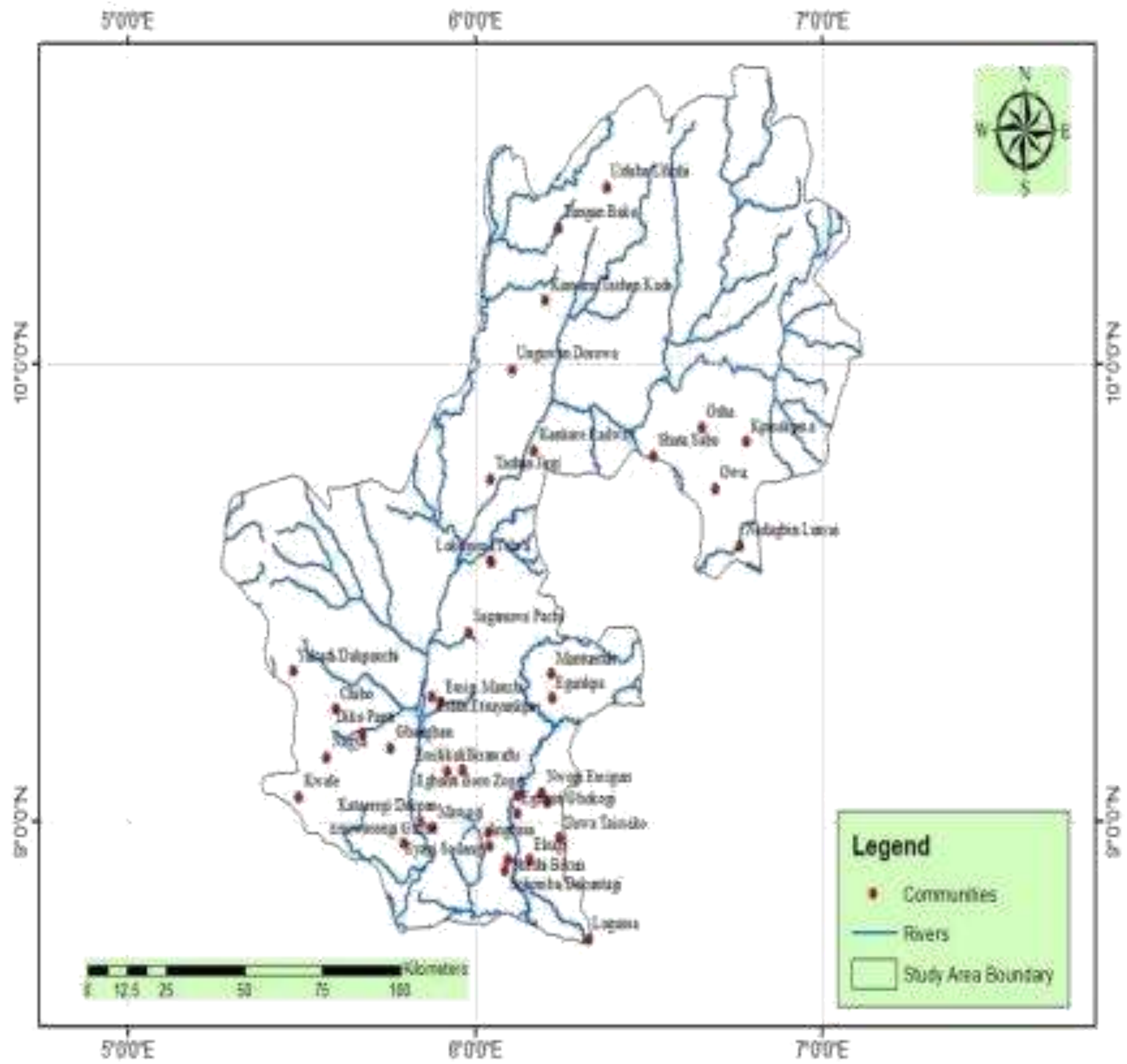


Figure 1.3. Drainage of the study area

The topography is highly undulating and varied in height. Isolated hills of over 600m and low lands as low as approximately 50 m are common in the study area.While valleys in between can get as low as 4000m. The underling hills are made up of granite rocks while the lower terrains are dominated by schist and gneiss (Eze, 2004). Figure 1.4 shows the relief of the study area.

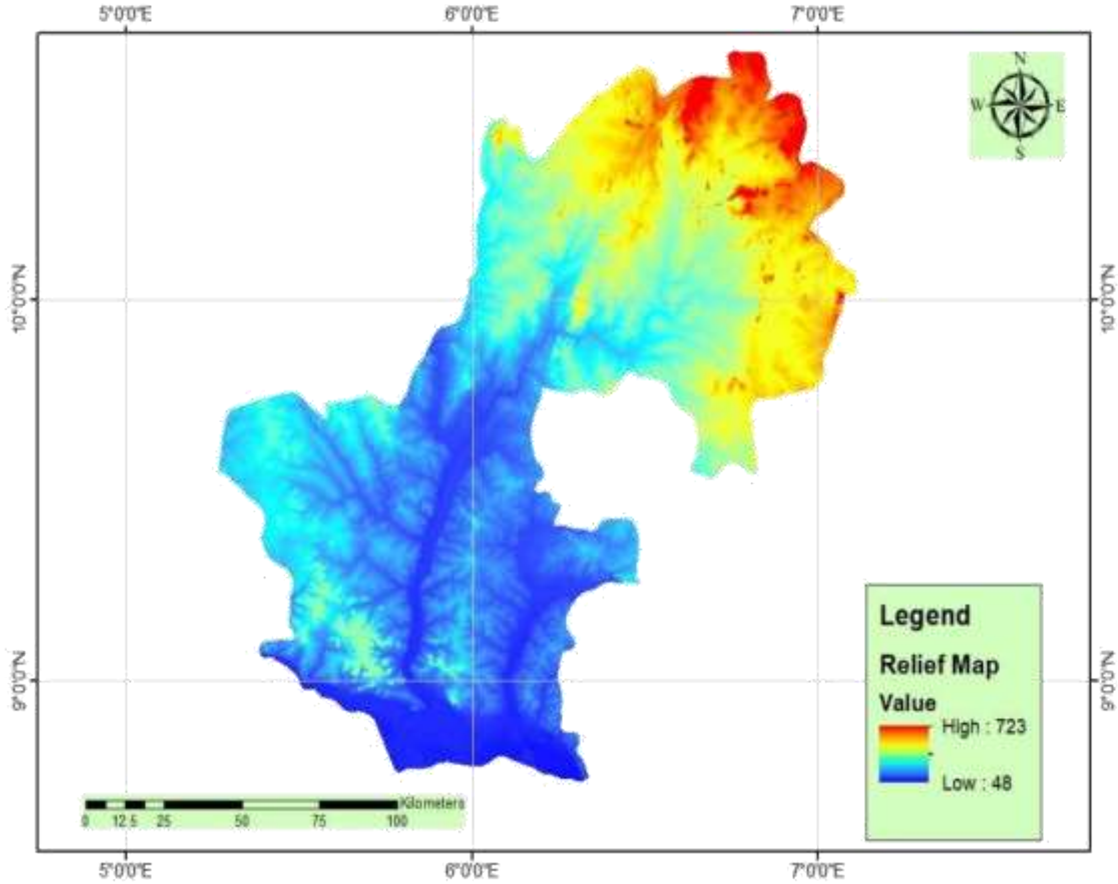


Figure 1.4. The relief of the study area

1.7.4 Hydrology of the study area

The two major rivers that traverse Niger State are Rivers Niger and Kaduna. River Kaduna being the major tributary of the Niger River in central Nigeria, rises from the Jos Plateau and travels a distance of about 350km before emptying into the reservoir (Garba *et al.* 2013). It flows through the Jos Plateau 29km southwest of Jos town near Vom and flows in a north-westerly direction to a bend 35km northeast of Kaduna town (Iloeje, 1982) cited in (Eze, 2004). It then takes up a southwesterly and southerly path before finishing its 340-mile (550-kilometre) flow to the Niger at Muregi, Shiroro lake was built on river Kaduna. The reservoir is about 12.8km wide and the regime of the river is characterized by the occurrence of the wet and dry season. Rainy season between April and October, peak falls between August and September, dry seasons spell usually between November and march (Eze, 2004).

1.7.5 Economic activities in the study area

The Gbagyi communities across the study area are utilizing River Kaduna's upper floodplains for rice cultivation, while in the southern plains, in Nupe land, rice, sugarcane production and fishing are the most important economic activities. In the vicinity of Bida, Edozhigi and Badeggi natural irrigation such as rice-growing is major economic activity, while in the floodplain in Shiroro, yam, cassava, sugar cane and guinea corn, are the main crops (SLG, 1999, Niger State, 2012;).

1.7.6 Vegetation of the study area

The vegetation of the area is typical of that of savannah with patches of few woodlands mainly tress with little shrubs and grasses. The trees are short broad-leaved plants of up to 16.5m height while the grasses are between 1.5-3.5m high. The trees shed their leaves in the dry season in order to minimize loss of water by transpiration while the grasses have durable rooting system which remain underground such that even when they have been burnt after dry season bush fires, they regenerate again with the onset of the rain the following year (SLG, 1999; Eze, 2004). Figure 1.5 shows the vegetation of the study area.

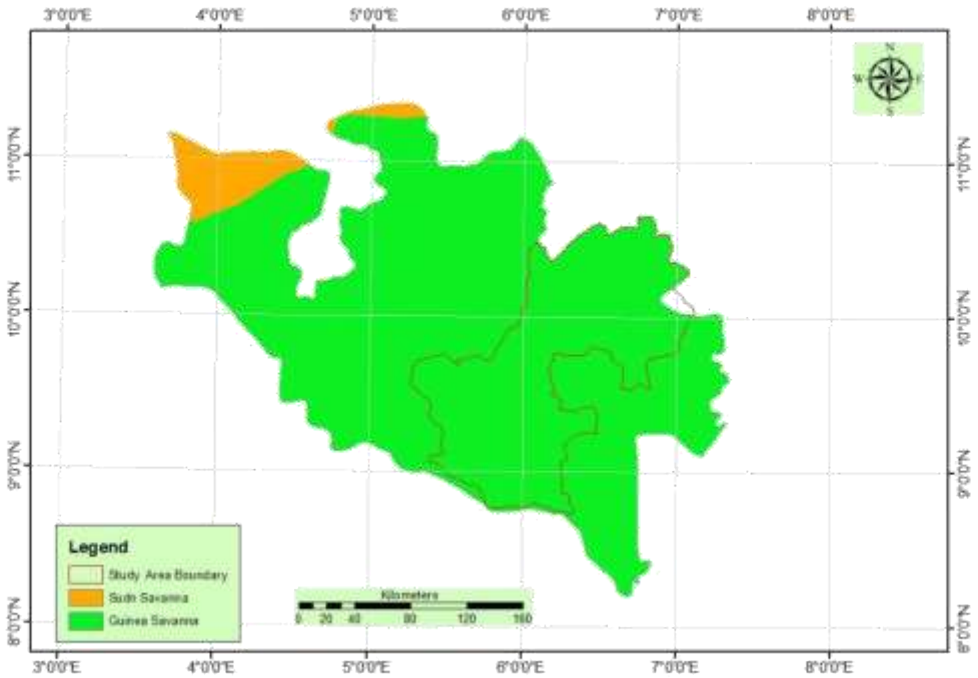


Figure 1. 5. Vegetation of the study area

1.7.7 Soil of the study area

Soil types within the study areas are dominantly hydrological soil group C (HSG-C): moderately high runoff potential (<50% sand and 20-40% clay) with some traces of HSG-B: moderately low runoff potential (50-90% sand and 10-20% clay) downstream, well drained shallow to moderately deep; the colour varies from very dark grayish brown to dark or strong brown to yellow red (SLG, 1999). The names of the soils of the Shiroro catchment area are derived from pre-existing Precambrian basement (complex rock) consisting of gneiss, granite, amphibole and schist (SLG, 1999). Figure 1. 6 shows the soil of the study area.

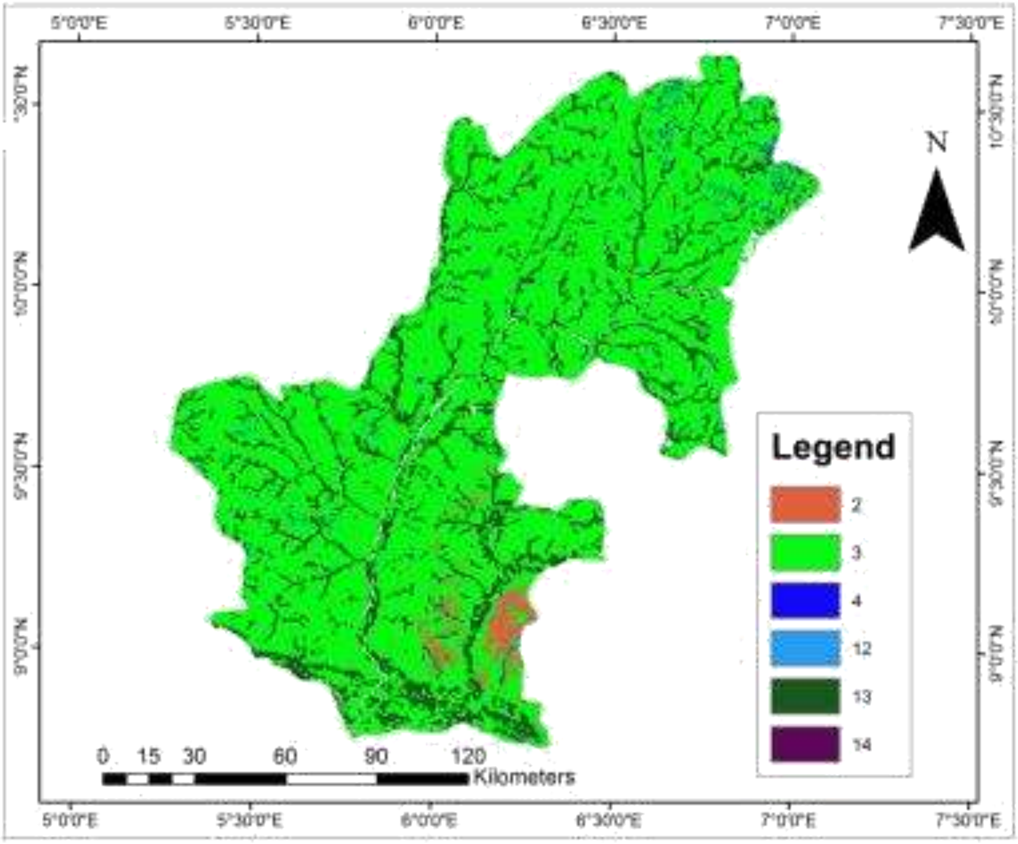


Figure 1.6. Soil classification of the study area

1.7.8 Land use of the study area

Because of the rich fertile land of the area, the predominant occupation of the people is farming while other inhabitants earn their living through fishing due to their proximity to the river. The area is endowed with abundant natural land and water resources. The occurrence of commercially viable mineral resources like Gold, Columbite and Diamond have been proved, while it also ranked as a major producer of rice, yam, maize, cottons, beniseed, groundnut, millet and guinea corn in the State (SLG, 1999).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Preamble

This section reviews concepts and some existing literatures related to the impact of land use and land cover on runoff, extraction of hydrological parameters for flood modelling, the role of geospatial technology on flood modelling, and flood frequency and forecasting. Inferences will be drawn based on the reviewed literatures.

2.2 Definition of Concepts

This section looked at the various concepts related to hydrology and hydrological cycle, runoff, flood and its types in Nigeria, models and their classification and flood forecasting.

2.2.1 Concepts of hydrologic cycle

The problems of flood can best be understood when we understand the concept of hydrologic cycle, which is the theory that describes the fluxes of water between the different repositories of the hydrosphere. The hydrologic cycle maintains a mass balance. Thus, the total amount of water in the hydrologic system is fixed and the cycle is in a state of dynamic equilibrium, that is seen as the exchange of water via processes of phase exchange, precipitation, transportation and runoff (Onwuka *et al.*, 2015).

The process that generates precipitation is often referred as the start of the terrestrial hydrological cycle. The precipitation could be in the form of rainfall or snow. The rainwater may be blocked by vegetation cover or locked up by land surface depressions, may get into the soil as soil moisture, may flow over land surface into streams which significantly increase in the runoff volumes which could lead to flooding or may penetrate to deeper layers to be stored as groundwater. Earth’s atmosphere is a huge solar-powered heat engine that draws up water

as vapour and cloud, and discharges water after condensation as rain and for snow. The precipitated water may complete its cycle by following via the rivers, streams and/or infiltrate down into ground water systems back to the oceans. It may also be routed back into the atmosphere by evaporation from the land surface or by transportation from plants. The hydrologic cycle is important in moving chemical elements, carving the landscape, weathering rocks, transporting and depositing sediments and supplying water resources Hutchinson and Ridgeway (1975) cited in (Onwuka *et al*., 2015).

2.2.2 Anthropogenic activities in the hydrological cycle

On a local scale, Man influence the hydrologic cycle indirectly through environmental change such as desertification and deforestation which can affect the sum of total rainfall in an area. The management of water by man is often through hydraulic construction and protection work such as dams and drainages which often changes or destroys the natural environment, especially the floodplains by increasing the peak discharge, frequency and volume of floods in the nearby streams (Tarboton, 2003). These affects the means of livelihood of the communities living downstream (Salami *et al.,* 2015).

2.2.3 Rainfall-runoff coefficient

Rainfall is the main source of water that generates surface runoff. Runoff according to Tarboton (2003), refers to the "water leaving an area of drainage and flowing across the land surface to points of lower elevation". It happens in one of three forms: surface runoff, subsurface runoff and base flow. Further stated that, runoff involves the following events:

i. Rainfall intensity exceeds the soil's infiltration rate.

ii. A thin layer forms that begins to move because of the influence of slope and gravity.

iii. Flowing water accumulates in depressions.

iv. Deflation overflows and form small rills that merge to form larger streams and rivers. And

v. Streams and rivers then flow into lakes and rivers

Runoff coefficient is a function of two main factors: Permanent factors (Slope of the basin/watershed, soil type and structure, vegetation and channel density) and temporary factors (precipitation input, size of storm, intensity and duration of rainfall). The minimum infiltration rate for the different soil groups are summarised in Table 2.1.

Table 2.1: minimum infiltration rates for different soil groups

Soil Group	Soil Types	Infiltration Rate (in/hr)
A	Deep sand; deep loess; aggregated soils	0.30 – 0.45
B	Shallow loess; sandy loam	0.15 – 0.30
C	Clay loam; shallow sandy loam; soils low in organic content; soils usually high in clay	0.05 – 0.15
D	Soils that swell significantly when wet; heavy plastic clays; certain saline soils	0.00 – 0.05

Source: (Shaari *et al.*,2016)

The runoff coefficient of a sandy soil is low because of its low storm water runoff rate and very high infiltration rate. Clay soils however, have high runoff coefficients as a result of its low infiltration rates and high storm water runoff. Four different soil groups have been classified by the United States' Soil Conservation Service (SCS) used in identifying the values for drainage area runoff coefficients. Land use factors that influence runoff coefficient include the areas with moderately impervious surfaces such as parking lots, buildings, roads and the spatial extent of vegetal cover. Greater slope watersheds will have higher runoff coefficients than the ones with lesser slopes. (Shaari *et al*.,2016 provides in (Appendix A) a comprehensive summary of the effect on slope and different land uses, for the soil groups discussed in table 2.1, for inferences of runoff coefficients values.

2.2.4 Types of flood risk models

Hydrological models are significant for a wide choice of applications; comprising water resources planning, flood forecasting, modelling and planning. These applications depends on the structure of the model on one hand (Pechlivanidis *et al.*, (2011), and the spatio-temporal extent and data input on the other hand (Gharbi *et al*., 2016).

2.2.4.1 Model structure based classification

These are models classified based on their arrangement. They include:

i. **Metric Models:** These are basically empirical models characterised based on the scrutiny and search for the structural response from the available data, examples of these models are Data Based Mechanistic (DBM) and Artificial Neural Networks (ANN) models. DBM models uses time series analysis and simulations while ANN uses limited input normally two variables (rainfall and runoff) and a hidden layer to simulate rainfall-runoff relationship for stream flow.

ii. Conceptual Models: Conceptual models are based on two principles; the initial formation of the model is precised prior to any execution of the model, and not all of the modeling parameters have a direct physical interpretation because they are not independently measurable. Hence, in any case some conceptual model considerations have to be estimated during calibration of the model alongside observed data. Conceptual models commonly signify all of the constituents hydrological procedures perceived to be vital in catchment scale input-output relationships.

iii. **Physics-Based Models:** These models symbolizes the constituents of hydrological processes such as overflow, evapotranspiration, infiltration, and saturated and unsaturated regions of flow using the Newton's equations of motion based on continuum mechanics. Such models are a dominant compilation of the pertinent hydrologic processes but raised two of important issues. Firstly, the physics behind the simulation is based on laboratory observation; therefore it can easily be affected by natural influence. Secondly, catchments are characterized with high level of spatial heterogeneity. This can hinder observation and comprehensive model observation.

iv. **Hybrid models:** To overcome the shortcomings of the models mentioned earlier, hybrid models were used to combine the capability of one or more models.

2.2.4.2 Models classification based on spatio-temporal extent

Flood models that are majorly distinguished based on their spatial and temporal aspects the spatial categories include:

i. **One-dimensional (1D) models**: These models assume a single preferred direction along river cross-section where flow differs slowly alongside a channel length to establish the velocity of the flow of water using 1D Saint Venant equation. It is best applicable along river channels with no floodplains example is in mountainous regions.

ii. **Two-dimensional (2D) models**: These are derived from Reynolds' 3D equation to Saint Venant's 2D flow equation. It assumes a flow within a spatial spread of a floodplain where a flow is computed in the spatial dimensions considering the depth- averaged flood velocities in X and Y directions. It is best applicable in floodplains and estuaries.

iii. **Three dimensional (3D) models**: These type of models are more complex than 1D and 2D models. They simulate flow velocities in all 3 (x,y,z) spatial dimensions, and normally confined to modelling in small areas.

2.2.4.3 Models classification based on data input

Classified base on their data input requirement, these models are categorised into;

i. **Lumped Models:** These models consider a whole catchment as a single unit based on spatial average methods.

ii. **Distributed Models:** These require spatially dispersed data, such as infiltration, rainfall, interception and base flow for flood warning and forecasting. It varies from Lumped model, basically because it requires more data input, and a knowledge of the complex relationship between the different variables.

iii. **Hydraulic Models:** These are used for steady and unsteady flow simulation mostly applied to modelling drainage channel travel time and flood wave attenuation.

2.3 Review of Empherical Studies

Some literatures related to the impact of LULC on runoff, extraction of hydrologic parameters, the role of geospatial technology in flood modelling and flood frequency analysis and forecasting are examined in this section.

2.3.1 Extraction of hydrological layers/ from digital elevation models

The importance of Hydrologic layers or parameters such as catchment hydrological parameters, extraction of multiple outlets or entry points, flow accumulation, flow direction, watershed delineation, slope and aspect is a very important task in hydrologic study, Zang *et.al*. (2010). It is also part of pre-processing of hydrological simulation analysis as it is part of spatial data input that can integrate the hydrological processes with surface flow routing on floodplain modelling, (Yu and Dapeng, 2015).

Isioye *et al*. (2012) analyzed the effect of Digital Terrain Analysis (DTA) on the surface runoff in Basawa area of Kaduna, Nigeria. They achieved this by generating and extracting contour data from a topographic survey, and a high-resolution satellite image of the area respectively. These information pieces were then used to derive the DEM of the area that was consequently used for surface runoff analysis of the area. The DEM was analyzed by extracting topographic variables such as slope, aspect, flow direction and flow accumulation flow accumulation, using ILWIS GIS software. The extracted variables were further used as input to analyze the surface runoff in the locality. Their result indicated that 61% of the land area is relatively flat. This may be considered as the reason for the flooding, as surface runoff cannot be perfectly discharged because of these flat areas, particularly since rising high terrain surrounds them.

Chaurasia and Garg (2015) adopted an object-oriented approach to develop GIS and remote sensing aided flood inundation mapping of Yamuna River, Haryana, India. Based on feature extraction of various thematic layers, from high resolution Cartosat-1 and LISS-III Imageries, the imageries were fused to produce a single composite image depicting both high spatial and spectral resolution using ERDAS software. The fused images were later classified using object oriented classification method. Five parameters namely; Topographic variables (slope, aspect and elevation), LULC, Time series of surface water elevation, River geometry and location of rainwater elevation were considered. The data sets were integrated in GIS environment and processed using Arc hydro extension tools in ARC GIS. The result was a flood inundation map of the area.

Fosu *et al.* (2013) have suggested a new method for river flood inundation and hazard mapping using GIS, remote sensing and HEC-RAS hydraulic capabilities. Affected structures were marked out using GIS's spatial operation, by overlaying the flooded area onto the topographic maps. Their result revealed that high water depth transpired along the main channel and gradually extends to the floodplain. Saleh *et al.* (2011) conducted a research to test the sensitivity of 1D Saint–Venant hydraulic model using different types of river morphological data. They concluded that the precision of the predicted water levels and maximum water depths modelled using the 1D depends on exact depiction of channel geometry and bed level slopes along the river reach. The implication here is that care must be taken in defining the river geometry during digitization.

Garg *et al*. (2013) utilised IRS-Cartosat 1 derived DEM and two scenes of Cartosat 1 satellite to extract hydrologic features for estimation of the impact of slope on Solani watershed runoff India. The DEM was processed to obtain slope and other morphological variables of the watershed in GIS environment. LULC map was prepared using multidate LISS III imagery into nine major classes; dense forest, sparse forest, agriculture, fallow land, agriculture plantation, built up, river perennial, river seasonal and scrub. The percentage of each land cover was estimated. The Natural Resources Conservation Service-Curve Number (NRCS-CN) was adopted to estimate runoff in the watershed. They found that slope factor effects runoff estimation considerably.

2.3.2 Impact of land use and land cover (LULC) on runoff

Land use and land cover (LULC) change is one of the key factors changing the hydrological processes over a variety of time and space. Change in LULC can influence the runoff propagation and concentration by altering hydrological factors such as infiltration, interception, and evaporation. Consequently, it lead to changes in the occurrence and magnitude of flooding and generates runoff for shorter return periods and increases the vulnerability to damage (Li and Gao, 2015). In addition, rainfall-runoff according to Garg *et al*. (2013) is an extremely intricate hydrological incident, as this process is very non-linear, time-varying and spatially distributed. The average slope within a watershed collectively with the overall length and impedence of overland flow are regarded to be the major issues that direct the runoff process. (Chaurasia and Garg, 2015). Thus, to understand the impacts of LULC on flooding, the sum runoff slope and height must be estimated.

Globally, especially in the developed nations, flood is believed to have been aggravated by alterations to catchments, for example, deforestation and urbanisation that augment runoff, increase in population in areas vulnerable to flooding and climate change, as a result of the increases in weather variability and severity, such as intense rainfall and possibly more severe tropical cyclones (Cosgrave, 2014). The foregoing trend signifies that the global amount, and magnitude of flood disasters are expected to persist.

In addition, the insight that these events are more and more recurrent and might continue to worsen in a changing climate has led to a global response to mitigate the impact of further disasters. In view of the above, the United Nations responded by setting up in 1999, the United Nations International Strategy for Disaster Reduction (ISDR) as a successor to the International Decade for Natural Disaster Reduction to facilitate the implementation of ISDR at regional and local levels (SFDRR 2015-2030, 2015; UNISDR, 2012). Subsequently, Hyogo Framework for Action (HFA) (2005-2015) was endorsed by the UN General assembly as an aftermath of the World Conference on Disaster Risk Reduction (WCDRR) (WCDRR, 2015). Likewise, the Sendai Framework for Disaster Risk Reduction (SFDRR), was conceived in 2015 to ensure continuity with the work carried out by States and other stakeholders in the HFA, and initiate a number of improvements for the period ear marked. The overall objective of the United Nations participation in DRR is to substantially; reduce social vulnerability and risks related to natural hazards, facilitate communities to develop resilience, raise communities' awareness about disaster reduction and encourage inter-disciplinary corporation that can develop the scientific knowledge on natural hazards and disasters (UNOOSA, 2011)

In the developed nations especially Europe and the US, response revolves around the development of a strategic evaluation of current and future risk, recognition of the possible alternatives for mitigation; judging the most efficient choices and estimating the costs and benefits of effecting the solutions for short and long-term application (Jha *et al*., 2011). The continued propensity of flood incidents in Nigeria called for the creation of institutions such as the Federal Environmental Protection Agency (FEPA), National and State Emergency Management Agencies (NEMA), National Commission for Refugees (NCFR), National Erosion and Flood Control Policy (NEFCP) and Nigerian Metrological Agency (NIMET) to aid in flood disaster management in the country (Obeta, 2014). Nonetheless, the intervention of these agencies has always been limited to relief and rescue in the form of evacuation of victims, urgent assisstance in terms of food, shelter, clothing and medicine (Orok, 2011). Salihu (2014) pointed that flood forecasting and warning systems failed in the country due to lack of a coordinated system. He further added that a successful system requires sufficient integration of components such as data, technology, skill, collaboration and coordination between multiple institutions to provide a blueprint and models that will serve as long term mitigative and adaptive measures against floods.

An essential requirement for a substantial reduction of communities' vulnerability to natural hazard noted by ISDR (2005) is flood modelling. Flood modelling, estimation, prediction, and forecasting became noticeable in the 1930's and 40's after the work of Sharman and Horton (1932) cited in (Ramírez, 2011). Their work led to the understanding of laws governing the hydrological processes and behaviour of floodwaters following improvements in observational capability based on progressively higher computational power. With the break-through in science and technology that brought about the development of computers, programmes and GIS, these models began to be tested and calibrated. Ramírez (2000) defined flood modelling and prediction as "a process of transformation of rainfall into a flood hydrograph, and to the translation of that hydrograph throughout a watershed or any hydrologic system". This process generally involves the approximate description of rainfall-runoff transformation, based on the representation of the physical process involved. Thus, the need for flood modelling as a decision support system for sustainability of floodplains and other relevant socio-economic sectors such as agriculture is long overdue. Consequently, this work will incorporate GIS and remote sensing technology, that will integrate runoff from land use land cover map, slope and height to develop a flood modelling and forecasting scheme that will provide sustainable mitigation measures.

Joshi and Tambe (2010) cited in Das *et al*. (2013) calculated the effect of slope and grass-cover on infiltration rate, runoff and sediment yield under simulated rainfall conditions.

They disclosed that maximum runoff as well as sediment yield, were generated from the bare land with steep slopes and lowest from vegetated area with a gentle slope. A laboratory experiment for studying runoff and sediment generation processes under different coverage of grass plots in simulated rainfall conditions illustrated that grass cover significantly reduced runoff and sediment compared to the bare lands Yin *et al*., (2017). It can thus be concluded that bareground triggered the rate of runoff and especially on steep slopes thereby increasing the likelihood of flooding.

Similarly, Hassaballah *et al.* (2017) conducted a study to identify the land use and land cover changes (LULCC) in the Dinder and Rahad basins in Sudan, and its implications on stream flow response. Land cover, catchment topography and soil maps were used to estimate model parameters while hydrological model derived from different sets of LULC maps from 1972, 1986, 1998 and 2011 multi temporal satellite imageries, were used. Their result revealed that LULCC was found to decrease considerably between 1972 and 2011, indicating a significant decrease of woodland and an increase of cropland. The model results also indicated that stream flow was affected by LULCC in both the Dinder and the Rahad River, and was more severe on stream flow during 1986 and 2011. The severity within the period was attributed to the stern drought during mid 1980s.

Anaba *et al*. (2017) used Soil Water Assessment Tool (SWAT) to simulate stream flow and estimate sediment yield and nutrients loss from the Murchison Bay catchment as a result of land use changes. The Murchison Bay is an extension of Lake Victoria located in the southeast of Kampala. A 30m DEM, Landsat ETM and TM, soil and Hydro-Meteorological data were used as input into the model. ArcSWATv2012.10.1.18 was installed in ArcGIS 10.1 to process the raster data. The SWAT model was calibrated and validated for stream flow using observed data from 1997 to 3002 and 2004 to 2008 respectively. The Sequential Uncertainty Fitting (SUFI-2) global sensitivity method in SWAT Calibration and Uncertainty Procedures (SWAT-CUP) were used to categorize the most sensitive stream flow parameters. Their results demonstrated an acceptable model stream flow simulation. Also the result of runoff and average highlands sediment yield computed from the catchment showed that, both have considerably increased over the period of study. Thus increase in runoff can lead to severe and recurrent flooding, lower water quality and decrease crop yield in the catchment. Therefore, comprehensive water management steps should be taken to reduce surface runoff in the catchment.

The impact of LULC on natural hazards was investigated by (Reis, 2008) using GIS and remote sensing in Rize, North-East Turkey. Supervised classification technique using maximum likelihood method was carried out on 1976 and 2000 Landsat imageries. Ground truth data was obtained from aerial photos of 1973 and 2002. A pixel-by-pixel change detection comparison was done for land use land cover changes. The land cover changes were analyzed with respect to slope and height in ArcGIS. The result indicated that severe land cover changes have taken place in agricultural (36.2%) (particularly in tea gardens), urban (117%), pasture (-72.8%) and forestry (-12.8%). It was also observed that LULC changes occurred mostly in coastal areas and in areas with low slope values. Therefore it can be deduced that, areas with low slope promotes changes in land use thereby increasing runoff.

Awoniran *et al*. (2013) examined the trend of land use / land cover dynamic in the Lower Ogun River Basin from1984 to 2012. Landsat-5 TM image of 1984, Landsat-7 ETM+ of 2000, a Google Earth image of 2012 and two sets of topographical maps, were utilized. The topographical maps and satellite images were processed using ILWIS 3.2 software and exported to ArcGIS 9.3 for additional processing and analysis. The processed images were afterwards classified using the maximum likelihood classification algorithm. Seven land use classes were identified. Moreover, the Cross Module function in ILWIS was employed for change detection analysis. The resultant change detection analysis pointed out that between 1984 and 2000, 80.08 % of the land cover in the study area has been transformed to other land uses while only 19.92 % remained unchanged. In addition between the same period, non-forested wetlands, forested wetlands and light forests declined at an average annual rates of 8.26%, 4.66% and 2.81% respectively. Similarly water bodies reduced at an annual rate of 0.17 %. Also, built-up areas farmlands and shrubs stretched at an average annual rate of 7.23%, 6.74% and 4.65% respectively. The result further revealed that between 2000 and 2012, 49.86 % of the land cover has been converted to other land uses, while 50.14% remained unchanged. Light forests, non-forested wetlands and water bodies decreased annually by 8.26%, 2.70% and 1.40% respectively. Findings showed the growing impact of urban agriculture on wetland ecosystem within the study area, manifesting in soil degradation and biodiversity loss. The deduction of these findings is that the area is made to be susceptible to devastating flooding which can culminate in the loss of lives and properties due to removal of vegetation.

Investigation was carried out to ascertain the impact of land use/ land cover (LULC) dynamic on stream flow pattern of Mahanadi river basin in India by (Dadhwal *et al*., 2010). A macro-scale hydrological model (Variable Infiltration Capacity) (VIC) was used to simulate the hydrology of the river. Initial boundary and drainage characteristics of the watershed were derived using HEC-GeoHMS add-in, in ArcView 3.2a, while USGS GTopo30 Digital Elevation Model (DEM) with 1km spatial resolution was used as major input for geospatial database extraction after pit removal. An outlet at a station in the river basin was defined to extract basin boundary and subsequently a basin was delineated with its river networks. Furthermore super imposing 25x25km^2 grid subdivided the basin. This was further overlaid with other extracted layers. Because the imageries were of different dates, unsupervised classification was carried out to classify the imageries into 200 classes. These were later reduced into seven classes by merging features with similar spectral signatures. The resultant land cover types were; moist deciduous forest, water body, dry deciduous forest, agriculture, barren land, built up/settlement and dry river bed. The result revealed an estimated increase in stream flow at an outlet of the Mahanadi basin. In addition, a similar classification approach was carried out on NOAA AVHRR image to simulate surface runoff for the years 1972, 1985 and 2003. Changes in surface runoff as a result of LULC dynamics were computed and the result revealed a decrease in forest cover by 5.71% and an increase of annual stream flow by 4.53% between 1972 and 2003. Thus a decrease in the vegetation cover increases runoff. Also, though the use of HEC-HMS model is suitable for sub-basin delineation flood forecasting (Bhuiyan *et al.*, 2017), the use of 1km DEM will not be suitable in this research due to its coarse resolution

Muller and Reinstorf, (2011) developed three spatially precise land-use/land-cover scenario alternatives of Chile. Preceding land use developments were investigated using ASTER satellite imagery. They showed how applying a distributed event modelling approach to simulate runoff used HEC-HMS. The derived runoff values were integrated with existing flood hazard maps to produce a flood inundation map as a source of information for the adaptation to changing conditions in the study area. In addition, the result indicated that continuous land use changes and long drought periods could cause the highest risk of flood. They also demonstrated how HEC-HMS could be used, by applying a distributed event modelling approach to simulate runoff based on LULC changes.

Owing to an increase in serious environmental problems (such as severe floods, landslides, soil erosion and water pollution), as a result of Storm water runoff in Rwanda, Karamage *et al.* (2017) have assessed the changes in rainfall runoff depth, from 1990 to 2016, in response to precipitation and land use changes. InWetspa runoff model was used to estimate runoff volume and depth, based on the possible runoff coefficient per pixel at 30m resolution. The long-term mean rainfall intensity was also estimated at 30m resolution using ArcGIS raster calculator tool using the equation:

$$R_v = R_d * A * 10 \tag{2.4}$$

$$R = P * P_j * C_0 \tag{2.5}$$

where

R_v = runoff volume (m^3) in the area of interest;

Rd = average runoff depth (mm) in the area of interest;

A = area of interest (ha);

10 is a unit conversion constant;

P = precipitation for time period of interest (mm);

C_0 - Potential runoff coefficient

P_j = Fraction of annual rainfall that produces runoff (usually 90%) and is constant.

The constant P_j was brought in to distinguish the fact that many small storms do not produce runoff. Using LULC, soil texture and slope maps, they developed a map of potential runoff coefficient for Ruwanda. Their result indicated that the increase in national runoff depth in Rwanda from 1990 to 2016 was as a result of extensive deforestation over the past 27 years (1990–2016). The continuing trend of runoff transformation was also attributed to the land use change, leading to severe environmental disasters such as floods, soil erosion and landslides. Consequently, vegetal cover removal speed the rate of runoff and in so doing causing flood

Samson *et al*. (2016) examined the morphometry of Owu drainage basin in South Western Nigeria to assess the vulnerability of the community to flood. Topographic maps and satellite imageries of the region were used as input dta. The topographic map was scanned, digitized and converted to Triangulated Irregular Network (TIN) then to DEM using spatial analyst tool in ArcGIS. Hydrological and GIS techniques were used for basin definition, stream ordering and digital elevation modelling. Their Results showed that the drainage basin is typified by about 429 stream segments, and denote divergence ratio of about 1.9, and that about 23% of the entire basin area is susceptible to severe flooding. Also High rainfall concentration, land use and slopes, as well as morphometric characteristics were found to affect flood potential in the study area. Thus areas with steep slopes with dendritic elongated basin are likely to have severe flooding in the lower course of the drainage basin due to excessive accumulation of runoff discharge via a single outlet. In addition, inappropriate land-use coupled with anthropogenic activities (particularly vegetation degradation and poor land-use management) were observed to be the leading cause of flooding within the basin.

Rongrong and Guishan (2007) conducted a research on the impact of LULC changes on the short-term flood process. They used sequences of joining hydrologic and hydraulic constituents in HEC-HMS, to delineate Xitiaoxi river basin in upstream of Taihu lake watershed, China. Inverse-distance-squared method was applied to calculate the mean areal precipitation depth in all sub-basins. The method was selected to account for spatial variation of precipitation. Soil Conservation Service (SCS) Curve Number (CN) was chosen for the estimation of precipitation excess. Kinematic wave model was also selected for modelling direct runoff and channel routing. Finally, they recommended that afforestation would alleviate flood disaster while urbanization would contribute to flood disaster due to reduction in infiltration.

Wagner *et al.* (2013), analysed the impact of land use changes between 1989 and 2009 on the water balance in the Mula and Mutha Rivers catchment upstream of Pune, India. Soil and Water Assessment Tool (SWAT) were used to determine the impact of land use on runoff and evapotranspiration. Landuse for the three decades were classified. Two model runs were carried out and compared using the land use classifications of 1989/1990 and 2009/2010. The main land use changes were identified as an increase of urban area from 5.1% to 10.1% and cropland from 9.7% to 13.5% of the catchment area. At the catchment scale they established that the impacts of the land use dynamics on the water balance complement each other. However, at the sub-basin levels, increase in built up areas led to an increase in the water yield by up to 7.6 %. This clearly indicated the role of vegetation in surface reducing the rate of runoff there by reducing the likelihood of flooding

To assess the impact of 2012 flooding in Mararaba, Karu local government area of Nasarawa State, Nigeria, (Nicholas, 2014) prepared LULC map using remote sensing technique of visual interpretation. Eight classes of land use land cover from 2005 Spot 5 satellite imagery were identified in a GIS environment. Soil Conservation Service (SCS) model was used to establish rainfall-runoff relationship of the study using ILWIS GIS package. Daily rainfall data, 5m resolution SPOT 5 satellite Imagery, Digital Elevation Model (DEM) and soil texture maps were used as input for the runoff modeling. The blind weight approach was used to create flood hazard map for the study area. The result showed an estimated total rainfall runoff of 831.24mm calculated from April to October 2012. About 52 percent of total rainfall was converted into surface runoff. Month-wise runoff contribution ranged between 3% and 21%. The peak runoff estimates was 174.21mm in the Month of July, which confirmed the reported flood incident on the 14 July 2012. Because the above method can estimate runoff without adjusting slope values, it was adopted for slope and runoff estimation in HECGeo-HMS.

Langhammer and Vilimek (2008) examined the intricate relationship between landscape changes and the effects of the disastrous flood in Otava river basin, Czech Republic. Historical maps, remote sensing, GIS data and field mapping were integrated to generate information on the intensity of landscape modifications. Unsupervised classification (Clustering) analysis was carried out to establish the interrelationship between physio-geographical features of the river basin, landscape modifications, and the flood paths. Their results revealed that narrowing of river courses, modifications of the riverbed and drainage from agricultural areas have only little impact on the effects of flood. While land use and land cover of the floodplain by obstructing free water flow, have amplified the consequences of flooding. Similarly, Zhang *et al*. (2011) observed the relationship between rapid changes due anthropogenic activities and flood risk in Foshan, the Pearl River delta region, China. Remote Sensing and Geographic Information System techniques were employed to analyze the impact of land use and cover changes on runoff between 1988 and 2003. They discovered that rapid deforestation has resulted in losses of forest cover, farmlands and scrub since 1988 while runoff increases significantly. Saghafian, *et al.* (2008) incorporated different tools such as GIS, remotely sensed data and hydrologic models, to assess the effect of past land use changes and to predict the effect of future land use scenarios on the flood regime of Golestan Watershed, Iran. An event-based rainfall runoff model was used to generate flood hydrographs related to land use conditions in 1967and 1996. The input of each sub watershed to flood peak at the outlet was computed using Unit Flood Response (UFR) technique. The sub watersheds were classed based on their input per unit area to the outlet flood peak. The comparative change in the peak flow of the two succeeding conditions (1967 and 1996) land use pattern was established for different return periods. Their results indicated that land cover declined has triggered the flood peak and volume. Likewise, the flood peak was more sensitive to land use change in comparison to flood volume.

Chen *et al*. (2017) utilized the Conversion of Land Use Change and its Effects model (CLUE-s) and HEC-HMS to examine the impacts of potential land use changes on storm runoff propagation under a design storm. Future land use situations were derived using CLUEs model based on different land use classes. The model was calibrated and validated. The projected land use scenarios were used to model the storm runoff routes for design storms with different frequency intervals using HEC-HMS. Their result revealed that the sensitivity of hydrologic response to land use change is likely to increase as the frequency of rainfall incident decreases. Hence land use pattern can increase or decrease runoff.

Similarly, Olang *et al.* (2012) evaluated the effects of land cover change between deforestation and reforestation on the propagation of storm runoffs in the Nyando River Basin, Kenya. Artificial storm scenarios of 40, 60 and 80mm depths were devised based on the rainfall patterns and runoff duration using NRCS-CN model. These were afterwards redirected downstream to get effects of the simulation in the whole basin for different land use changes. The impacts of the simulated landcover change were calculated in relation to the values obtained from the actual land cover condition in 2000. They discovered that, runoff volumes increased by 12% in a majorly agricultural land scenario while a combination of an agricultural and forested land cover scenario showed a reduction in runoff volumes by about 12%. On the other hand, a simulation comprising majorly forest cover reduced runoff volumes by about 25%. Therefore, it can be deduced from the above that the more expose the land cover is to direct impact of rainfall, the more the runoff.

Marfai (2003) applied hydrological HECGeo-RAS and HECGeo-HMS ArcGIS extension, to produce river flood model in Semerang city, Indonesia. Neighbourhood operation was carried out on raster DEM and satellite imagery. The spatial patterns of the river flooding and tidal flooding were illustrated in maps. The result showed that the flooded areas generally cover coastal and alluvial landforms. The DEM values of areas where no flood was observed were removed and replaced with manipulated values. Total area of river flood was computed as 1245, 78 hectare, while total area of tidal flood is 1514 hectare. Landuse types such as built up area, fishpond, and agriculture were observed to influence the river floods and tidal flood.

Waheed and Ogunwamba (2010) carried out a comprehensive hydrological investigation to determine the causes, level and the probability of occurrences of flooding, in the Kaduna River valley, Nigeria. Data on river mechanics geomorphology, and channel hydraulic geometry were obtained through field and topographic surveys. The surveyed cross section data was superimposed on the 1962 topographical map of the area and the degree of advancement into the flood plain was determined. The extents of flood risk zones corresponding to the 2, 5, 10 , 25, 50, 100 and 200 years return period were established by reading the water stages. Their results revealed that urbanization has progressively changed the flood plain and its flow between 1962 and 2009. This result is flawed because some gauge values were manipulated for some missing values due to obsolete equipment, by substituting them using authors field observation and response from questionnaire. A more acceptable method of estimating these values is by using catchment hydrologic modelling in HEC-HMS using global hydro-meteorological dataset Che-Ghani (2014), this research work therefore intends to use HEC-HMS to quantify the catchments discharge for input into HEC-RAS hydraulic model.

Al-ghamdi *et al.* (2012) investigated the effects of urban growth on runoff volume and peak discharge in Makkah city, Saudi Arabia, between 1990 and 2010. 105 cadastral maps in AutoCAD format for 1990, 2010 land use map and 5m DEM were used. The maps were rectified, residential shapefiles were digitised and AutoCAD files were converted to ArcGIS shapefiles. The spatial references for all datasets were harmonized by projecting all to latlong. Flood characteristics were estimated using the Curve Number (CN) methodology, and compared with the attained quantitative value for 1990 and 2010. The ArcGIS and ArcHydro tools were employed to extract the basin parameters in the study area, and their sub-basins. The ArcGIS spatial analysis module was utilized to assign the CN value of each sub-basin based on their geological, soil, and land use properties. Visual basic application (VBA) was utilised to calculate sub-basins' flood characteristics, for 1990 and 2010, within the attribute table of GIS shape files. Flood extent map of the study area was mapped. Their result revealed that the built-up areas of Makkah city have increased, within the period under study by 197%, while flood volumes increased by 248%. Furthermore, a significant positive correlation was also observed between urbanization and both peak discharge and flood volume.

Wagesho (2014) conducted a study to determine response of a catchment to runoff for temporally varied land use and land cover conditions using physically based distributed hydrologic modelling, in Rift Valley Watershed, Ethiopia. DEM, Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) imageries, soil and hydro-meteorological dataset were used as input data. Both the DEM and imageries were processed using ERDAS Imagine software. Supervised and unsupervised image classification was carried out on the imageries and further assimilated based on land use class similarity. The catchment response was examined by simulating runoff for different LULC conditions. His result revealed that, simulated surface runoff constituent increased gradually since 1970s. While percentage annual surface runoff varies from 10 to 23% at Bilate, and 16% at Hare watersheds for different land uses. Thus, Land use and land cover influences runoff by speeding up or slowing down overland flow.

Laks *et al*. (2017) developed a method for the improvement of low resolution DEMs, using aerial photographs, for 2D flood modeling of Warta River, Poland. The method was developed and examined on the example of the river floodplain. The improvement was based on a sequence of taking small height measurements using GPS-RTK. Statistical measurements such as mean error (ME), standard deviation (SD) and root mean square error (RMSE) were carried out. Errors were computed as the differences in height between the original DEM and field measurement. Also, they checked error distribution in the original DEM against the normal one using the Shapiro-Wilk test graphically. The DEM accuracy was predicted using a 2D numerical model in ArcGIS 9.3. Lastly, the relationships between the error, land use type within the floodplain and the topographic indices, (slopes, aspect and curvature, were established directly from the DEM). The calculated values of flow velocities; inundation area and volume of floodplain for each tested DEM were compared. The result indicated that, after DEM improvement, the prediction power of the corrected DEM based on low resolution is in good agreement with the referenced LIDAR DEM. They proposed the use of this method where high resolution DEMs are not obtainable.

2.3.3 Geospatial technology in flood modelling and disaster risk reduction

The role of geospatial technology (Remote Sensing, GIS and GPS) in disaster management is being elaborated by an increasing number of studies such as (Adeniran *et al*. 2013; Botes *et al.* 2012; Canevari-luzardo *et al*. 2015; Chaurasia and Garg, 2015; Dukiya, 2012; Elias, 2010; Jayasinghe *et.al* 2013; Boonya-aroonnet *et al*. 2007; Marfai 2003; McCall, 2008; Musungu, *et al*. 2011; Patel, 2010; Pedzisai, *et al.* 2015; Pincott-Miller, *et al.* 2012; Tymko, *et al.* 2016). This is attributed to the fact that, the technology is the fastest way of obtaining spatial data for the three phases of disaster management; pre-disaster, during disaster and post disaster (Bello and Aina, 2014). High temporal resolution imageries are being used to produce maps of affected areas.

Bello and Aina (2014) examined the modern development in the application of remotely sensed data in disaster management, by improving data resolution and integration. They examined how recent development helped in bridging the gap of data limitation in the study of floods, earthquake, hurricane and landslides. They recommended the need for collaborative and multidisciplinary research to fully utilise the capabilities of these technologies.

The major advantage of using GIS for flood management however is that, it does not only generate a flood map, but also produces a possibility for further analysis of noticeable damage due to flood (Maniyar and Bhatt, 2015). It facilitates integration of 3D and non-spatial information such as rainfall and tributary movements, river basin features and river cross-sections. Additional Information such as flood maps, land-use and socio-economic data can be documented for upcoming use. Flood charts categorized using satellite imageries of actual flood events and ground data are useful for flood loss calculation forthcoming flood modification planning and justification of hydrologic and hydraulic investigation. It is believed that these advancements will present a more efficient and precise choices to conventional techniques for studying watersheds (Lawal *et al*., 2011)

Qi *et al*. (2006) developed a decision support tool based on a 2D flood simulation results using CCHE2D-FLOOD flood simulation software developed at the Centre for Computational Hydroscience and Engineering, University of Mississippi U.S.A. The 2D. Census data, survey data and remote sensing images, were integrated to estimate loss-of-life and direct damages to property under ambiguity at small and large-scale levels. Damages to residential, commercial and industrial buildings in urban areas, and damages to crops in rural areas were calculated. The developed tool takes benefit of GIS’s fast raster layer operations to produce flood hazard maps based on various user-defined conditions. Monte Carlo method event tree analysis was employed to explain for uncertainties at different parameters. The flood's spatial extent, depth, velocities, arrival time and its duration at each point of the computational domain were determined. The results shows that the proposed decision support tool permits stake holders to have an improved appreciation of the consequences of the flood. It can also be used for design, planning, and evaluation of potential flood mitigation measures. However, on like similar hydrologic models that freely available for download and use, such as HEC-RAS, HEC-HMS, MIKE FLOOD, FLOOD MODELLER, the free version of CCHE2D-FLOOD has limitations.

Adeniran *et al*. (2013) carried out research to map out areas vulnerable to flood along Asa plain in Ilorin, Kwara State, Nigeria. GIS proximity operations were employed to divide the area into three buffered zones, based on two criteria; Town and country planning regulation, and flood extent based on past records. The buffer zones were classified into 30m, 50m and 70m corresponding to high, moderate and low risk zones. A total of 1259 buildings were delineated out of which 211, 112, and 120 buildings fell within the 30m, 50m, and 70m buffered risk zones respectively. DEM of the area generated from topographic map of the area was used as input raster data in to ArcGIS for geospatial data generation. Flow accumulation map was generated and used to identify flow accumulation points. Four spots located in the densely populated area were identified. Population density and areal extent map were employed as determinants of population at risk. Their result revealed that 51, 22 and 30 buildings were highly, moderately and less vulnerable respectively; while a total of 2693, 3609 and 4158 people from high, moderate and low buffered zones respectively could be vulnerable to flooding.

Botes *et al*. (2012) assembled cost effective methods for flood modeling by integrating GIS data and HEC-RAS, as an alternative method for flood risk modeling, to determine flood lines in Kwazulu-Natal province of South Africa. This was triggered due to the lack of established flood data to guide settlement planning and proactive management of the existing settlement and infrastructure in flood risk areas. DEM of the area was used to extract hydrological data using HEC-RAS's ArcGIS extension HECGeo-RAS. The result produced a flood elevation maps by calculating the water elevation-hydrological surface extraction.

Dukiya (2012) applied GIS and remote sensing techniques to assess the vulnerability of Lakoja town in Nigeria to flooding using benchmark minimum and maximum water levels from 1995 to 2005 and series of satellite imageries (Landsat TM and ETM of 1987, 1992 and 2001, and Nigeria Sat I of 2006). LULC map of the area was produced using ILWIS GIS software, while golden software Surfer was used in creating Digital Terrain Model (DTM) of the area. Delineation of flood vulnerable areas was carried out in ArcGIS and ILWIS environment. The result revealed that some areas were within 8.023m when the Niger River level was as high as 10m above sea level in the year 1998 and 1999. This makes these areas vulnerable to flooding.

A study on the application of remote sensing and GIS techniques in natural resource mapping, for enhanced decision making was conducted by (Elias, 2010) in some parts of the middle east. IRS-P6, LISS III and LISS IV imageries coupled with soil, topographic and climatic maps were used as input data. The imageries were geo-referenced and enhanced in both spatial and spectral domain using ENVI software. LULC map was generated from LISS IV imagery, the vegetation cover of the area was generated from LISS III and LISS IV while the soil map was generated using IRS-P6 and LISS IV. All the three themes were incorporated in GIS environment to produce hydro-geomorphology map.

Jinadu (2014), conducted a research to identify and assess rural hazard and vulnerability of Gusoro and Gurmana communities downstream of Shiroro dam, Nigeria. Direct field survey instruments (Questionnaire administration, oral interview and field measurement) were used. The result revealed that the communities are exposed to flood, erosion, health, risk of building collapse and environmental degradation due to high level of illiteracy, high percentage of dependent population (50%) coupled with lack of basic social amenities makes them highly exposed and vulnerable.

Dalil *et al.* (2015) analyzed the causes of flooding in parts of Minna, Nigeria, with a view to offer solution to its impacts along River Suka channel. Secondary and primary data were collected. The primary data (questionnaire) were analysed using Statistical Packages for Social Sciences (SPSS) while the secondary data (topographic and land use maps of Minna) were processed using ArcView GIS package. Flood risk vulnerable areas were mapped. The result revealed that anthropogenic activities like poor drainage network, relief of the area and construction on the flood plains, are largely accountable for the recurrent floods along the river. The research recommended that the government and stakeholders should embark upon awareness campaign in order to create public awareness to the likely effects of flooding on the residents of the flood plains. The paper also recommended the monitoring by authorities, of water levels during the raining season, thereby allowing for the transmission of warning signals to the residents of the floodplains.

Komolafe *et al*. (2015) reviewed and assessed flood impacts in Nigeria under fundamental components of flood risk analysis: Exposure and vulnerability assessment, hazards mapping and modeling, with the aim of proposing feasible vital requirements and additional development. Based on their review, they concluded that, there is need to investigate more efficiently the use of effective flood models, which integrates all hydrological processes for more precise forecast and mapping of flood and its related risks. In addition, the preparation for adaptation and mitigation of prospective flood risk and climate change, requires a detailed research in the advancement of regional and or national flood damage functions for pre-disaster flood damage evaluation.

Ikusemoran *et al*. (2014) have applied remote sensing data, GIS techniques and field survey for terrain analysis of flood disaster vulnerability assessment of Niger State, Nigeria. Shuttle Radar Topography Mission (SRTM), Digital Elevation Model (DEM) of the State was generated and classified into four classes: Niger valley (0m - 172m above sea level) as highly vulnerable, plains (172m -o 267m) as vulnerable, uplands (267m-382m above sea level) as marginally vulnerable and highlands (383m - 744m above sea level) as not vulnerable using ArcGIS 9.3 software and the DEM. The communities were selected from downstream of the three hydroelectric dams in the state, using 5km and 10km buffer. It was revealed that the Niger valley and the plain terrain of the state which were classified as “highly vulnerable” and “vulnerable” respectively to flood disaster together cover a land area of 58.43% of the state overall land area. Furthermore, Katcha, Gbako, Bida, Agaei, Wushishi, Mokwa, Edati and Lapai were discovered to be almost entirely located in the Niger valley that is extremely vulnerable to flood, while Agwara, Borgu, Bosso, Lavun, Magama and Mashegu have large portions of their lands located in the plains, which were considered as vulnerable to flood. Shiroro Wushishi, Bida, Lavun and Gbako LGAs were also found to be vulnerable to flood disaster due to their locations at the downstream of Shiroro dam along River Kaduna. It was recommended that the use of geo-spatial techniques should be adopted in creating database for flood disaster in the State.

Similarly, Mayomi *et al*. (2013), conducted a research to assess the vulnerability of communities situated along River Benue floodplains in Adamawa State, Nigeria. The communities experience seasonal flood as a result of the release of water from Lagdo dam, upstream in Cameroon. The communities' vulnerability was categorised into four: highly vulnerable, vulnerable, marginally vulnerable and not vulnerable. The main findings revealed that 120 communities selected in the area were depicted as vulnerable to flood as they are highly vulnerable, vulnerable or marginally vulnerable. 29

communities accounting for 32.5% were situated in highly vulnerable areas, 35 communities accounting for 29.17%, were found to be situated within the Benue Basin but outside the buffered zones classified as vulnerable areas, while the remaining 46 communities (38.33%) were situated on the plains, which are identified as marginally vulnerable areas. They recommended that, all the highly vulnerable settlements should be moved to highlands to avert future incidence. The issue of relocation has almost always failed because of the communities' perception of the flood plain as a means of livelihood. Thus a more proactive approach of flood modelling and forecasting is needed to control the situation.

In 1992, the United States Army Corps of Engineers, developed a Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), a rainfall-runoff model. This model is being widely used to study the flood regimes based on different land use land cover types as the most widely integrated set of software for computation of 1-D for surface water study. The HEC-RAS consists of four river assessment tools for: (1) stable flow water surface outline computations; (2) unstable flow simulation; (3) detachable boundary sediment carrying calculation; and (4) water quality investigation. A significant element was that all four tools used a geometric data procedure in addition to the four river examination components (Maniyar and Bhatt, 2015).

Al-Abed *et al.* (2005), explored the advantages of using hydrological simulation models (HEC-HMS/HEC-GeoHMS extension model and Spatial Water Budget Model (SWBM) interfaced with GIS. The results of calibration and validation of the two models were evaluated and presented. It was found from their study that HEC-HMS model provided more satisfactory results then the SWBM.

Paudel (2010) outlined the various existing distributed hydrologic models (MIKE SHE, Gridded Surface/ Subsurface Hydrologic Analysis (GSSHA), Modular Modeling System (MMS), Hydrologic Research Center Distributed Hydrologic Model (HRCDHM), TIN-based Real-Time Integrated Basin Simulator (tRIBS), Soil and Water Assessment Tool (SWAT) Variable Infiltration Capacity (VIC), CASC2D, VfloTM), SSARR, Sacramento model, Tank model, HEC-1, HYMO, TR-20, TR-55, NFF) and hydrologic model (HEC-HMS, ARNO model, KINEROS, lumped models (Stanford Watershed Model, TOPMODEL, Hydrologic Simulation Program-Fortran (HSPF), TOPNET, Storm Water Management Model (SWMM), WATFLOOD).

An in-depth methodology of floodplain mapping to delineate flood hazard maps and improve the precision of the hydraulic modeling at ungauged rivers have been presented by (Sarhadi *et al.,* 2012). Satellite stereoscope images of Cartosat-1 together with the Rational Polynomial Coefficients (RPC) were used to extract a high resolution DTM. The detailed parameterization of the channel was estimated and use as input to 1D HEC-RAS hydraulic model. Past flood record was used to evaluate the hydraulic model performance to forecast flood inundations.

Kute *et al.* (2014) performed the flood modelling of River Godavari in India, using HEC-RAS model. They used data from the storage area, inline structure (weir depth and coefficient and crest shape), and geometric data (cross section). The normal depth of the river was adapted as the initial boundary condition and opening all the gates of the dam to their full extent simulated a worst-flow scenario. The outputs were presented in forms of tables and graphs. The result produced a rating curve, which gives an idea about water level at different discharge values. They deduced that rainfall; runoff, catchment characteristics and return periods are the primary parameters, which govern flood.

Jung *et al*. (2013) have used Generalized Likelihood Uncertainty Estimation (GLUE) methodology, 1D HEC-RAS hydraulic model, remote sensing and topographic data to estimate a flood discharge. Iterative Self-Organizing Data Analysis (ISODATA) algorithm was applied to Landsat 5 TM for unsupervised classification. Manning's n value (Roughness coefficient) was extracted from land use map from the National Land Cover Database (NLCD) based on established literature. River cross section was extracted from 10mx10m SRTM DEM using HECGeoRAS in ARC GIS. Monte Carlo simulation was conducted using 1D HEC-RAS model. The GLUE methodology was used to estimate flood by randomly selecting datasets from a feasible range. Their results shows that the use of Landsat leads to a better discharge estimation on a large-scale river reach than on a small-scale reach. However, discharge approximation using the GLUE is dependent on the selection of likelihood measures. The author’s choice of 1D model for floodplain modelling is not recommended due to the fact that the 1D model is suitable for channel reach modelling. A hybrid choice of coupled 1D2D would have been more appropriate for the study areas.

Jung, *et al*. (2014), suggested a methodology to obtain flood extent border lines using GIS analysis based on Landsat 5 TM imageries and DEM. Unsupervised classification was performed to classify the four TM imageries using ISODATA algorithm. Flood inundation maps were then extracted from the classified imageries. The ground elevations at the junctions of the flood inundation map and river cross sections were read from the DEM in ArcGIS using HECGeo-RAS module, to estimate elevation-discharge relationship. Lastly, the flood extent map was generated based on the estimated elevation-discharge relationship. The approach was tested over two river reaches in Indiana, U.S.A. The estimated elevation-discharge relationship demonstrated an excellent match with the correlation coefficients varying between 0.82 and 0.99. They suggested that the methodology would assist under-developed and developing nations to obtain flood maps, without difficulties of getting these maps via traditional methods.

Kindl (2012) developed a structural guideline for regional scale flood modeling that incorporates the next generation radar (NEXRAD) data, GIS with the HEC-RAS river hydraulic model and HEC-HMS rainfall-runoff model. HEC-HMS was used to convert excess precipitation to overland flow and channel runoff, while the HEC-RAS was used to model unsteady state flow via the river channel network based on the hydrographs derived from HEC-HMS. The model was adjusted and calibrated using observed discharge data. HEC-RAS was further used to produce floodplains shape files that are similar to the satellite imagery. Sanders, (2007) observed the applicability of numerous on-line DEMs to test steady and unsteady flow problems. The distinction between Light Detection and Ranging (LIDAR), National Elevation Dataset (NED), Interferrometric Synthetic Aperture RADAR (IfSAR) and SRTM were described. DEMs derived from LIDAR appeared to be more precise due to its vertical accuracy, horizontal resolution, and ability to separate manmade structures and vegetation. IfSAR DEMs were found to have superior horizontal resolution but their gridded elevations affects manmade features and vegetation. Hence, it cannot allow flood modeling without processing. The NED however, overestimates flood extent when evaluated with all other DEMs. He concluded that, SRTM DEMs could be used as a source of terrain global dataset for flood modeling.

As a result of an increase in loss of lives and property damages due to flood, particularly in 2012, (Demir and Kisi, 2016) prepared flood hazard map for the Mert River Basin, Samsun, Turkey. They used HEC-RAS 4.10, ArcGIS 10.2, HECGeo-RAS 10.2 and

DEM. The DEM was derived from contour lines extracted from topographical map. Geospatial database such as river cross-section, stream network, river reach and flow paths, were derived from the DEM using HEC-GeoRAS. The database was imported into HEC-RAS for further processing. Water level for each cross section was computed by entering Flood value of different return period (10, 25, 50, and 100 years) and Manning roughness coefficient the HEC-RAS model. The results were imported into the ArcGIS using Hec-GeoRAS module where flood hazard maps were computed for each return period. Their result revealed that maximum flow depth reached 6.2m and affected areas were roughly 30% in the downstream of the river. Furthermore, the flood affected 650 houses.

Chen and Liu (2017) used a two-dimensional (2D) high-resolution unstructured-grid hydrodynamic model, to assess how an original and resample river cross-section on a simulated river stage will perform, under low and high flow states. The simulated river stages ware significantly improved using a resample cross-section data, based on linear interpolation in the tidal river and non-tidal river sections. The resample cross-section data based on the linear interpolation adequately preserved the topographic and morphological features of the river channel. In addition, the 2D and three-dimensional (3D) models on the simulated river stage were also assessed using the resample cross-section data. The results signified that the two models replicate similar river stages in both tidal and non-tidal river sections under the low flow condition. Nevertheless, the 2D model was observed to overrate the river stages.

Tymkow *et al.* (2016), have used GIS and remote sensing to develop a system for hydrodynamic modelling of flood flows in river valleys in Poland. Data was acquired using aerial laser scanning and optical remote sensing, Geospatial database for flood modelling was generated using PostgreSQL. For the internal structure of feature classes in the database, CityGML standard was used. Real world flood simulation of Widawa River valley was demonstrated to test the applicability of the system.

Mamodu *et al*. (2015) carried out a flood vulnerability assessment incorporating field observation and geo-spatial techniques in Benue, Nigeria. They used Nigeria Sat 1, NigeriaSat X, Spot imageries and SRTM DEM with rainfall data were used to categorise the study area in to different vulnerability levels. The research established that, flooding is mainly caused by multiple factors such as heavy rainfall, high illiteracy level, population increase, poverty, lack of environmental education on the danger of living along flood plains, improper waste disposal inadequate drainage systems, dilapidated buildings, sedimentation, and lack of political will from the government. These factors combined together increases the vulnerability of communities to flood hazard.

Mccall (2014) employed GIS in mapping land resources and territories in Brazil, Latin America by engaging the local people in the mapping process. He concluded that their participation developed their technical, social and political will, and built their confidence, to utilise their local and indigenous spatial knowledge in a respectful manner. To preserve the information in a sustainable manner, the maps were digitized, modified and presented to the communities through their leader as a form of heritage.

Musungu *et al.* (2011), used GIS to acquire information for flood modelling in Cape Town South Africa. One of the consequences of the apartheid era in the country is the development of informal settlement on marginal and poorly drained areas. The city's flood management techniques were not intended to consider these settlements on the fringes. The city's flood management techniques were not intended to consider these settlements on the fringes. Therefore, they become more and more vulnerable to flood.

With the aid of the communities, aerial photos were used to delineate and digitise the affected areas. Questionnaires were captured, alongside the household coordinates of the respondents. Vulnerabilities associated to flooding, such as incidence of diseases, direct exposure to the hazard, income level and mitigation measures were assessed. Pairwise method was employed to calculate the level of exposure to risk by comparing response from each household. The exposure levels were then mapped in ArcGIS to depict the spatial gap in risk. The analysis of the results showed that households situated on flat plains and low-income areas are the most affected by flooding.

The capability of GIS for data collection in flood risk management was explored by (Chingombe, *et al*., 2015). Due to the lack of hydrometeorological and climate data in flood vulnerable communities of Chadereka in Muzarabani district, Zimbabwe, historical and projected flood events cannot be obtained using flood modelling. Twelve flood extent map of the district was drawn using GIS, as well as the information obtained from interviews and focus group discussions. A flood extent evaluation map was drawn by incorporating the resultant 12 GIS maps generated by the local community, information from the interview and focus group discussion. The study suggested that GIS and flood modelling should be incorporated with GIS and fieldwork results, to cross check the spatial characteristics of floods in ungauged flood-prone areas.

2.3.4 Empirical studies on flood frequency

Models are the backbone of flood forecasting systems (Rogelis, 2016). According to the World Meteorological Organisation (W.M.O), in its Integrated Flood Management (IFM) approach contained in the framework of Integrated Water Resources Management (IWRM), the method and data requirement for flood analysis depends on a particular forecast and its objectives (WMO, 2011). However the primary data needed are;

Hydrological data (stream gauges and discharges) and Meteorological data (rainfall intensity and duration). Other requirements are population and demographic data to indicate settlements at risk; inventories of properties at risk; reservoir and flood protection infrastructure control rules; location of key infrastructures; and post-flood damage assessments.

As a response to the failure of previous forecasting models, in the upper and lower Humber River Basin, Canada (Cai, 2010) developed an artificial neural network (ANN) models for river flow forecasting for the basin. Two types of ANN were used. General Regression Neural Network (GRNN) and Back Propagation Neural Network (BPNN). The GRNN does not require training values to be altered while BPNN on the other hand has several parameters such as the learning rate, momentum, and calibration interval, which can be adjusted during the training to improve the model. A Design Of Experiment (DOE) method was used to study the effects of the diverse inputs and network parameters at different stages of the network development, to attain a best model. One-day ahead forecasts were obtained from the two ANNs using air temperature, precipitation, cumulative degree-days, and flow data all suitably lagged as inputs. His result revealed that the GRNN model produced slightly better forecasts than the BPNN for the Upper Humber and both models performed equally well for the Lower Humber. The ANN approach also produced much better forecasts than the previous models, though it was not better than the dynamic regression model except for the Upper Humber. Therefore this indicated that the ANN is not the most suitable for flood forecasting. In addition, the ANN described by Ahmad (2015) uses a black box learning approach that cannot interpret the relationship between input and output data, as well as deal with data uncertainties. ANN is also suggested to be most suitable for urban flood and drainage modelling (Bruen and Yang, 2006) rather than riverine flood.

The use of extensive data series for the frequency analysis, the ability to simulate stream flow under climate conditions and future land use makes these methods advantageous for continuous simulation modeling (Mukherjee, 2013). Frequently, the result of the frequency analysis depends on the length of data on hand. The minimum number of years of record essential to obtain reasonable estimates depends upon the variability of data and the climatological and physical condition of the basin under study.

A flood frequency analysis was carried out by (Manta and Ahaneku, 2009) to predict flood along Gurara River Catchment at Jere, Kaduna State, Nigeria. Seven years daily gauge and discharge data of four station; Izom, Gantan, Jere and Kurmin Musa stations were collected. However only Jere station has data for 17 years. The remaining three stations have data for only seven years, this averted the use of Gumbel's distribution method. Consequently, Four probability methods were used namely, extreme value type 1, Normal, Exponential and Pearson type 3. Pearson type 3 distribution exhibited the best fit for the data. This shows that in the absence of long duration data, the aforementioned methods could be employed for frequency analysis.

A methodology to integrate HEC-RAS and GIS models for delineation of flood extents and depths in some selected areas of Zaremroud River, in Iran, was developed by Machado and Ahmad (2007). HEC-GeoRAS and 3D Analyst tools were used for generation of digital terrain data and spatial analyst for extraction of cross sections. Water surface profiles were produced for different recurrence interval (T-year) floods with the aid of HEC-RAS geometry. Their results showed that integration of hydraulic simulation and GIS analysis is an effective tool for flood plain management and mitigation and they established that Log-Pearson Type III flood frequency distribution is most appropriate method to estimate peak flows for different return periods.

Yangbo *et al*. (2017) developed a physically based distributed hydrological model for flood forecasting of the Liujiang River basin in south China. They used DEM, soil and land data to set up a model structure with a high of 200m×200m resolution. The initial model inputs were derived from the DEM. Optimum model was selected using Particle Swarm Optimization (PSO) algorithm. 29 observed flood events were simulated. They discovered that by isolating the river channels into effective channel portions and assuming the cross section shapes as trapezoid, the model largely increases computation effectiveness and at the same time gives good model presentation making it possible to apply the model in larger watersheds. Their result also revealed that parameter ambiguity exists for physically derived model values, while parameter optimization could reduce the ambiguity. They recommended an increase in computation time distributed hydrologic models to be increased exponentially at a power of 2, not linearly with the increase in model spatial resolution.

Mujere, (2011) has used Gumbel's distribution method to analyse and predict extreme floods of Nyanyadzi River, in Zimbabwe. Thirty years daily maximum flow data were obtained and expressed in terms of exceedance probabilities and return intervals. Gumbel's distribution equation was used to fit the observed and the predicted series of flood flows at different return periods. The Chi-square (x^2) test was carried out to find the goodness of fit between the measured and predicted flood flows. It was applied to test the hypothesis that the flood data fit the Gumbel distribution. Subsequently, flood magnitudes were calculated for 0.5, 0.2, 0.1, 0.05, 0.04, 0.02, 0.01 and 0.005 exceedance probabilities. His result showed that Nyanyadzi River flood flows were varies during the study period. The (x^2) test revealed an acceptable fit between observed and estimated flood flow values. Therefore, Gumbel distribution method was discovered to be an appropriate tool to forecast flood frequency. In a similar attempt, (Mukherjee, 2013) combined the same method with a computer generated hydrographs to forecast flood frequency of River Subernarekha, India. He observed that the peak flood discharge for a given return period computed by the two methods do not differ much.

Generally, a minimum of thirty (30) years of data is considered as critical in flood frequency analysis (Subramanya, 2013; Strupczewski *et al*., 2014). Smaller lengths of records are also used when it is unavoidable (due to the lack of existing record). Conversely, frequency analysis should not be implemented if the length of data is less than ten (10) years (Mujere, 2011; Mukherjee, 2013; Lankreijer and Ngen, 2016; Strupczewski *et al.*, 2014; Subramanya, 2013). Due to the availability of long series data for twenty seven (27) years because the Dam became operational in 1990, and since the condition of the study area is uniform year round (Eze, 2004) the Gumbel's frequency distribution method was adopted for flood forecasting in this research.

2.3 Strength and Weaknesses of the Reviewed Models

All numerical models are required to make some form of approximation to solve real life problems, and consequently all have their limitations. Real-life situations are frequently too complex to solve without the aid of numerical models. Armas *et.al* (2017) observed that, there is a tendency among some engineers (developers) to discard the basic principles taught at university and blindly assume that the results produced by the model are correct. For each model reviewed, several limitations to practical applications are described. In some cases, these limitations are attributable to inadequacy of data for calibration and verification of the model, complexity of programming algorithms, and numerousness of the input variables which have to be estimated by judgment. Regardless of the complexity of models and despite the claims of their developers, all numerical models are required to make approximations. These may be related to geometric limitations, numerical simplification, or the use of empirical correlations. Some of these, such as the inability of one-dimensional unsteady models to simulate supercritical flow can cause significant inaccuracy in the model predictions. Thus, the flexibility of HEC models and its compatibility to ArcGIS dictated the choice of these models for this work.

2.4 Inferences From literature review

A pool of related literatures were accessed and reviewed. The vulnerability of any community to natural hazard is a function of its geographical location, socio-economic status, illiteracy level, population type and political will (Ikusemoran *et al*., 2014; Mayomi *et al*., 2013). Second to these are the land use land cover types and slope degree (Onwuka, *et al*. 2015; Boucher, 2010). While the integration of geospatial technology and field survey was found to be widely applied technique by researchers in the study area, there is still a gap to be filled in the application of hydrologic models to significantly lessen the impact of the flood disaster across the flood plain.

Multiple datasets and methods were integrated in flood modelling to produce reliable and acceptable models (Machado and Ahmad, 2007; Botes *et al*., 2012). However, the fundamental data requirement is in any hydrological Modelling is DEM. Global coverage DEMs are readily available for downloads free from various sources such as; Earth explorer, Global Land Cover Facility and United State Geological Survey. Series of geospatial data layers can be extracted

from the DEM in a GIS environment, such as slope, aspect, height e.t.c.. Other data needed are; Satellite imagery, Hydro-meteorological records, Inflow and Discharge data, Land use and Land cover map, Population and Infrastructural map. The software requirements revealed are; HEC-HMS and HECGeo-HMS, HEC-RAS and HECGeo-RAS and ArcGIS. Even though many hydrologic models and DEMs are available (Paudel, 2010), HEC-HMS and HEC-RAS will be preferred for this research because they offers an interactive graphical user interface making it flexible to use the programme in ArcGIS (using HECGeo-HMS and HECGeo-RAS add ins) They have also been in use for more than 30 years of experience in hydrologic simulation and is widely used and accepted for many hydrologic simulations (Yuan and Qaiser, 2011). The choice of or combination of models is dependent on the nature of the terrain under investigation and the objectives of the study (Paudel, 2010; Sarhadi *et al*., 2012; Fosu *et al*., 2013), 1D modelling is applied along the river channel for example in a mountainous regions while 2D modelling is applied across areas with lower terrain such as the floodplains. Moreover, the choice of this model is dictated by data availability and the objective of study. Thus coupled 1D/2D modelling will be used across River Kaduna and its floodplain

Therefore, the preceding disclosed that, flood modelling is fundamental for Disaster Risk Reduction (DRR) and sustainable flood plain management

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials and data used for the study

The following materials and data were used for this research: 30 years daily rainfall and averaged daily temperature, 26 years daily inflow and discharge data, DEM, LANDSAT imageries, records on past floods from (1990 to 2016).

Daily Hydro-meteorological data and past flood records were sourced from the authorities of North South Power Company of Nigeria (NSPC) at Shiroro dam station. Because pre analysis of the data at NSPC revealed that it does not cover the wider watershed to account for the inflow from the major contributing rivers (Koriga, Durumi and Mariga) to River Kaduna downstream, Jimo *et al*. (1992) cited in Eze (2004), supplementary grided rainfall and temperature data of the region were obtained from the American National Centers for Environmental Prediction (NCEP) available at https://www.globalweather.ta mu.edu.

SRTM 30m DEM, Landsat 4 Thematic Mapper (TM) and Enhanced Thematic Mapper ETM+ imageries of (1990, 2010 and 2016) of the study area were downloaded from the joint USGS/NASA data site in decimal degrees and WGS84 datum, available at https://ers.cr.usgs.gov/ and http://srtm.csi.cgiar.org/ for free download.

HEC-RAS 5.0 and HEC-HMS 4.2 were downloaded from the United State’s Army Corp of Engineers free data download site at http://www.hec.usace.army.mil/software/hec-ras/ and http://www.hec.usace.army.mil/software/hec-hms/ respectively. While their associating ArcGIS add-ins (HECGeo-RAS and HECGeo-HMS) were downloaded from Environmental System Researc Institute’s (ESRI) http://downloads.esri.com/archydro/.

Data on socio-economic record and communities' perception were acquired with the aid of questionnaires through GIS.

Environmental disaster checklist was obtained, from the National Environmental Standards and Regulation Agency (NESREA).

A comprehensive set of shape files for the whole country, was obtained from the Nigeria's National Space Research and Development Agency (NARSDA) for the preparation of the Map of the Study area and further cartographic work.

ArcGIS 10.3, ERDAS IMAGINE 2014 and Global Positioning System (GPS) Etrex 20x for fiel survey were obtain from the Department of Geography, Federal University of Technology, Minna. The summary of the data used, data source and used is presented in table 3.1. While the characteristics of the Landsat TM and Landsat ETM+ Imegeries are presented in tables 3.2 and 3.3 respectively.

Table 3.1. Summary of Data Source and Use

S/N	OBJECTIVE	DATA/MATERIAL	SOURCE	USE
1	2, 3 and 4	SRTM 30m DEM,	USGS/NASA at http://glovis.usgs.gov/ and http://edcsns17.cr.usgs.gov/NewEarthExplorer/	Input data for Generation of Hydrologic Parameters.
2	1, 3 and 4	LANDSAT TM and ETM		Land Use and land Cover Map for Manning's Coefficient.
3	3 and 4	Hydro-Meteorological data and past flood records	NSPC Limited	For input into HEC-RAS as inflow, discharge, temperature records and input into HEC-RAS
4	3 and 4	Rainfall and Temperature	NCEP http://www.globalweather.tamu.edu	For estimation of discharge from the catchment watersheds and as one of the input data in objective 3
5	4	HEC-RAS 5.0.3	http://www.hec.usace.army.mil/software/hec-ras/	For river and floodplain modelling.
6	2 and 3	HEC-HMS 4. 2	http://www.hec.usace.army.mil/software/hec-hms/	For hydrologic modelling of the catchment sub-basins.
7	2, 3 and 4	HEC-GeoHMS, HEC-GeoRAS and ArcHydroTools_64	http://downloads.esri.com/archydro/ or at http://yellow.esri.com-/archydro/	For generation of databases for input into HEC-HMS and HEC-RAS respectively.
8	2	Nigeria Shape Files	NARSDA	For input into HEC-RAS model
9	1, 2, 3 and 4	ArcGIS 10.3, ERDAS IMAGINE 2014 and Etrex 20x GPS and Digital camera	Department of Geography, F.U.T Minna	For data processing, analysis and obtaining ground control points respectively.

Table 3.2 Characteristics of Landsat TM Image

	Bands	Wavelength (mµ)	Resolution (m)
Landsat Thematic Mapper TM 5	1= Blue	0.45 - 0.52	30
	2= Green	0.52 - 0.60	30
	3 = Red	0.63 - 0.69	30
	4 = NIR	0.76 - 0.90	30
	5 = (SWIR)	1.55 - 1.75	120
	6 = (Thermal)	10.40 - 12.50	30
	7 = (SWIR)	2.08-2.35	30

Source: http://glovis.usgs.gov/

Table 3.3 Characteristics of Landsat ETM+ Image

	Bands	Wavelength (mµ)	Resolution (m)
Landsat Enhanced Thematic Mapper ETM+	1= Blue	0.45 - 0.52	30
	2= Green	0.52 - 0.60	30
	3 = Red	0.63 - 0.69	30
	4 = NIR	0.76 - 0.90	30
	5 = (SWIR)	1.55 - 1.75	60
	6 = (Thermal)	10.40 - 12.50	30
	7 = (SWIR)	2.08-2.35	30
	8 = Panchromatic	0.50 - 0.90	15

Source: Source: http://glovis.usgs.gov/

3.2 Preliminary Investigation

A simple technique to classify and delineate areas liable to flood inundation was carried out based on height adopted from Ndanusa, *et al.* (2018), slope and proximity to river. A distance of 4 km – 10 km from the river bank was used. In this way, a prelirninary description of flood-prone areas may be easily achieved solely based on the information contained in the DEM.

Bhuiyan *et.al.* (2007) recommended that prior to any analysis using DEM, pits/holes/depressions or sinks regarded as areas whose elevation is lower than their neighbouring cells should be filled. Thus, this spatial operation was carried on the raw DEM in HEC-GeoHMS add ins to ARCGIS using Terrain processing function with the raw DEM as the input layer. The DEM was reclassified into 3 different classes namely; high risk areas, hoderate risk areas and very low risk areas. The result of the preliminary investigation provided an insight in to the general understanding of the terrain and expected outcome of the research findings.

3.3 Methods of Analysis Based on Stated Objectives

3.3.1 Generation of hydrological layers

The hydrologic layers for input into HEC-HMS and HEC-RAS models were generated using HEC-GeoHMS and HEC-GeoRAS ArcGIS extensions respectively. The filled DEM used in section 3.2 was used as the primary input layer for the generation of subsequent hydrologic layers recommended in *(Isioye and Jobin (2012), and Isioye et al.*, 2012)). The HEC-HMS components are; terrain pre-processing, HMS project setup, basin processing, stream and watershed characteristics, hydrologic parameters and HMS model files while the produced layers are depression less DEM, Flow direction, flow accumulation, stream definition, stream segmentation, catchment grid delineation, catchment polygon processing, drainage line processing and adjoint catchment processing. All these layers were generated sequentially with the preceding layer as input layer for the extraction of subsequent layer.

In addition, the hydrologic layers for input into the HEC-RAS model were generated from the HEC-GeoRAS ArcGIS add-in using spatial analyst tool. The required layers for input into HEC-RAS are stream center lines, river bank, flow path, river cross section line, storage area, storage area connections and river cross section.

3.3.1.1 Extraction of hydrological layers using HEC-GeoHMS and HEC-GeoRAS

The hydrologic layers required for this study were extracted from the filled Dem used in section 3.1 The slope degree was reclassified to topography of the map and further re-classification of the map was carried out to convert the slope from degrees to meters to obtain a uniform unit of measurement with other generated layers. ArcGIS map calculator was then used to calculate the slope map in percentages rise for flood studies.

3.3.2 Land use and land cover (LULC) classification

A landuse landcover map was analysed from digital image processing of the satellite imageries, The Imageries were unzipped and imported into ERDAS Imagine image processing software. The imageries were mosaicked to reduce computation time while processing.

Image enhancement, supervised classification and accuracy accessment were conducted for the ddigital image processing of the images.

3.3.2.1 Image enhancement

It is recommended that prior to further analysis, the imageries should be enhanced to improve their contrast for better visual interpretation *(Chima, 2012; Khosroshahizadeh et al.*, 2016; Musa *et el.*, 2015). Thus contrast enhancement using histogram equalisation was carried out on the imageries to improvevisual interpretability by increasing the various feature distinctions.

After the enhancement process, band combination operations was performed to highlight brightness values associated with. A band combination of 4, 3, 2 was used for analysis of 1990 and 2010 imageriesnwhile band 5, 3, 2 was used for 2016 Landsat. Image reconstruction was carried out through sub-setting using boundary file of Area of interest (AOI) to extract the study area from the entire satellite image scene. This is because a single scene of Landsat image is larger than the study area. The major reason for this operation is to define the study area more precisely, reduce file size, less processing time and ensuring less computer storage space.

3.3.2.2 Image classification

Digital image classification is the process of assigning pixels to similar cluster of interest and is of two types: supervised and unsupervised (Elias, 2010, Campbell and Wynne, 2011) cited in (Palm, 2015). The classification process involves the recognition of patterns depicted by each spectral band to create a cluster of classes from the multispectral imageries. The objective of the image classification in this research was to create cluster classes that equals the classes of interest and the spatial extent of the different classes of the imageries were then compared to determine the Manning's n-value for estimation of surface runoff and for simulation of different flood scenarios under different land use conditions. When the prior knowledge of the features of pixels in an image are known, supervised classification is carried out on the image but when the features are unfamiliar, unsupervised classification is the alternative method (ESRI, 2011). Thus Supervised classification with maximum likelihood classifier was performed on the Landsat imageries because of its overall accuracy over other supervised classification algorithms (Ejikeme et al., 2015; Thakur *et. al.,* (2012).

3.3.2.3 Supervised classification

Supervised classification entails three stages; definition of training site, signature extraction and image classification. A sample training site should be selected in such a way that they are spatially spread throughout the study area (Chima, 2012). Thus a stratified random sampling technique across the study area was used to select training site and different spectral signatures were extracted . Based on prior knowledge of the area and field survey, a classification scheme on (Anderson *et al.*, 1976) level 1 classification was adopted and modified into five classes, representing builtup, vegetation, farmland, Bareground/rock outcrops and water body The classified imageries were subjected to accuracy assessment.

3.3.2.4 Accuracy assessment

the result of the classification was subjected to accuracy assessment, as recommended by Foody (2002). Accuracy assessment for individual classification is essential for correct and efficient analysis of LULC change (Butt *et al*., 2015). It indicates if the degree of classified images agrees with reality or conforms to the truth. A total of 250 random points recommended by Congalton (1991) was utilised in IDRISI Selva software.

These points represents the various sample points and these were checked against the classified imageries to determine the degree of conformance. The reason for this is to test the validity of the results derived from the classification process.

3.3.3 Surface runoff estimation

Since the data obtained from the NSPC does not include the inflow from the major contributing tributaries, estimation of the discharge was carried out using the downloaded rainfall and temperature data, generated hydrologic layers and land use and land cover map. This operation

was carried out in HEC-HMS by importing the HEC-HMS project generated in section 3.2**.** Additional input layers were watershed stream network and size, infiltration loss method, transport method for transforming excess precipitation into runoff SCS and time span of the simulation all available for selection and automatic computation. The rate of infiltration and calculated slope values were compared with established values in tables 2.1 and appendix A and substituted respectively.

The optimisation feature was used to calibrate the runoff model. Actual flow values were created from the Time Series Data Manager tab in HEC-HMS. The simulated flow was compared against the observed values by changing parameters manually and comparing simulated results with observed field values.

3.3.4. Flood modelling of river Kaduna and its floodplain

The hydrologic modelling was carried out using geometry database created in section previous sections by importing the project into the HEC-RAS Model. River cross sections are one of the key input into HEC-RAS . Cross-section cutlines were used to extract the elevation data from the terrain to create a ground profile across channel flow. The intersection of cutlines with other RAS layers such as centerline and flow path lines were used to compute HEC-RAS attributes such as locations that separate main channel from the floodplain, downstream reach lengths and Mannings n values.

3.3.4.1 Analysis of flood modelling of river Kaduna

Using GIS for hydrologic modeling usually involves three steps; preprocessing of data, model execution, and post-processing and visualization of results (Botes *et al*., 2012). To create a geometry file, a surface elevation data was needed and this was added using ArcGIS add layer command.

The stream centre lines were digitized from upstream to downstream using a base map. This was used to calculate the river stationing at each cross section. The stream attributes such as river topology, length/stations, and elevations were created. Shape length, hydro ID, river reach, from node, to node and the arc length were generated automatically in the attribute table. Each digitized river have a unique combination of its River Name (*River*) and Reach Name (*Reach*) (Gharbi *et al*., 2016). All river reaches were connected at junctions; these were formed when the downstream endpoint “ToNode" of a reach coincides with the upstream endpoint "FromNode" of the next reach downstream. Junctions formed the intersection of two or more rivers, each having a different River Name (*River*). A River name represents one continuous flow path.

Bank lines were located at the edge of the main channel and were used with the cross sectional cutlines to determine bank stations at each cross section. Shape length, hydro ID, river, reach, from node, to node and the arc length were generated automatically in the attribute table. Flow path lines were used to calculate the downstream reach lengths in the left overbank, main channel and right overbank between cross sections. Shape length and line type were generated automatically in the attribute table. Cross sectional cut lines were digitized from left to right over bank and these were created perpendicular to the flow. The river/ reach name, bank stations and downstream reach lengths were generated automatically in the attribute table. Triangular Irregular Network (TIN) was generated from DEM and used as input to convert 2D cross section layer to 3D. The attribute table for 3D cross section cut lines was generated accordingly.

Land use areas were used to estimate Manning's coefficient (n) values in Appendix A for each cross section. The land use data was imported as a polygon layer and the reference runoff (n values) was entered for different land uses. Finally land use Manning table was created where n values were extracted along each cross section. Storage areas were used to model the flood plain detention storage. Storage areas where the major tributaries join River Kaduna and inundate were digitized. The DEM was used as an input grid for the generation of the maximum and minimum elevations table automatically where the storage area connections was used to pass flow between storage areas oriented from left to right, and the storage connection data was e extracted as in Vijayalakshmi and Babu, (2010)

3.3.4.2 Flood Simulation

The choice of combined 1D/2D model over other models for flood simulation is necessitated by the fact that 1D modelling is applied along river channel without flood plain for example in mountainous areas while the 2D model is applied to the flood plains (Gharbi *et al*., 2016; Jung et al., 2013; Leandro, 2008; Moore, 2011). Initial boundary conditions was set in the form of (x, y). Horizontal coordinate projection was established and used, from HEC-RAS mapper interface, by selecting an existing projection file from an ESRI shape file. The geometric database generated in section 3.2.2,1 was used to establish the geometric and hydraulic properties of the 2D cells and cell features. The

DEM was also used to perform inundation mapping. Boundary conditions in the form of polygon was drawned for each of the 2D flow areas. Physical structures such as roads, embankment within the 2D flow area were outlined to represent significant barriers to flow. 2D computational mesh for each 2D flow areas were created. The 2D geometric pre-processor from RAS Mapper was run in order to create the cell and face hydraulic property tables. The 2D flow areas were connected to 1D elements such as river reaches, as needed. External boundary conditions were drawned in form of lines along the border of the 2D flow areas. Computational options and settings needed for the 2D flow areas were selected from the RAS Mapper window. Final flow was run to produce the final output.

3.3.4.3 Model Calibration

Because hydrologic model calibration is very difficult due to uncertainly of climatic condition (Yuan and Qaiser, 2011), multiple observed peak flow discharges were selected to run and validate the model. Different future flood and land use scenarios were simulated and results were documented and discussed in comparison to related literature.

Figure 3.1 shows the flow chart for the study

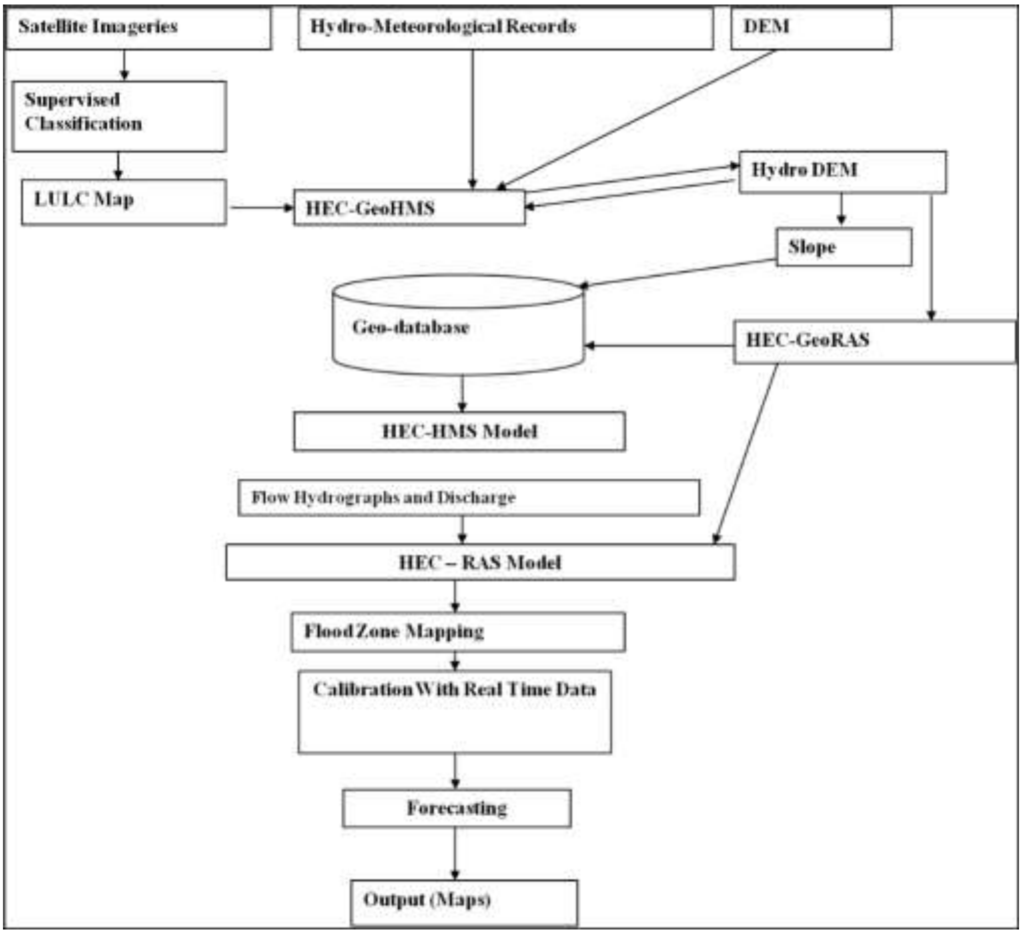


Figure 3.1 Flow Chart for the method

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents the results and discussions derived from the data analyzed and interpretation based on the research objectives.

4.1 Result and Analysis of Preliminary Investigation

The raw Digital elevation model (DEM) of the study area shown in figure 4.1 highlight the variation in hight in the study area from 48m to 723m above sea level. It shows that the northern part of the study area is an upland with the elevation value varying from 188 m to 723 m above sea level and depicted in red and yellow while the uppermost areas having the highest elevation indicating upstream. The Northern part of the study area (The upstream) has a moderate elevation between 190 m to 345 m while the southern part corresponding to the downstream, has the lowest elevation between 48 m and 339 m above sea level.

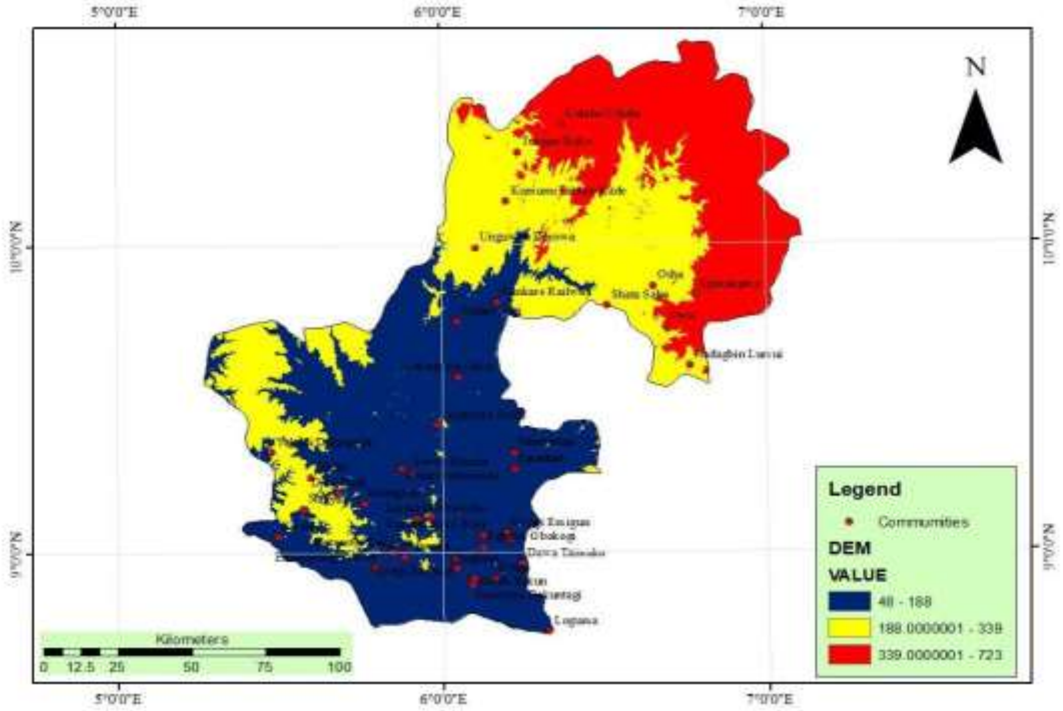


Figure 4.1 Filled DEM of the Study Area

4.1.1 Flood risk zones based on elevation

The classified DEM reveals areas of high and low elevation and level of flood risk, based on hight, figure 4.2.

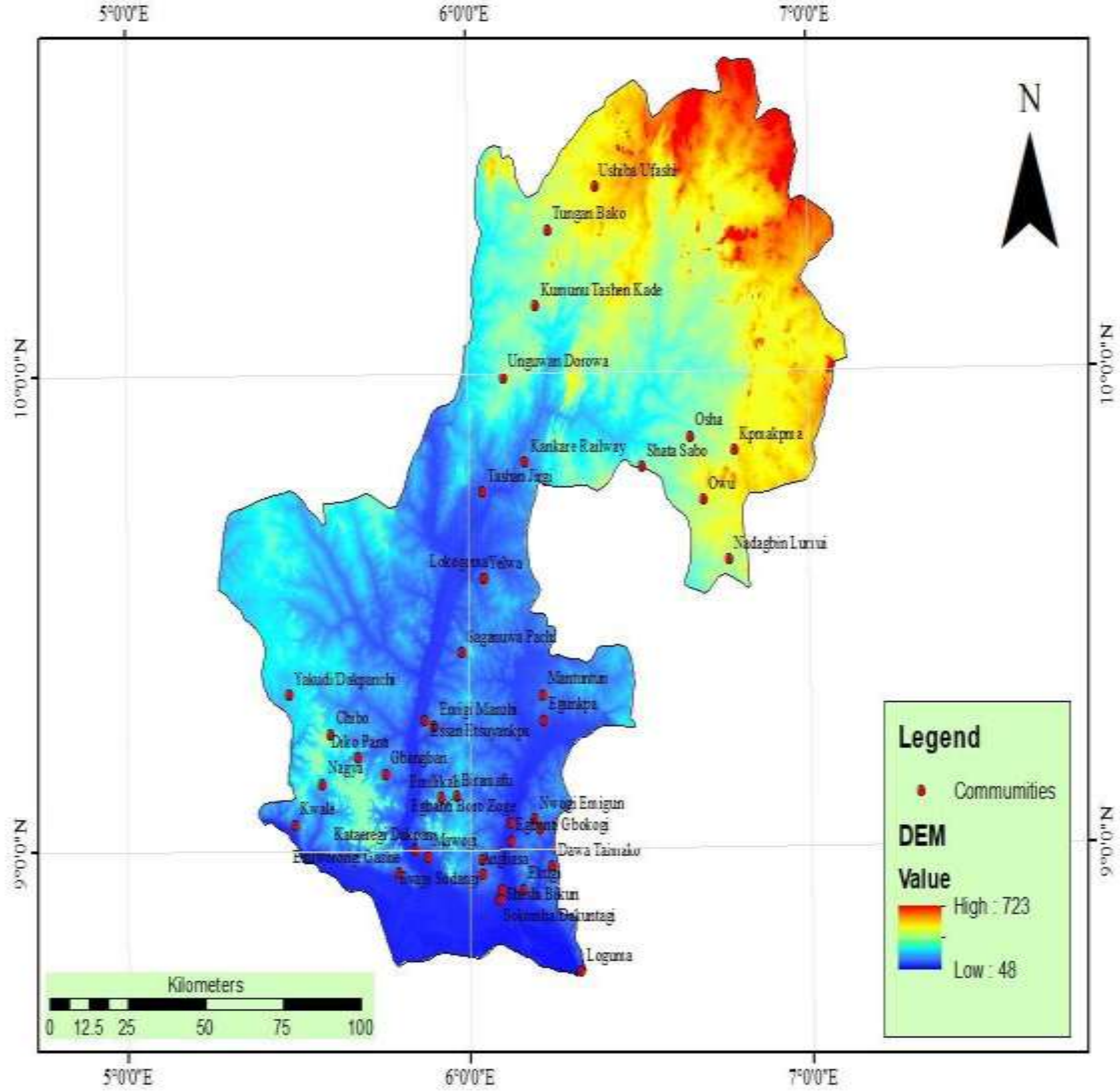


Figure 4.2 Classified DEM of the study area.

Further clssssifiction of the DEM into risk levels figure 4.3, shows the classified DEM based on risk levels. The areas marked as highly susceptible are mostly the areas closet to the rivers. Flooding is experienced yearly in most communities that falls under this classification. The areas are characterized by low relief and water-logged soils.

The result from the classified DEM shows that about 8515.09 square kilometer (44.21%) of the area is on lower elevation which is an evidence of recurrent flooding in the study area. 6199.83 square kilometer (32.19%) are moderate risk areas and 4545.66 square kilometer (23.60%) are low risk areas. it can therefore be concluded that the study area is generally a flood plain area.

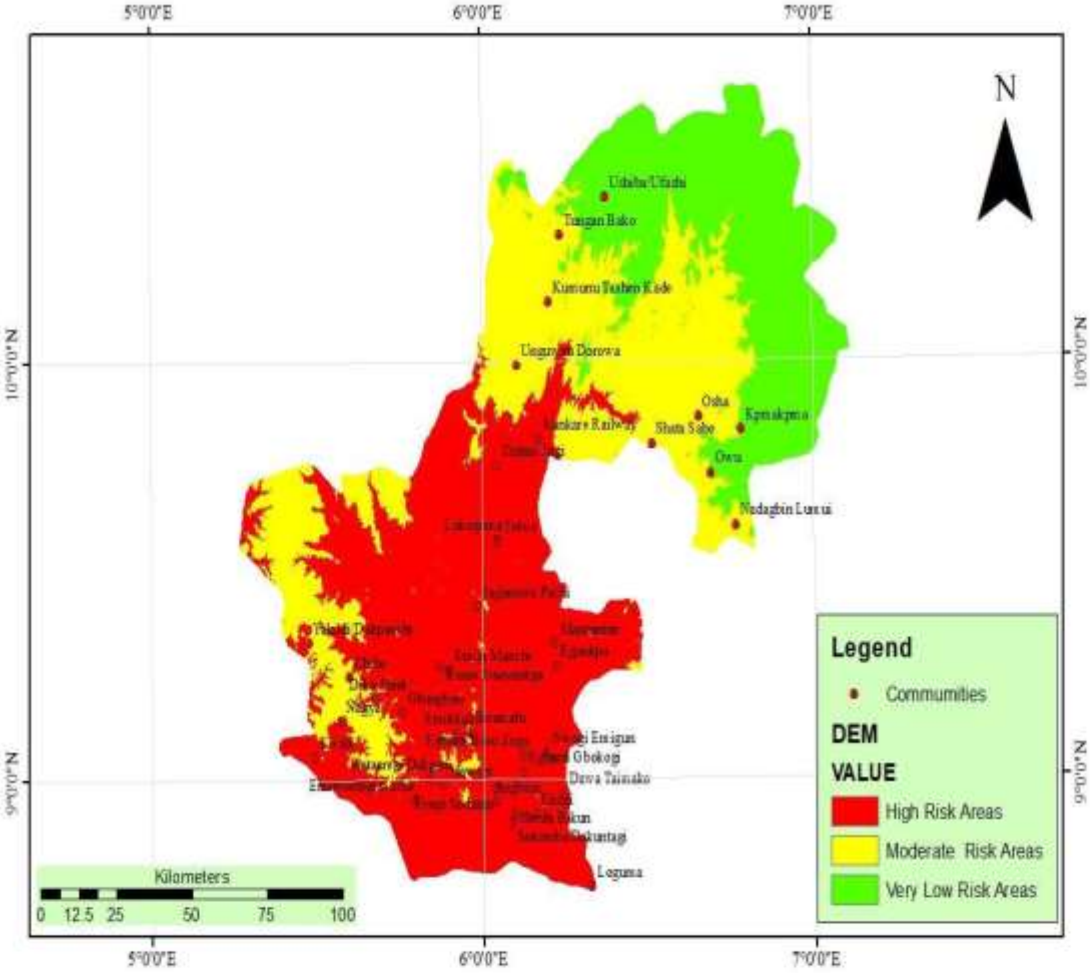


Figure 4.3: Flood risk map of the study area

4.1.2 Effect of DEM on flooding

The effect of DEM on regional flood vulnerability varies depending on the level of elevation. Where a region shows lower elevation, the vulnerability to flood is high and vice versa. This is in agreement with the work of Rahmati *et al.*, (2016). Illustratively,

Figure 4.3 also explains the influence of elevation to flood vulnerability by classifying various regions in the study area and their respective levels of risk. The value of elevation obtained for various regions represents the gradient of the surface within the region recorded in metres (m). The region of Lavun to Kankare is marked as the lowest level of elevation reading from 48m while Ushiba is on high elevation which ranges from 399 to 723m.

From the classification based on the influence of elevation, the three classes of vulnerability adopted in Ikusemoran *et al.,* (2014), have an influence in various regions of the study area. The findings agrees with the work of Ndanusa, *et al.* (2018) on Topographic-Based Framework for Flood Vulnerability Classification of Niger State. Plates 4.I shows the bridge Leading to Ketso Village one of the communities located on the lowland in the study area. During seasonal rains, the bridge is usually submerged with water and is not passable. Commuters usually employ the use of canoes to cross to ketso village, while plate 4.II shows members of the community demonstrating the height of water during the rains.

Plate III however depicted how rice farms in the study area were washed away during rains aggrevating the already devastating impact of food insecurity, shortage and high cost in the country. Coupled with the government’s policy on ban on rice importation high price of food stuffs will continue to go higher.

Consquently, the community adopted an indegeneous knowledge shown in plate IV by planting banana plantation in Nupeko community to adapt to the recurring flood and erosion in the study area.

Plate I . Bridge leading to Ketso village in the study area.

Plate II shows some members of the community demonstrating the water hight during flooding.

Plates II. Flood mark depicting water level in the study area

Plate III. Submerged rice farm in Nupeko in the study area

Plate IV: Flood adaptation strategy using indigenous knowledge in the study area

4.2 Analysis of Hydrologic Parameters

Hydrologic parameters were generated primarily from the acquired SRTM DEM and presented in this section.

4.2.1 Flow direction

The flow direction is the direction of the major drop in elevation to one of the surrounding eight cells. It is taken as the direction of the biggest drop in elevation from each cell. Figure 4.4 shows the eight-direction flow direction coding. The stream (255) flows to its eight neighbours (1,2,4,8,16,32,64 and 128) encoded as integer. The flow direction was identified by the steepest slope or the direction with the greatest height difference. If the water flows from center to the right side , the flow direction value was observed to be 1 and to the left it was observed to be 16. When the "Force edge cells to flow outward" was checked it was observed that, the cells on the edge of DEM flows outward across the elevation surface. This agrees with Jenson and Domingue (1998) rule of eight-direction flow direction coding. When a cell or multiple cells lower than its eight neighbouring cells, the cell(s) is/are given the value of its lowest neighbour and flow is defined towards that cell. Figure 4.4 shows the raster flow direction of the study area.

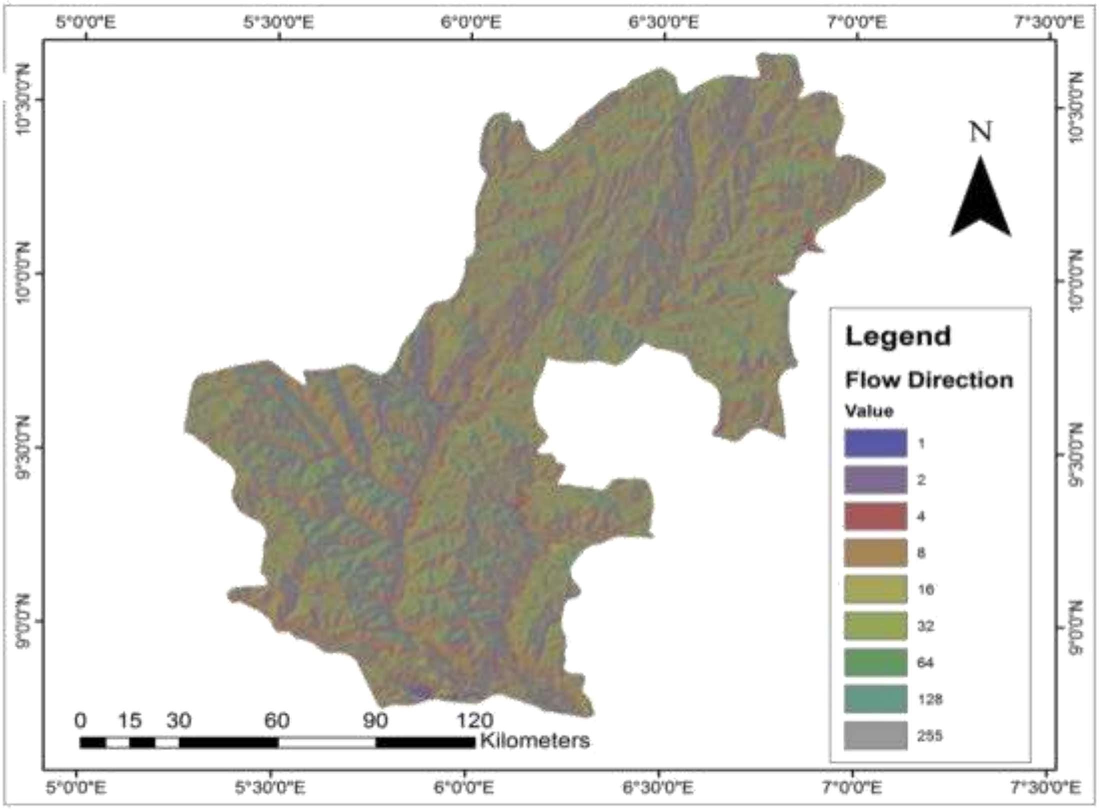


Figure 4.4: Raster flow direction of the study area

Similarly, the corresponding vector map shown in figure 4.5 shows the flow direction in a vector format showing magnitude aand direction. The longer the vector the longer the flow , while the vector direction is indicating the direction of flow.

It is observed in both figure 4.4 and figure 4.5 that areas along water channels, river banks and low elevation corresponding to the lowlands have the lowest value between 1 and 2 depicted in blue while the highlands have the highest values between 65 to 255. The magnitude and direction of the vector in figure 4.5 indicates the flow length and direction where the arrows points down the downhill direction the downhill direction of the steepest descent and the and the arrow length is proportional to the slope magnitude this agrees with the findings of Al-Abed *et al.* (2005) and Kute *et al.* (2014) that water flow are expected to begin from upstream to downstream.

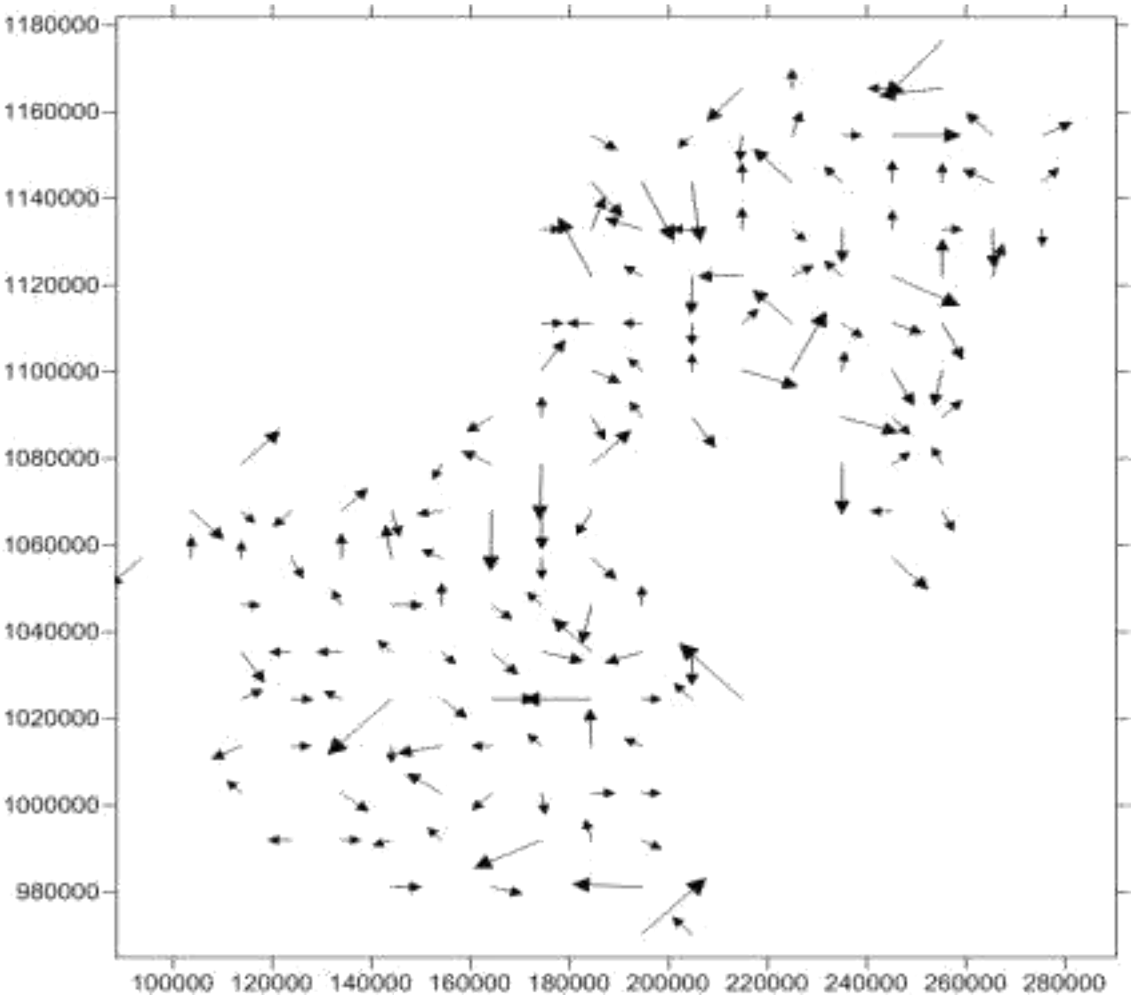


Figure 4.5: Vector flow direction of the study area

4.2.2: Morphology of the study area (slope)

Slope is an important variable for surface runoff, flood and erosion calculations. The higher the slope degree the more the erosion. Slope percentage however is an important variable in flow length calculation. The longer the slope percentage, the more the water flow. Figure 4.6 shows the morphology of the study area. The figure revealed that, the study area generally has lower percentage rise between 0-3.6. The lower the slope value, the flatter the terrain and in the same way the higher the slope value the steeper the terrain. Thus, this revealed that the study area is generally a floodplain dominated with lower elevation. Greater slope watersheds depicted in red have higher runoff coefficients than the ones with lesser slopes. This agrees with the work of Al-Smadi, (1998) and Shaari *et al.*, (2016).

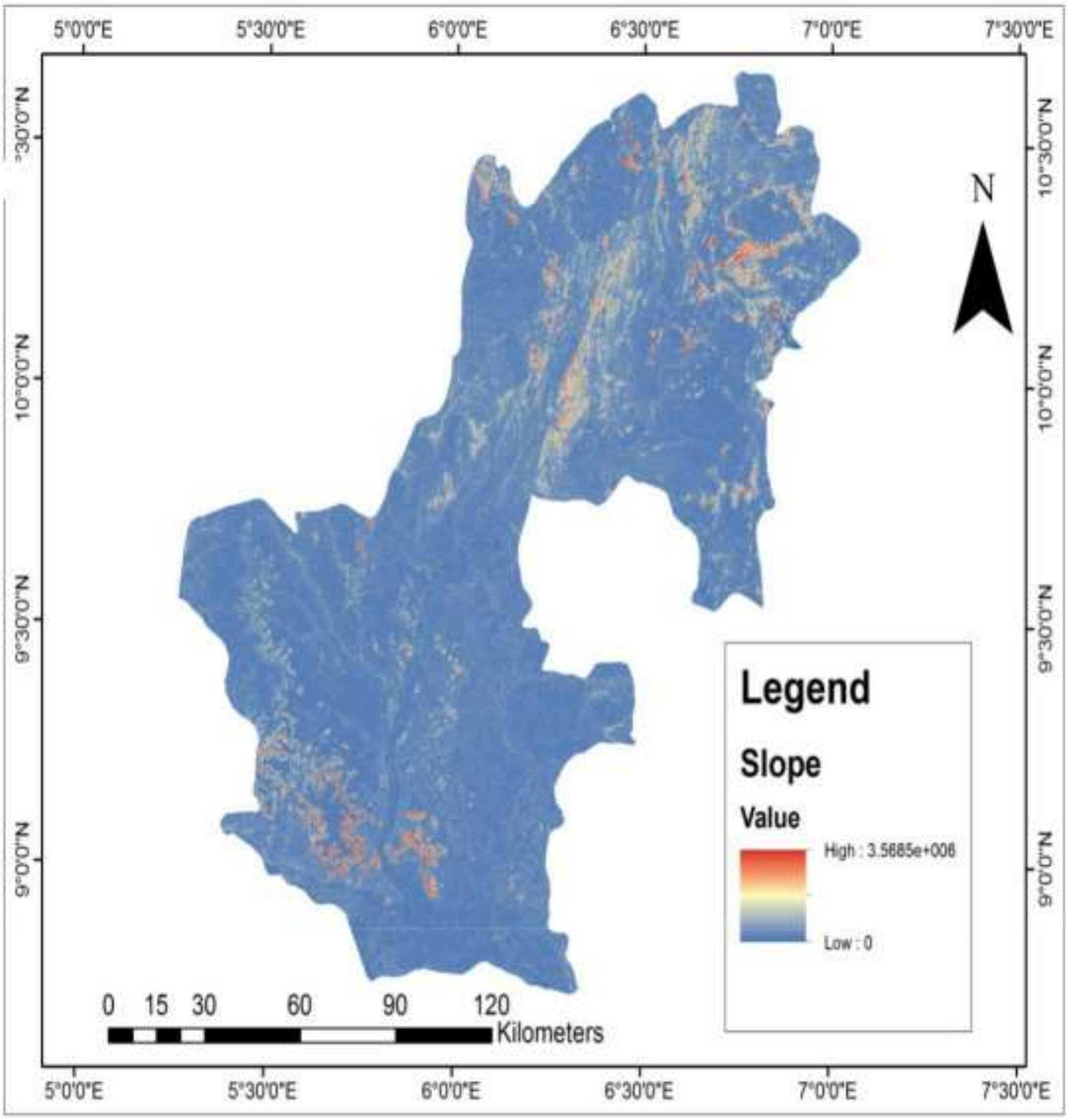


Figure 4.6: Morphology of the Study Area

4.2.3: Drainage network delineation

The network through which water travels to the outlet can be envisaged as a tree, with the base of the tree being the outlet Figure 4.7. The tributaries of the tree are stream channels. The joints of two stream channels are referred to as a node or junction. The sections of a stream channel connecting two successive junctions, or a junction and the outlet are referred to as interior links.

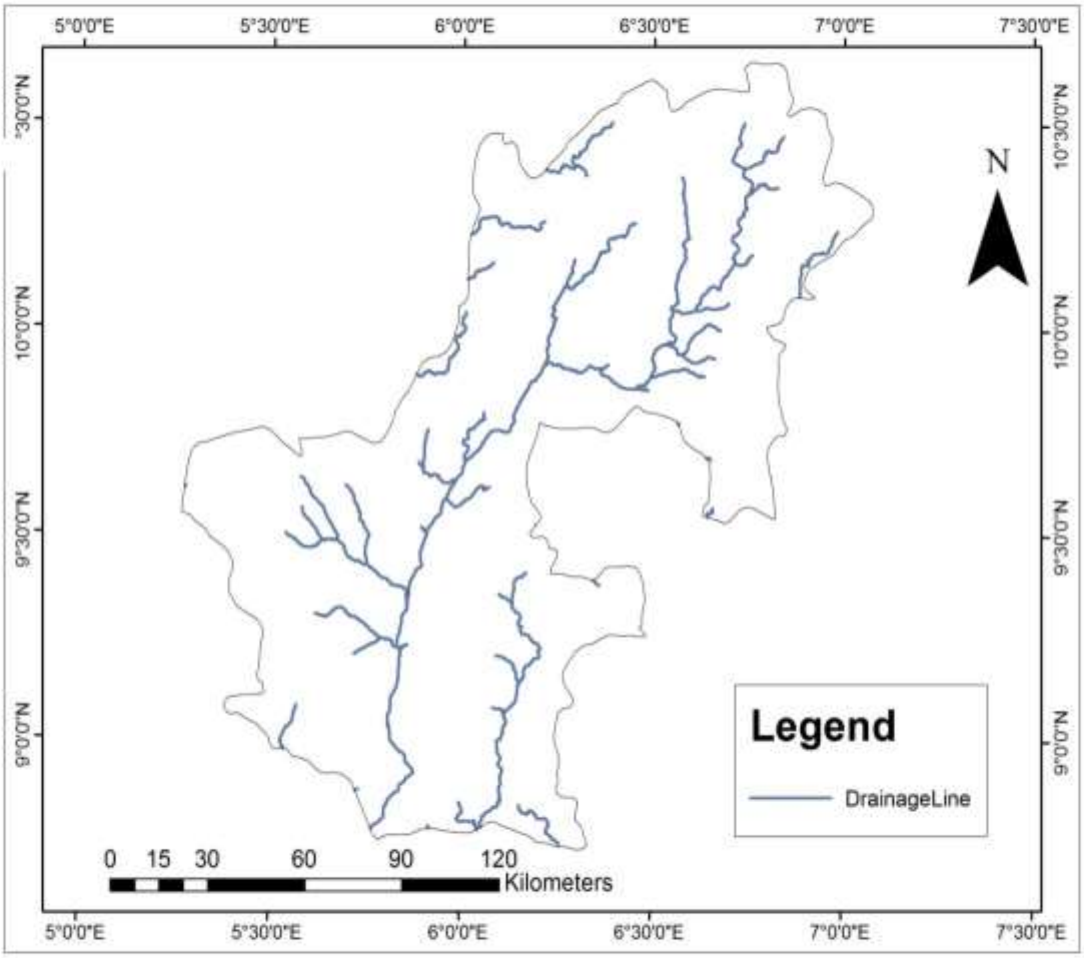


Figure 4.7: Drainage network of the study area

Dendrite and deranged drainage patterns were observed to be dominant in the study area. The dendritic is as a result of the regional underlying homogeneous material. That is, the subsurface geology has a similar resistance to weathering so there is no apparent control over the direction of the tributaries. The Tributaries joined larger streams at acute angle (less than 90 degrees). The Deranged drainage pattern depicted is as result of the disruption of a pre-existing dendritic drainage pattern altered by heavy flow. The implication of this type drainage is that, the study area can easily be eroded and washed away by flood.

4.3 Analysis of the Land Use And Land Cover of 1990, 2010 and 2016 Imageries

This section revealed the raw colour composite and supervised maximum likelihood Classifications for the year 1990, 2010 and 2016 satellite imagery over the study area as well as the different classes of land features present over the area.

4.3.1. Analysis of land use and land cover classification of 1990 image

Table 4.1 shows the classiffication scheme adopted from Anderson et al.,(1976). The result of the analysis of 1990 supervised maximum likelihood classification of the study area was presented in figure 4.8. The map revealed five (5) categories of land use and land cover table 4.1 depicting vegetation, agriculture, built-ups, water body and bare-grounds/rock outcrops.

Table 4.1: Classification scheme used for this study

S/N	Class	Description
1	water bodies	Open water features such as rivers, streams, lakes and reservoirs, permanent open water, ponds, canals, permanent/seasonal wetlands, low-lying areas, marshy land, and swamps.
2	Bare ground/rock outcrops	Open dry sand on the body of water, excavation sites, open space, soils, bare bareland.
3	Vegetation	Trees, natural vegetation, mixed forest, gardens, parks and playgrounds, grassland, vegetated lands, agricultural lands, and crop fields.
4	Agricultural land	Fallow land, earth and sand land in-fillings, construction sites, developed land, excavation sites, open space, bare soils, and the remaining Landcover types.
5	Built-up	Areas under urban and rural built-up including homestead area, residential, commercial, mixed use and industrial areas, villages, settlements, road network, pavements, and man-made structures.

Source: Adopted from Anderson *et al.,* 1976 and modified

The areal extent of these land use and land cover classes revealed that, the dominant land cover in the study area is vegetation with an areal coverage amounted to 126,229,8ha (62.84% of the total area), located in almost all parts of the study area. The next largest is agriculture with areal coverage of 450,573ha (22.43%). Bare ground/rock outcrops also covers a significant area of 179,293ha (8.93%). Water body and built up areas however, have the least areal coverage of 407,51ha (2.03%) and 758,15ha (3.77%) respectively.

The dominance of vegetation covering 62% of the study area in relation to water body that covers (2.03%), indicate the role of vegetation in reducing the rate of surface runoff thereby by incresing infiltration and decreasing the likelihood of flooding in the study area. This agree with the result of Wagner *et al*. (2013). These conditions were considered as a reference point for change detection over the study period.

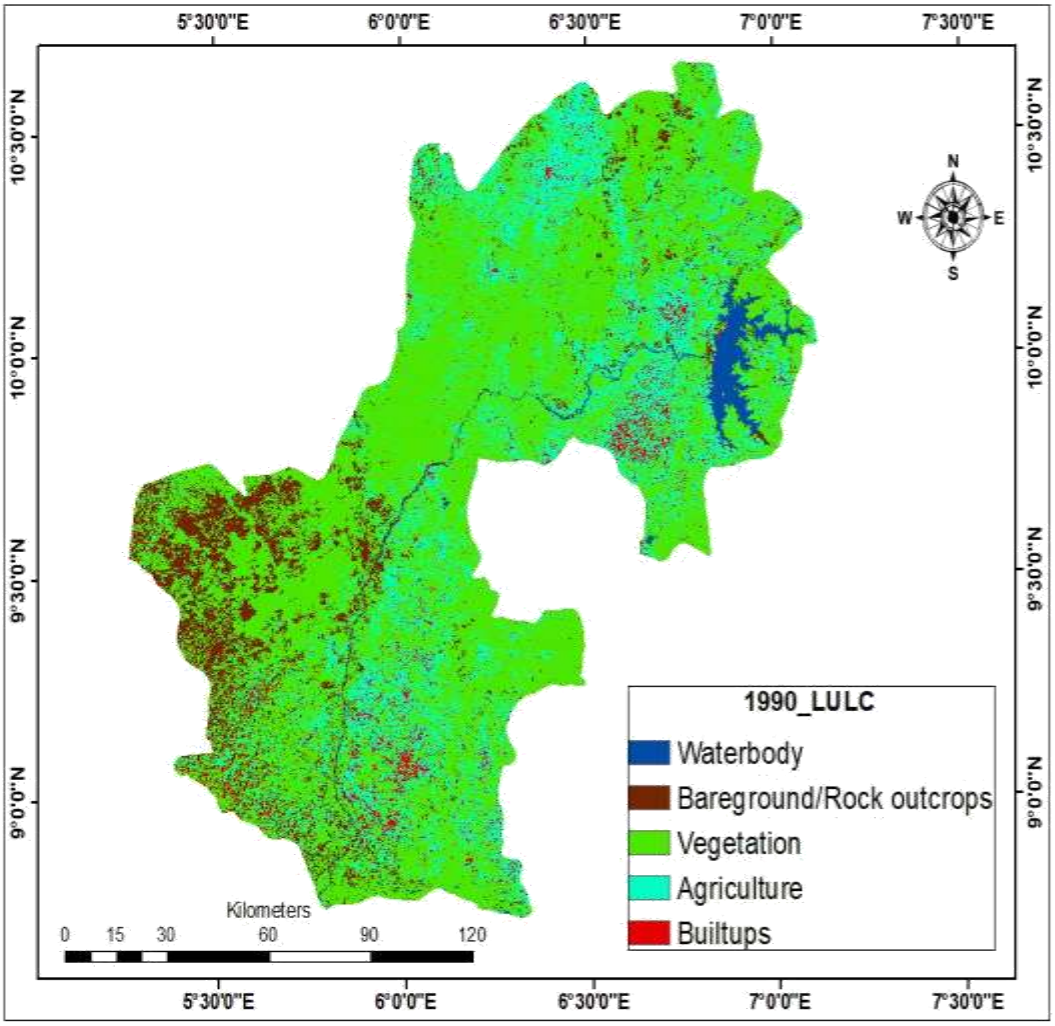


Figure 4.8: Land use and land cover classification map of 1990 imagse

4.3.2 Analysis of land use and land cover classification of 2010 image

This period witnessed a considerable decrease in vegetation cover from 62.84% during the previous decade to 868,716ha (43.25%) of the total area. This in turn resulted to an increased in agricultural land and built up areas from 407,51ha (2.03%) and 758,15ha (3.77%) to 861, 345 ha (42.88%) and 972,30ha (4.84%) respectively in 2010. This is attributed to increase in population, thereby increasing the need for food and shelter (evident from the increase in agricultural land and builtup areas) to meet the demand of the communities. While the Water body and bare ground/rock outcrops amount to

374.93Km^2 (1.87%) and 1439.46 Km^2 (7.17%) respectively, (figure 4.9). The decrease in water body can be attributed to siltation of the water due to the fact that the satellite imageries used was of dry season period. This agrees with the works of (Vivekananda *et al*., 2020) Multi-temporal image analysis for LULC classification and change detection at Ananthapuramu, findings shows that the area under built-up land and agriculture land increased considerably, whereas the area under vegetation land and water bodies drastically decreased.

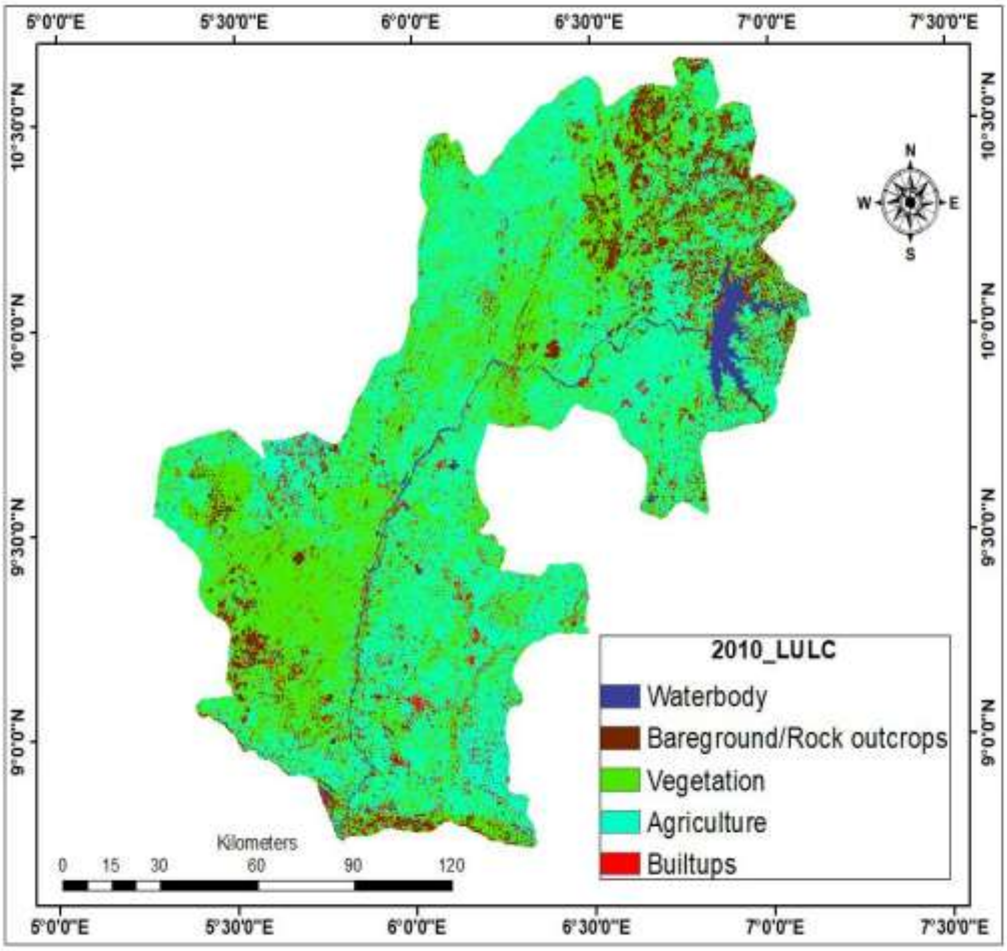


Figure 4.9: Land use and land cover classification map of 2010 image

4.3.3 Analysis of land use and land cover classification of 2016

The land use and land cover classification for the 2016 was carried out. It revealed that vegetation covers have continued to reduced drastically from 868,716ha (43.25%) in 2010 to 5692.71 Km^2 (28.34%) by 2016. However, bare ground/rock outcrops to 2479.14Km^2 (12.34%) and built ups covers

1280.3 Km^2 (6.37%) and Agriculture increased greatly for the year 2016. Among the various land use and land cover categories under consideration. This progressive increase in built-up areas is in agreement with the work of Ade and Afolabi (2013). Agricultural land has the largest areal coverage of 10241.01 Km^2 (50.98%) of the total area. Whereas water bodies have the least areal cover of 394.14 Km^2 (1.96%) of the total area as presented in figure 4.10. The increase Agriculture cover on the study areas can be linked to government efforts towards farmers by providing farm inputs such as fertilizer, pesticide and the anchored borrowers program for soft loans which is aimed at boasting food supply to meet the need of ever-increasing demand for food by the population. Niger state is one of the state who produce agricultural produce in large amounts which is been transported to other states of Nigeria.

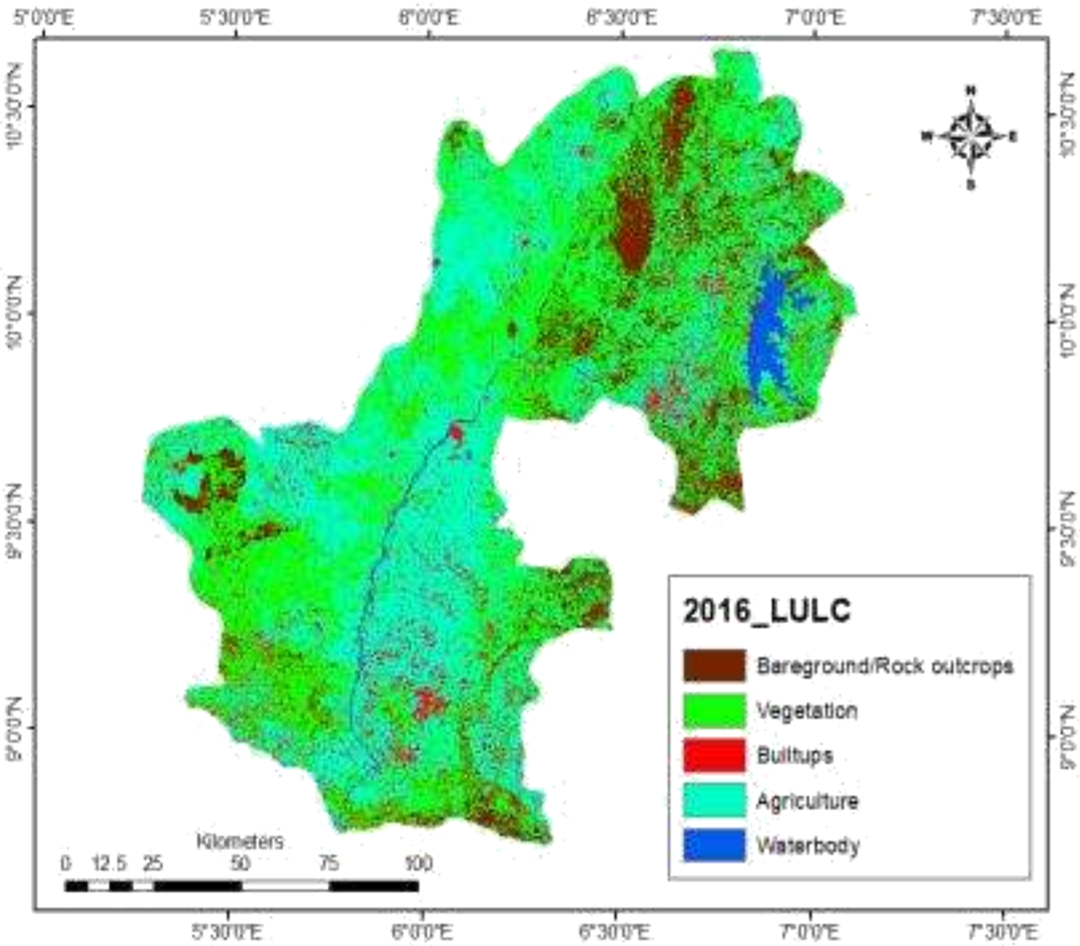


Figure 4.10: Land use and land cover classification map of 2016 satellite image

The LULC changes may not have sudden impact on the people, considerable environmental impact on the study area over the study period was observed. Thus, the LULC changes should be closely monitored in the future for the sustainability of the environment in order to reduce the impacts on the general environment.

4.3.4 Accuracy assessment

Table 4.2 shows summary of the results of accuracy assessment generated from the LULC maps of the study area (i.e.. the producer, user and overall accuracy and kappa coefficient) which was calculated using error matrix shows higher accuracy of **81.75%** in 1990,

84.36% in 2010 and **85.67** % in 2016 respectively and the corresponding Kappa statistics was **0. 785**, **0.827** and **0.831**, respectively. In general, the overall accuracy of the classification was consistently high which indicates high level of agreement between classified image and land cover categories on the field. These accuracies agree with other studies carried out using similar methodology such as (Vivekananda *et al.*, (2020) and Naikoo *et. al.*, (2020)).

Table 4.2 Comparison of classification accuracy (1990, 2010 & 2016) LULC image

	1990		2010		2016	
Class Name	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)	Producer's Accuracy (%)	User's Accuracy (%)
Water body	86.33	97.8	95.35	97.34	87.10	96.1
Bare-grounds/rock outcrops	80	68.29	80.1	87.09	84.5	97.1
Vegetation	85.71	89.30	83.74	95.38	96.3	65.6
And use Agriculture	84.29	85.65	93.20	85.67	79.5	79.5
Built-up	81	79.76	87.7	78.20	95.5	87.10
Overall Classification Accuracy (%)	**81.75**		**84.36**		**85.67**	
Overall Kappa	**0. 785**		**0.827**		**0.831**	

This accuracy was reported so that users of the products can decide if the product from the accuracy of the classification is good enough or not.

4.3.5 Analysis of surface roughness co-efficient

The land use and land cover map was used to extract surface roughnes coefficient (manning n's value) for use in objective three estimation of surface runoff in the sub-basin. The result revealed that study area is dominantly Agricultural land with manning n's values ranging from 0.03 for built-up areas to 0.04 for water body the implication here is that the peak discharge decreased with the increase in manning n's value.

Table 4.3 Land use and manning n's v,alue

S/N	Landuse	Manning n's
1	Water Body	0.040
2	Bareground	0.030
3	Vegetation	0.035
4	Agricullture	0.035
5	Builtup	0.030

Source: Author's Work , 2017

4.4. Estimation of Surface Runoff from the Sub-Basin

The estimation of runuoff was carried out by delineating the upstream into three different sub-sub-basins namely, Koriga Sub-basin (Catch1), Durumi Sub-basin (Catch2) and Mariga Sub-basin (Catch3) with similar hydologic charactetics, see appendix B. These sub-basins are the areas that contribute runoff to the corresponding drainage routes withing the basin and emptied into the main river Kaduna.

Though Mariga Sub-basin is the largest interms of areal coverage with about 5736311.67km2 it has the shortest length of stream channels in the drainage basin.

Similarly Koriga, second in size has the longest length about 382.04km. In addition, Durumi, the only elongated basin as shown in figure 4.12, has the smallest area but almost the same length with Koriga Sub-basin.

The basins were delineated from the larger Basin as shown in figure 4.11.

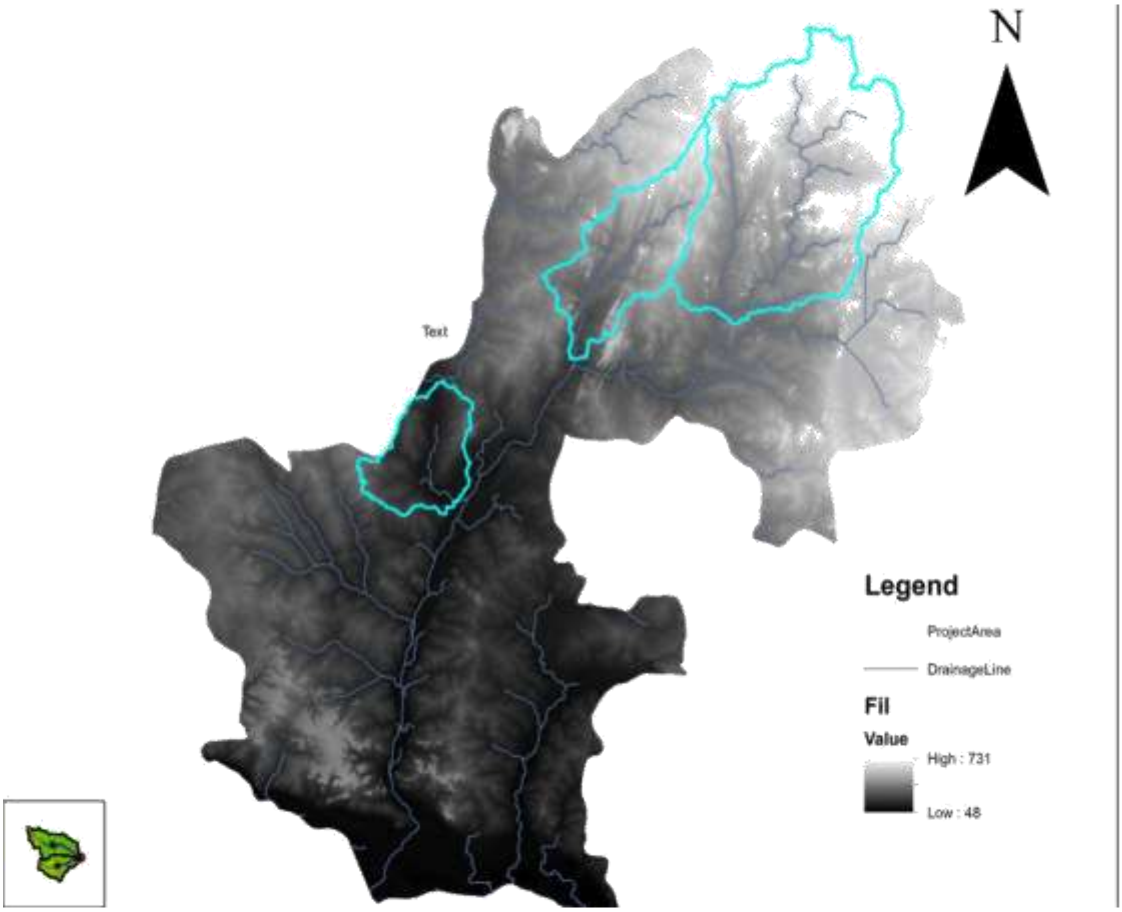


Figure 4.11 Delineated sub-basins withins the larger basin in the study area

Basin shape is controlled by structure, relief, and precipitation and varies from narrow elongated forms with irregular basin perimeter to circular or semicircular forms, Figure 4.12. (See appendix B, for details).

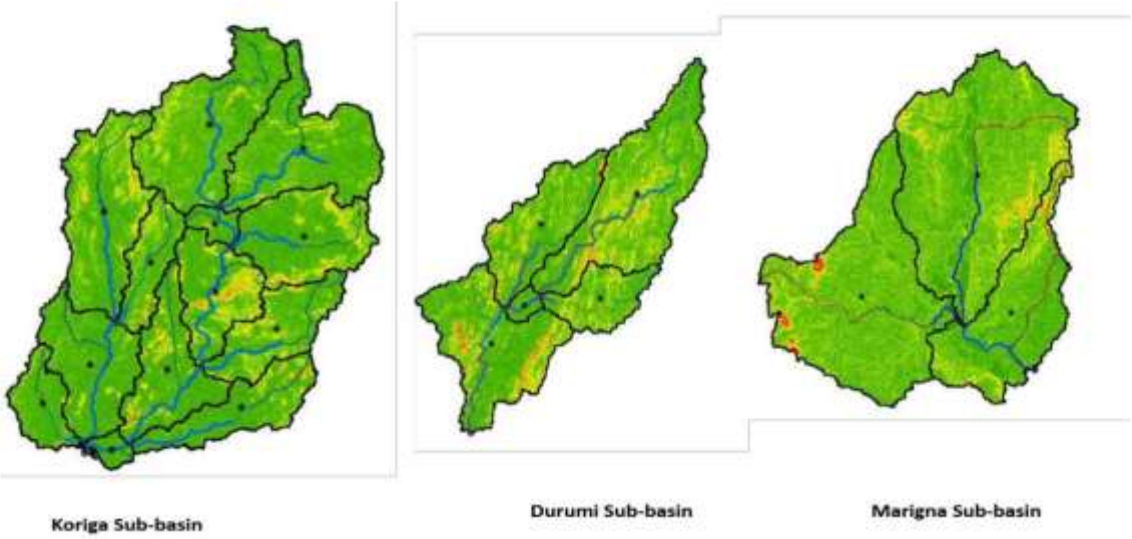

Koriga Sub-basin
Durumi Sub-basin
Marigna Sub-basin

Figure 4.12 The three delineated sub-basins at the upstream of the study area

4.4.1. Flood hydrograph

The Flood hydrographs in figure 4.13 shows how Koriga basin responds to a period of rainfall event. It shows the river discharge that occurs as a result of precipitation from an earlier storm. The choice of Koriga was neccessited because it has the longest river length as recommended by Oyegoke and Ifeadi (2008) and Das *et al.*, (2013) and it discharged 2459.3(M^3/S) cumec of water equivalent to 5306.10mm as a runoff, after a single rainfall event in to the main river Kaduna. See also appendix C.

The results of hydrologic layers in section 4.2 and land use in 4.3, were exported from ARCGIS as HMS project and imported into Hydrologic Modelling System (HMS) for runoff estimation. Hydro-meteorologic data (temperature, and rainfall), data were incorporated to estimate the runoff.

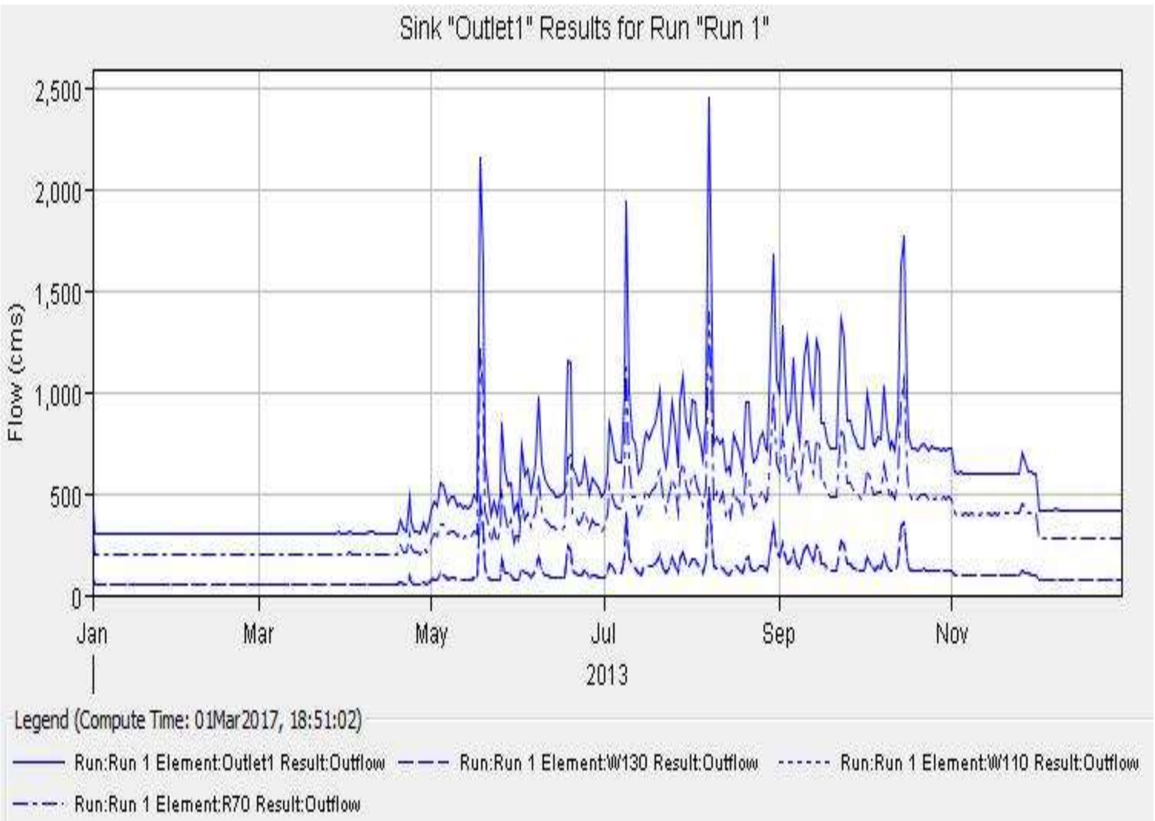


Figure 4.13: Flood hydrograph of Koriga basin

4.5 Flood Simulation

The geospatial and geometric datasets generated in sub sections 3.1, 3.2 and 3.3 were exported from ARCGIS and imported as a single geometric dataset into River Analisis System (RAS). Figure 4.14 shows the geometric data in HEC-RAS.

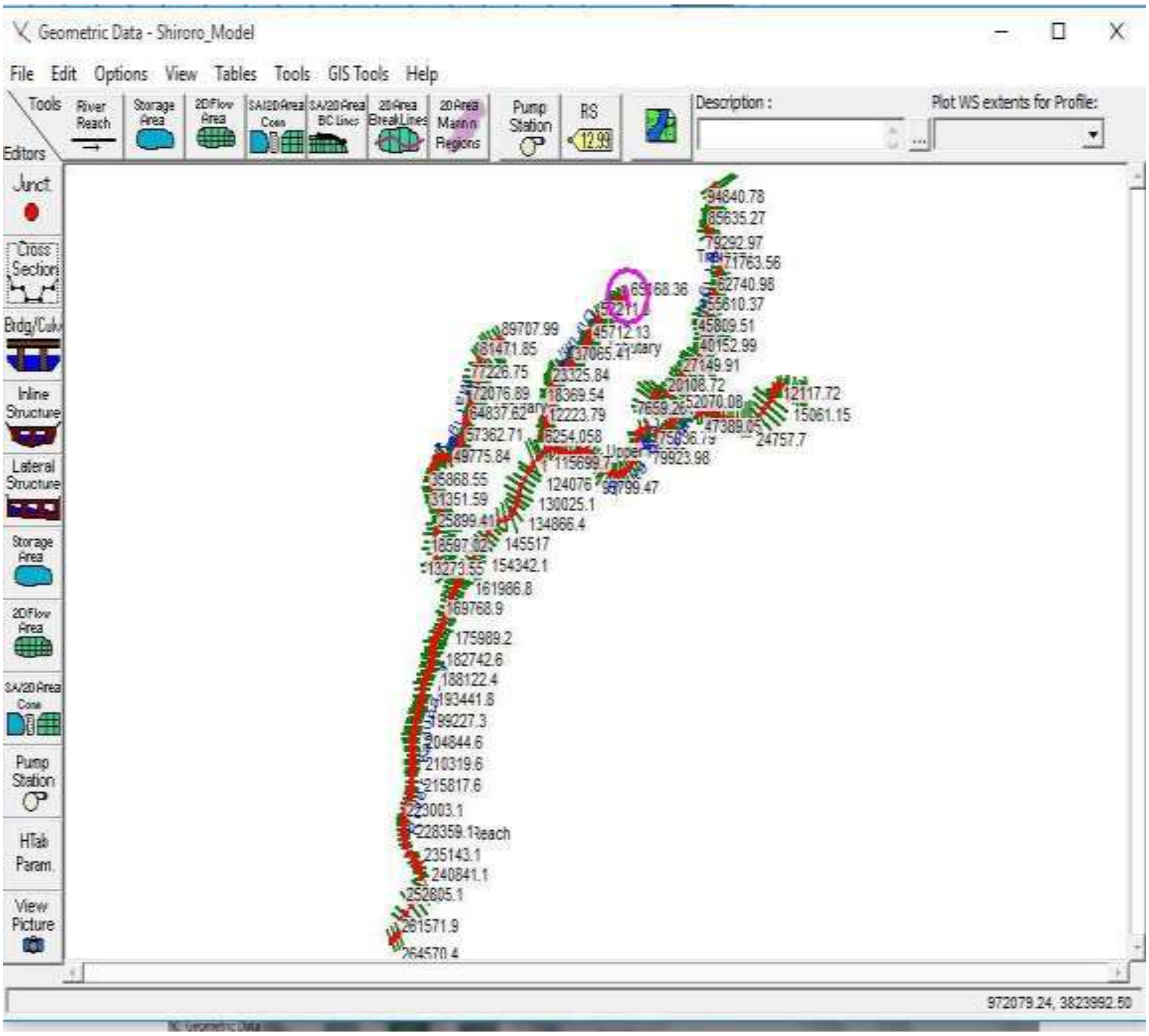


Figure 4.14. Geometric data showing river cross section from field survey

The geometric data was observed to have some missing cross section values which could be as a result of interpolation, in addition the river stations' values were also observed to be placed from right to left looking upward as against the ideal left to right looking downstream. This was corrected in rasmapper window of HEC-Ras by flipping the cross section.

Figure 4.15 shows the corrected geometri data of the river stations with reading flipped on the right side. Similarly this correction was applied to all the three tributries (Koriga, Durumi and Mariga).

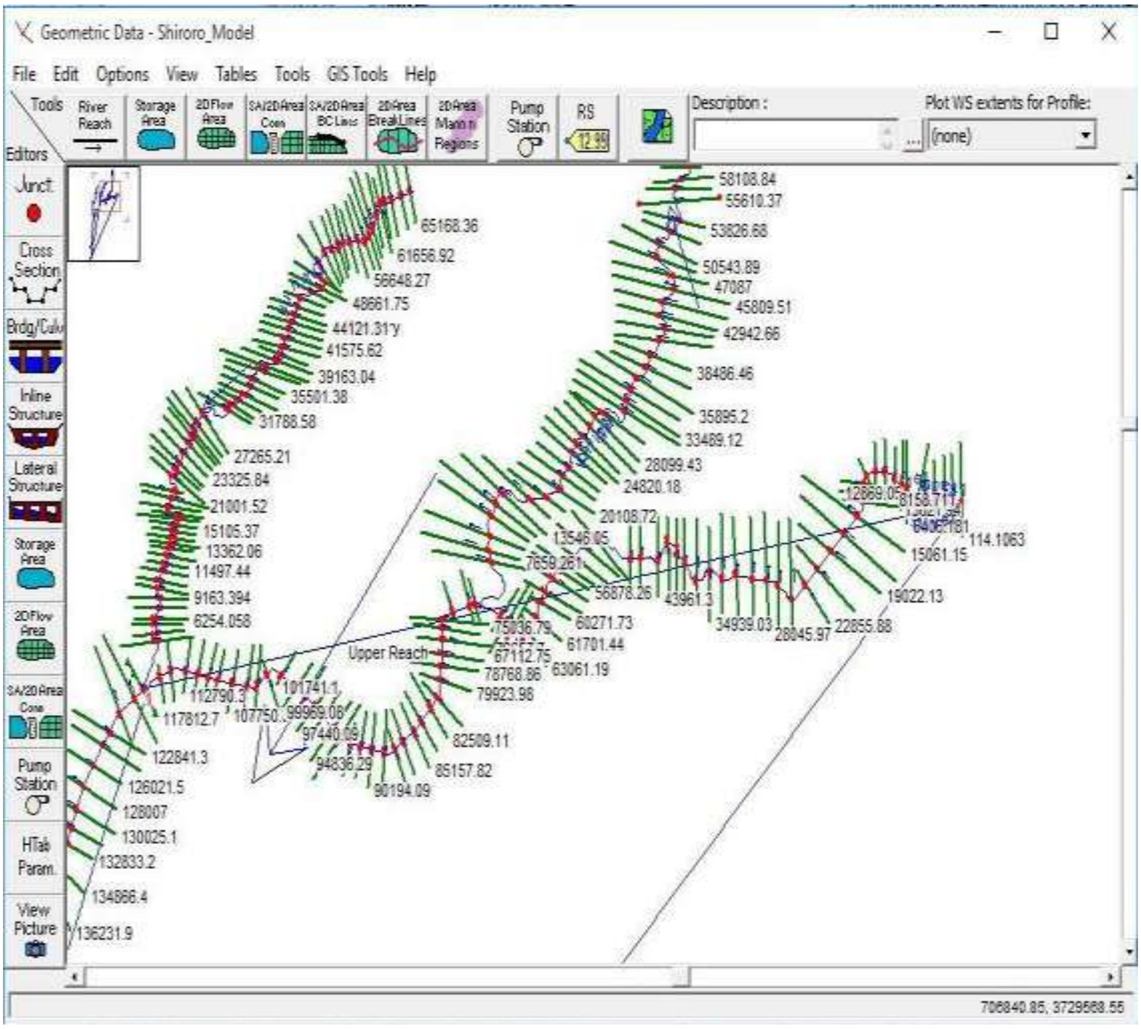
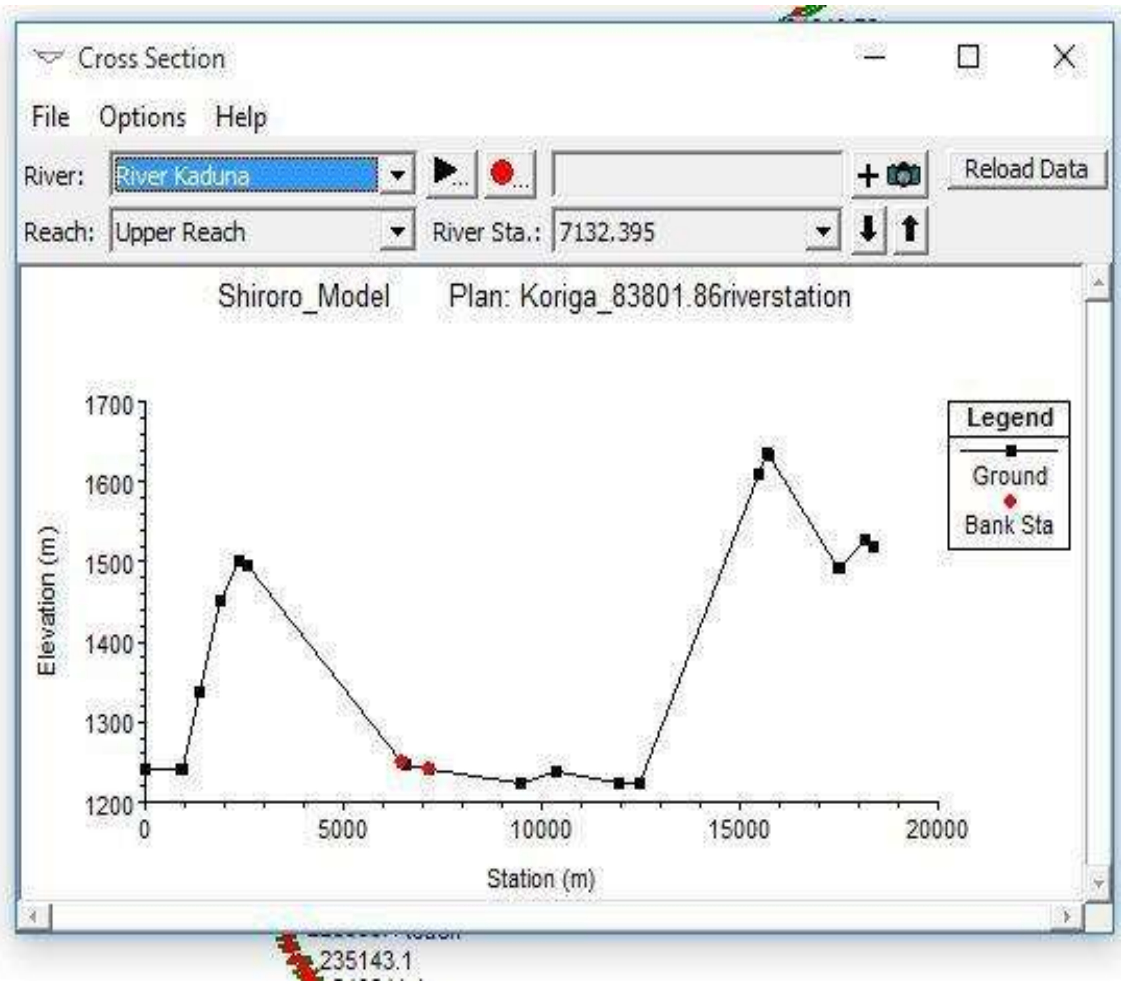


Figure 4.15. Corrected geometry

4.5.1.Analysis of river cross section

The river cross section shown in figure 4.16. was defined by station X and elevation Y with each station having atleast 10 cross section coordinates that defined that channel slope. Appendix D is the X and Y coordinates of River Kaduna. The table was edited to make sure the elevation was decreasing downslope. This was also applied to the three delineated tributaries in the study area. In addition, while editing the crosss sections, the station values were not changed so that it will not fall out side the boundary of the study area. However the elevation values were adjusted within the maximum and minimun elevation values in the study area as suggested by Che-Ghani, (2014). Figure 4.16 shows the cross section of of River Kaduna at river station 7132.395. See appendix D.



Cross Section

River: River Kaduna

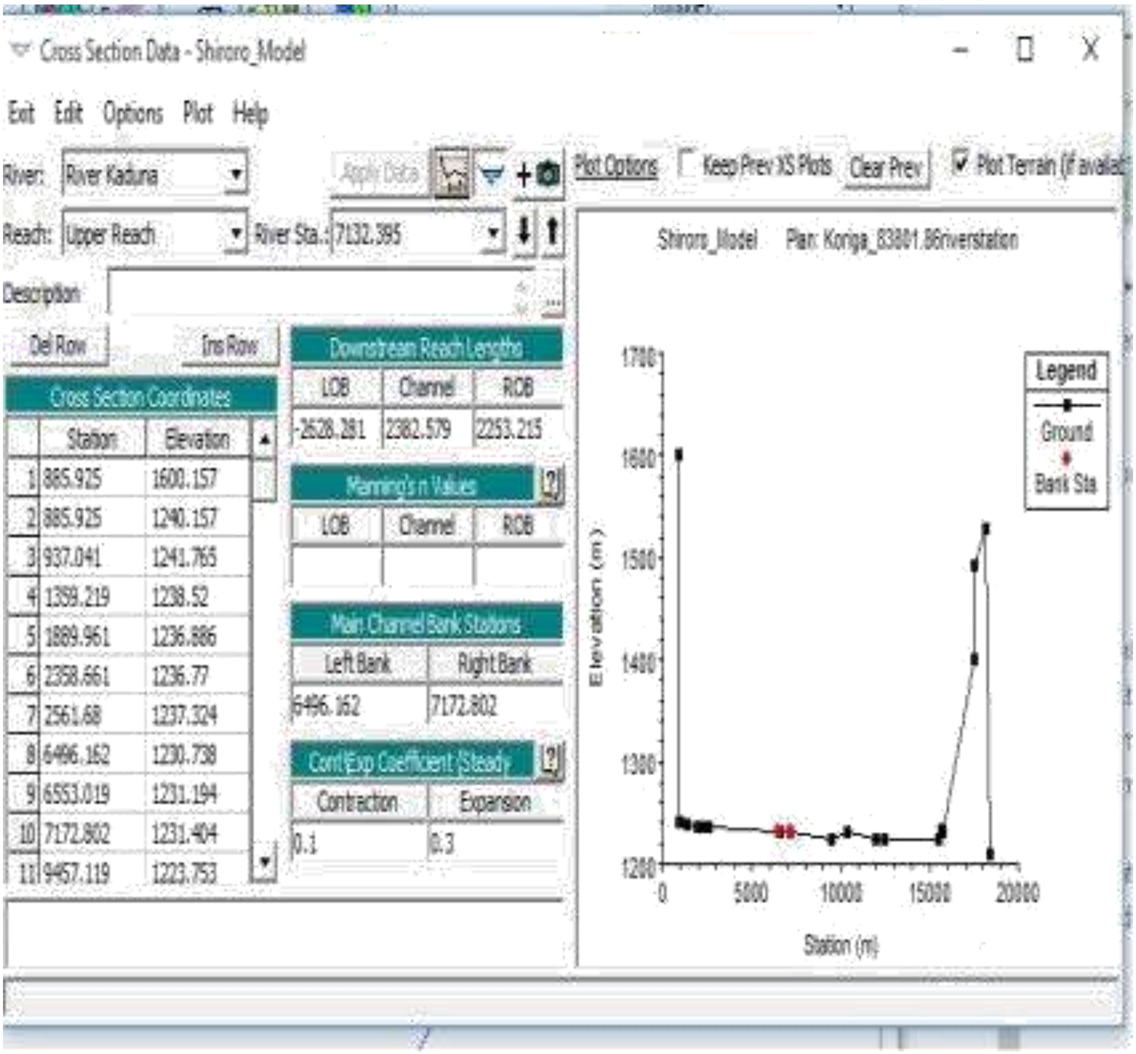
Reach: Upper Reach

River Sta.: 7132.395

Shiroro_Model Plan: Koriga_83801.86riverstation

Figure 4.16. River Cross section of river Kaduna before editing

The edited river cross section at the same river station 7132.395 presented in figure 4.17 reveals a different geometry from the original geometry in figure 4.16.



River: River Kaduna

Reach: Upper Reach

River Sta.: 7132.395

Description:

Cross Section Coordinates

	Station	Elevation
1	885.925	1600.157
2	885.925	1240.157
3	937.041	1241.765
4	1359.219	1238.52
5	1889.961	1236.886
6	2358.661	1236.77
7	2561.68	1237.324
8	6496.162	1230.738
9	6553.019	1231.194
10	7172.802	1231.404
11	9457.119	1223.753

Downstream Reach Lengths

LOB	Channel	ROB
-2628.281	2382.579	2253.215

Manning's n Values

LOB	Channel	ROB

Main Channel Bank Stations

Left Bank	Right Bank
6496.162	7172.802

Cont\Exp Coefficient (Steady

Contraction	Expansion
0.1	0.3

Figure 4.17: River cross section of river Kaduna after editing

The implication of geometry in floodplains is that, floodplains flows decreases with increasing width -depth ratio and does not produce a larger network and dispersion for the channel. Also the cross-section geometry can influence the relative contribution of hydrodynamic and kinematic dispersion.

4.5.2 Analysis of flood simulation in ArcGIS

Upon geometric data correction and further processing, flood simulation was carried out in ArcGIS through HECgeo-RAS plug-in and spatial analyst tool to determine the inundation level during an upsurge of water above the river bank. The inundation level was carried out for 50m, 100m, 150m and 200m respectively as volume of discharge increases. Table 4.4 indicates the areal coverage of the inundation.

Table 4.4 area covered by elevation

Water Level (m)	Area Covered (Sq.km)	(%)
50	1.787616	0.01
100	2729.162657	14.47
150	6647.622904	35.24
200	9486.40261	50.29
Total	**18864.97579**	**100.00**

The Findings revealed that at 50 meters above sea level 1.787616 km^2 about 0.01% of study area was inundated as shown in Figure 4.18.

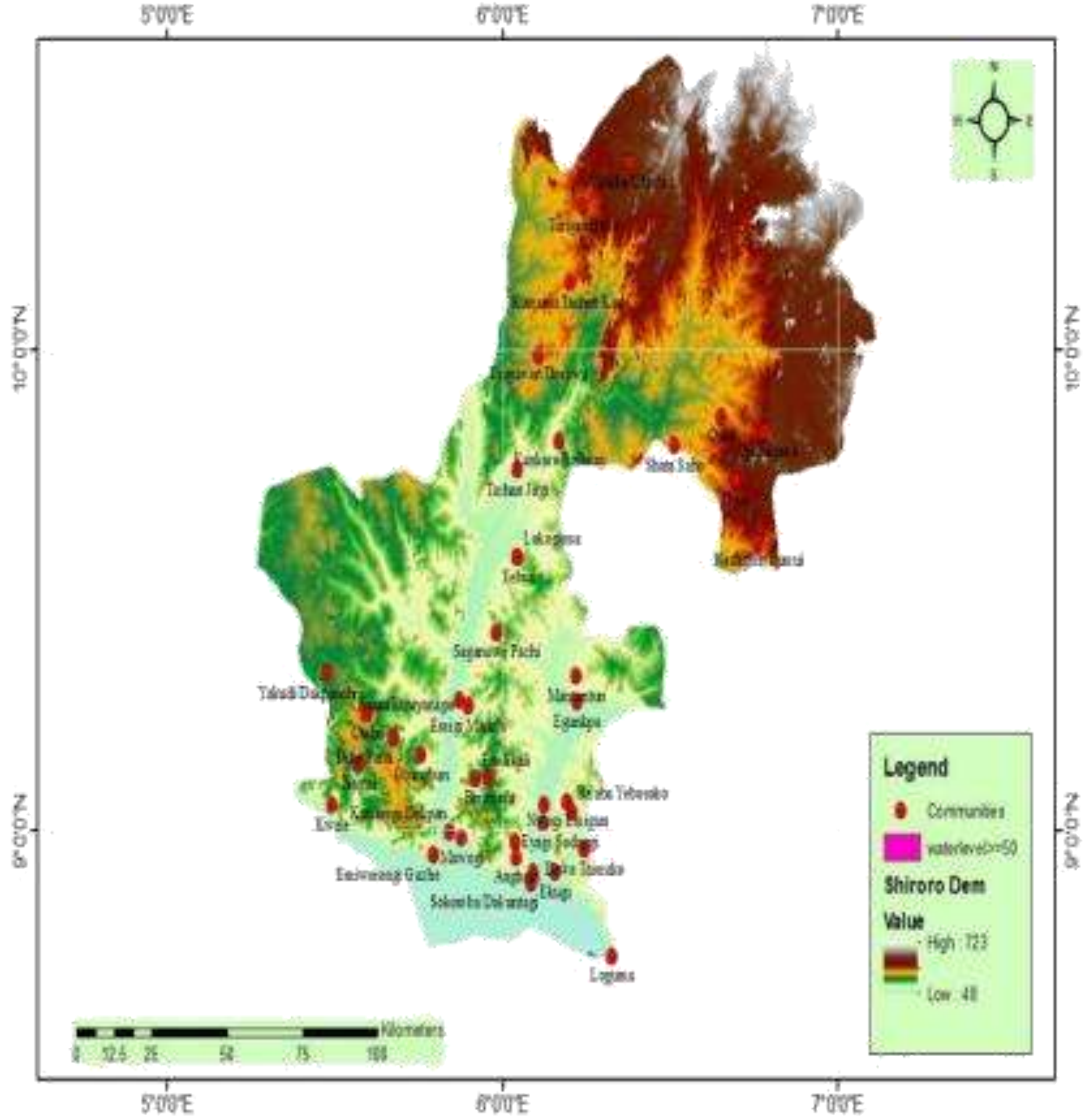


Figure 4.18: Flood inundation at 50 m above sea level

However, at an altitude of 100 meters above sea level, and further increase in the volume of discharge, a total of 2729.162657 km2 (14.47%) of land area was submaged depicting an increase of 14.46%. Figure 4.19 shows the flood inundation at 100m.

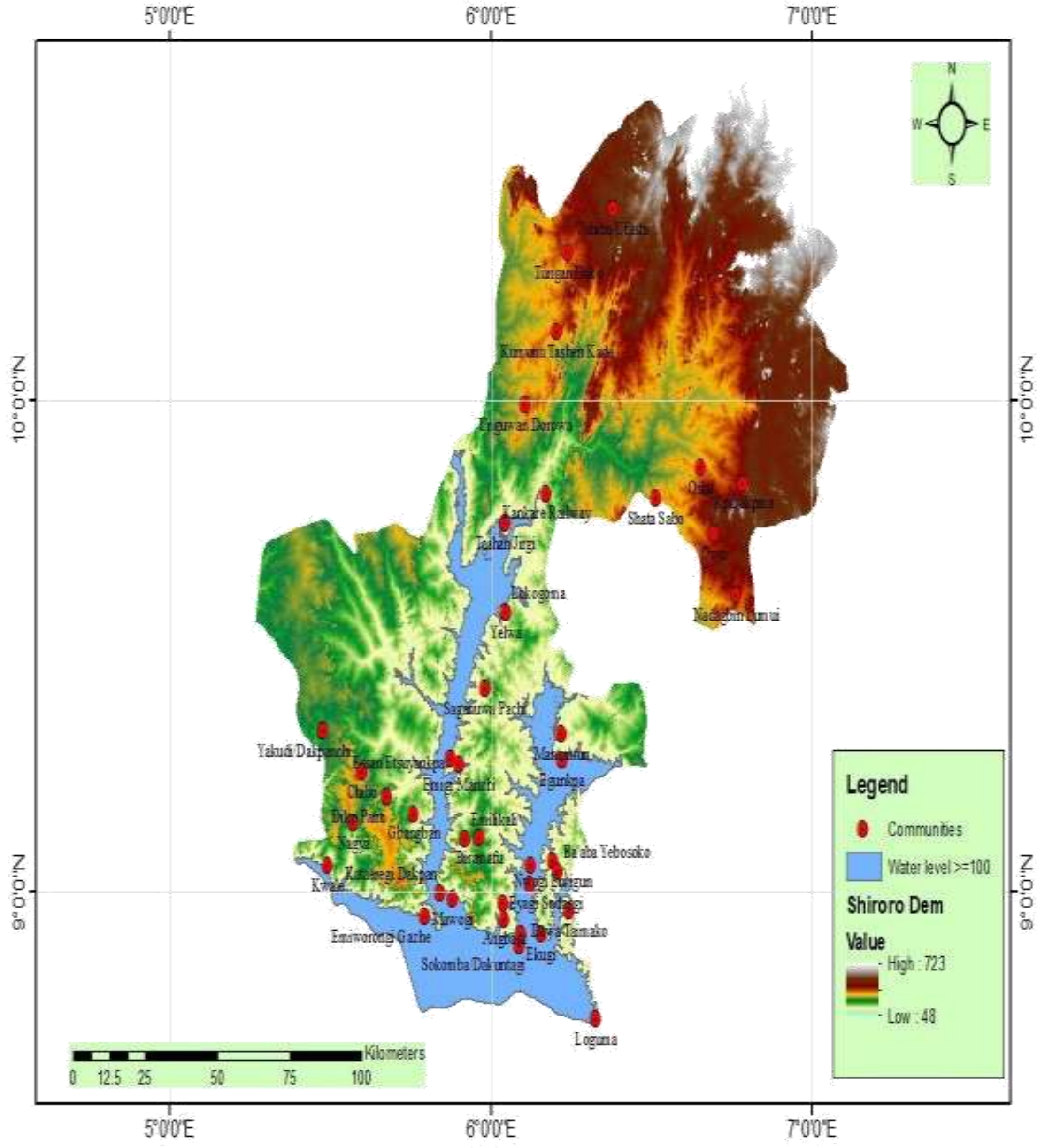


Figure 4.19: Flood inundation at 100 m above sea level

Furthermore, when the discharge was increased with an increase in altitude to 150 m, more communities and farm lands were submerged covering a total 6647.622904 km^2 (35%) depicting 20.53% increase. Figure 4.20 shows more communities inundated in the study area with increase in volume of discharge and altitude.

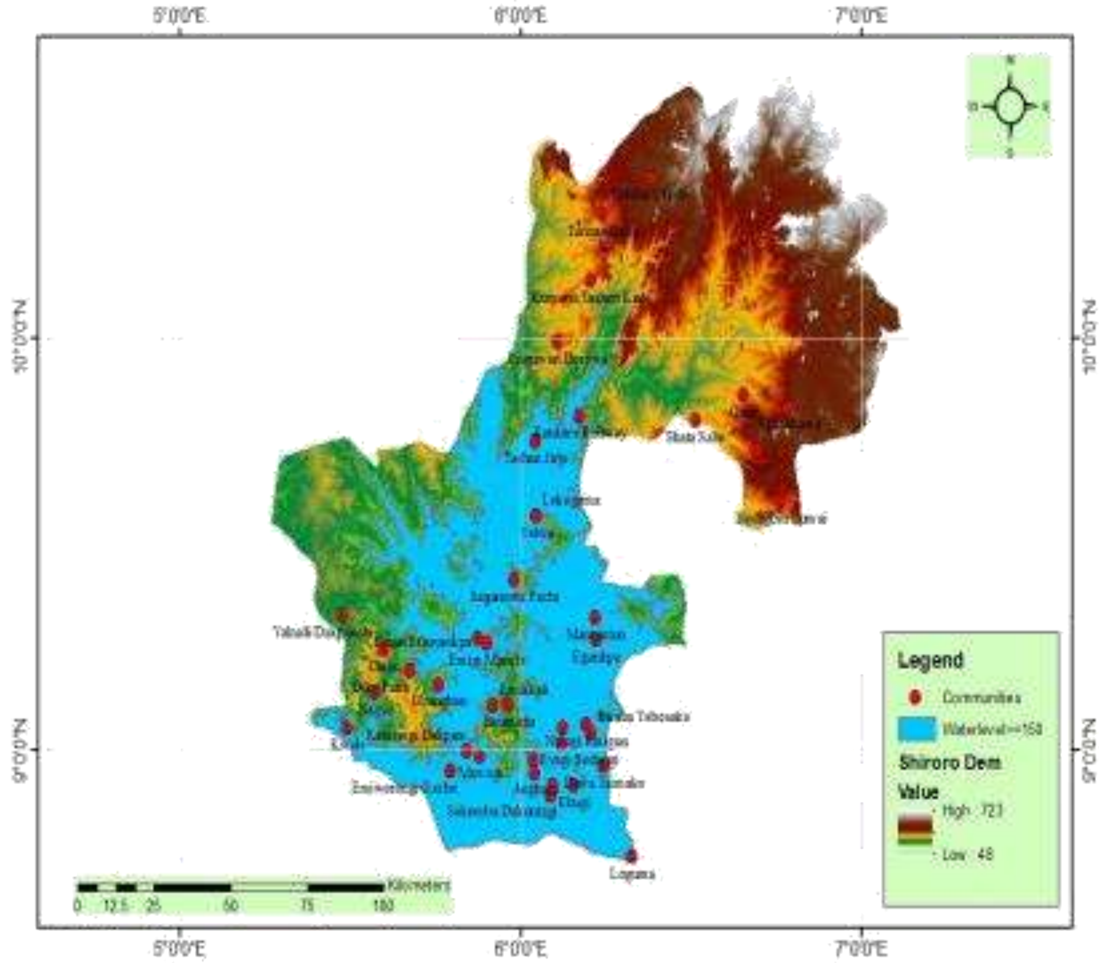


Figure 4.20: Flood inundation at 150 m above sea level

Additionally,when the volume of water was increased at an altitude of 200 m , 50% of the study area was submerged. More communities were inundated including farmlands covering a total of 9486.40261km^2 (50.29%). Figure 4.21 shows half of the study area submerged at 200m above sea level this agrees with the work of (IIRS, 2017).

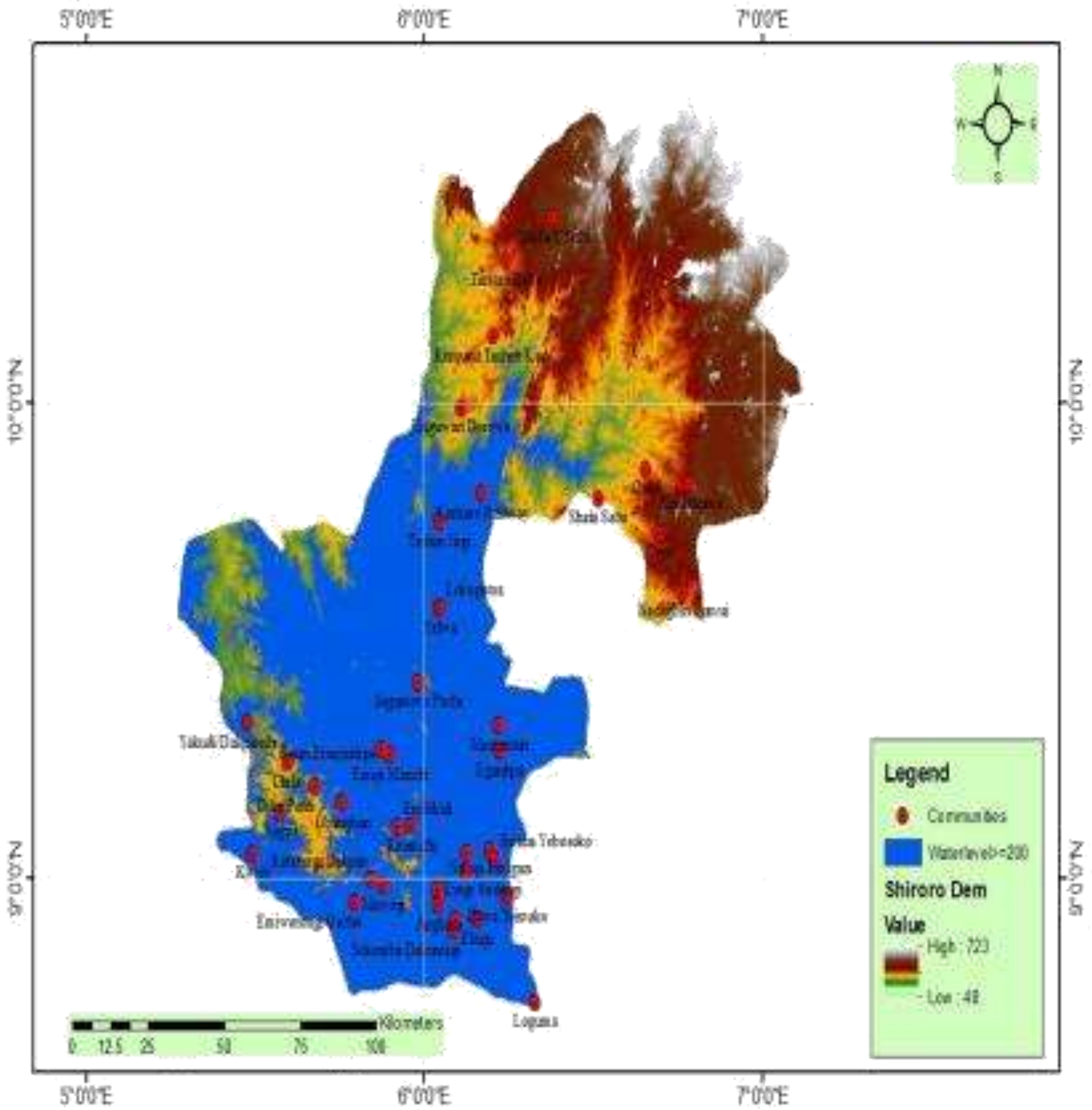


Figure 4.21: Flood inundation at 200 m above sea level

Consequently, it can be deduced that as environmental degredation continue unchecked in the uprestream majorly as a result of farming activities, the magnitude and devasting impact of flood continue to increase thereby putting more communities, lives and livelihoods at risk. Inaddition, with continues increase, the upstream communities are also at risk of the flood disaster in the near future.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

As indicated in the findings of this research work, geospatial data such as Digital elevation Model (DEM), hydrological layers such as flow direction, drainage network, land use and Land cover maps are major spatial data input in flood studies. The DEM is the primary and most important data in the application of Geospatial technology in flood studies because it is the base of other geospatial data extractions. The land use and land cover maps generated in objective two are also important for the sole reason of the extraction of surface roughness coefficient (manning n's value) for use in objective three estimation of surface roughness coefficient for surface runoff in the sub-basin. The result revealed that study area is dominantly Agricultural land with manning n's values ranging from 0.03 for built-up areas to 0.04 for water body.

The findings of surface runoff estmation in objective three shows that the tributaries play an important role in flooding activities in the study area because the release of inflow and discharge from the Dam is not the only factor responsible for flooding, but also the phenomena in each of the sub-basins. The data use for objective four was found to have some technical hitches which affect the outcome of objective four.

Flood simulation was carried out in ArcGIS through HECGeo-Ras Plug in and spatial analyst tool determine the inundation level during an upsurge of water above the river bank. The inundation level was done for 50m, 100m, 150m and 200m respectively. Findings reveals that on 50 meter above sea level, 0.01% of the study area was inundated, similarly, at 100 meter above sea level 14.47% of the study area was inundated, furthermore, at 150m 35% was inundated, while at 200m 50.29%) was inundated.

Furthermore, the integrated use of hydrologic Modelling softwares HEC-RAS and HEC-HMS with their corresponding add-ins HEC-Geo and HEC-GeoHMS GIS and remote sensing into is a welcome and promising development for water resources researchers. This is basically because projectes can be impoted in and exported out of the softwares for edtion with ease and flexibility.

5.2 Recommendations

Based the findings of this study, the following are recommendated to enhance further research and flood management in the study area.

1. Digital Elevation Model (DEM) is an important data in flood studies, therefore a high spatial resolution DEM with a resolution ≤ 10m should be used for further studies. Also Using DEM hydrologic features extraction is fast, flexible and reliable thus, should be used rather than tradtional methods of evaluating topographic maps.
2. Since the land use and land cover LULC map was only used to extract manning n's value and overlay for flood simulation, a high or low spatial resolution satellite imagery may suffice, and could be downloded from different well known and acceptable data sources online. This will reduce time and cost in any further and similar studies.
3. The authorities of Shiroro Dam should as a matter of community development and industry coporate responsibility, collaborate with academics, by sponsoring further and relevant research in the study area. This will strengthen and influence decision making with regards re satellment and compensation of the affected communities.

4. The authorities of Shiroro Dam should also embark on serious public enlightment through environmental education to sensitise the public especially the affected communities through radio jingles and television documentaries on the effects of floods and flood plains degredation on the upstream and downstram communities of the Dam.

5.3 Contributions to Knowledge

This study established the necessity of flood monitoring and risk assessment across floodplain communities downstream of hydroelectricity dams. The result further identified the expected challenges of human habitation of downstream communities as a pointer for planners, disaster managers and other relevant stakeholders in environmental management.

REFERENCES

Abdulkadir, A. (2011). Flood vulnerability assessment for enhanced utilization of wetl & ecosystem downstream of jebba hydroelectric dam. *Journal of Flood Engineering (JFE), 2*(1), 37–48.

Ade, M. A. & Afolabi, Y.D. (2013). monitoring urban sprawl in the federal capital territory of nigeria using remote sensing & gis techniques Article in *Ethiopian Journal of Environmental Studies & Management*

Adeniran, O., Alagbe, A., & Aboderin, O. (2013). delineation of flood vulnerable zones & disaster risk management along Asa River : A GIS Approach. In *Environment for RSustainability* (pp. 1–16). Abuja, Nigeria, 6 – 10 May 2013.

Adikari, Y., & Yoshitani, J. (2009). *global trends in water-related disasters : an insight for policymakers. the united nations world water development Report 3 Water in a Changing World*.

Ahmad, S. S. S. (2015). A Comparative study of concrete strength prediction using fuzzy modeling & neuro - fuzzy modeling techniques . In *Proceedings of Mechanical Engineering Research Day 2015* (pp. 147–149). Centre for Advanced Research on Energy.

Al-Abed, N., Abdulla, F., & Abu-Khyarah, A. (2005). GIS-hydrological models for managing water resources in the Zarqa river basin. *Environmental Geology, 47*, 2005.

Al-ghamdi, K. A., Elzahrany, R. A., Mirza, M. N., & Dawod, G. M. (2012). Impacts of Urban Growth on Flood Hazards in Makkah City , Saudi Arabia. *International Journal of Water Resources & Environmental Engineering*, *4*(2), 23–34. http://doi.org/10.5897/IJWREE11.128

Al-Smadi, M. (1998). incorporating spatial & temporal variation of watershed response in a gis based hydrologic model. *Hydrology*. Http//scholar/lib. Vt.Educlthesis/Availableetd/121698/112858/Unrestricted/smadi/Pdf

Anaba, L. A., Banadda, N., Kiggundu, N., Wanyama, J., Engel, B., & Moriasi, D. (2017). Application of SWAT to Assess the Effects of L & Use Change in the Murchison Bay Catchment in Ug & a. *Computational Water, Energy & Environmental Engineering*, *6*, 24–40. http://doi.org/10.4236/cweee.2017.61003

& erson, J.R., Hardy, E.E., Roach, J.T. & Witmer, W.E., (1976). A l & -use & l & -cover classification system for use with remote sensing data, *U.S. Geological Survey Professional Paper* 964, Reston, Virginia, *U.S. Geological Survey*, 23.

Awoniran, D. R., Adewole, D., Adegboyega, S. S., & Anifowose, Y. (2013). Assessment of Environmental Responses to L & Use / Land & Cover Dynamics in the Lower Ogun River Basin , Southwestern Nigeria. *International Journal of Sustainable L & Use & Urban Planning*, *1*(2), 16–31.

Bello, O. M., & Aina, Y. A. (2014). Satellite Remote Sensing as a Tool in Disaster Management & Sustainable Development : Towards a Synergistic Approach. *Procedia - Social & Behavioral Sciences, Elsevier*, *120*(March), 365–373. http://doi.org/10.1016/j.sbspro.2014.02.114

Bhuiyan, H. A., Mcnairn, H., Powers, J., & Merzouki, A. (2017). Application of HEC-HMS in a Cold Region Watershed & Use of RADARSAT-2 Soil Moisture in Initializing the Model. *Hydrology*, *4*(9), 1–19. http://doi.org/10.3390/hydrology4010009

Boonya-aroonnet, S., Maksimovi, Č., Prodanovi, D., & Djordjevi, S. (2007). *Urban Pluvial Flooding : Development of GIS Based Pathway Model for Surface Flooding & Interface with Surcharged Sewer Model*. *Novatech*.

Botes, R., Smith, A., & Uken, P. R. (2012). Application of technical GIS data models for regional flood risk determination. *Hydrology.3(2) 15-32*

Boucher, M. (2010). Rainfall Intensity - Duration - Frequency (IDF) Curves. *Contra Costa Coutry Flood Control & Water Conservation District*. 1-16

Butt, A., Shabbir, R., Ahmad, S.S., Aziz, N., (2015). L & use change mapping & analysis using Remote Sensing & GIS:. a case study of Simly watershed, Islamabad, Pakistan. Egyptian journal of Remote Sensing & Space Science. 18 (2), 251–259.

Bruen, M., & Yang, J. (2006). Combined Hydraulic & Black-Box Models for Flood Forecasting in Urban Drainage Systems. *Journal of Hydrologic Engineering*, *11*(6), 589–596. http://doi.org/10.1061/(ASCE)1084-0699(2006)11:6(589)

Cai, H. (2010). Flood Forecasting on the Humber River Using an Artificial Neural Network Approach. An published M.Engr. thesis. Memorial University of Newfoundl & , Faculty of Engineering & Applied Science, New foundl & , Canada. 1-116

Canevari-luzardo, L., Bastide, J., Choutet, I., & Liverman, D. (2015). Using partial participatory GIS in vulnerability & disaster risk reduction in Grenada. *Climate & Development , Taylor & Francis*, (September), 1756–5537. http://doi.org/10.1080/17565529.2015.1067593

Chaurasia, K., & Garg, P. K. (2015). The role of satellite derived data for flood inundation mapping using GIS. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences - ISPRS Archives, 40*(3W3), 235–239. http://doi.org/10.5194/isprsarchives-XL-3-W3-235-2015

Che-Ghani, N. B. (2014). *Flood Modelling for Small Urban Catchment of Sungai Raja, Alor Setar, Kedah*. Malaysia. An unpubissheddd MS.c thesis, Universiti Putra Malaysia. 1-44

Chen, W. B., & [illegible]

http://doi.org/10.3390/w9030203

Chen, Y., Li, J., Wang, H., Qin, J., & Dong, L. (2017). Large-watershed flood forecasting with high-resolution distributed hydrological model. *Hydrology & Earth System Sciences*, *21*, 735–749. http://doi.org/10.5194/hess-21-735-2017

Chen, Y., Xu, Y., & Yin, Y. (2009). Impacts of l & use change scenarios on storm runoff generation in Xitiaoxi basin, China. *Quaternary International*, 208, 1–8.

Chima, C. I. (2012). Monitoring & Modelling of Urban L & Use in Abuja Nigeria, Using Geospatial Information Technologies. Unpublished MSc thesis, Coventry University, United Kingdom. Retrieved from http://curve.coventry.ac.uk/open

Chingombe, W., Pedzisai, E., Manatsa, D., Mukwada, G., & Taru, P. (2015). A participatory approach in GIS data collection for flood risk management, Muzarabani district, Zimbabwe. *Arabian Journal of Geoscience, Springer, 1*(2), 1–18. http://doi.org/10.1007/s12517-014-1265-6

Cosgrave, J. (2014). Responding to Flood Disasters: Learning from previous relief & recovery operations. London: ALNAP/ODI. Retrieved from www.alnap.org

Congalton, R. G. (1991). A review of assessing the accuracy of classifications of remotely sensed data. *Remote sensing of environment*, *37*(1), 35-46.

Dapang, Y. & Coulthard ,T. J. (2015). Evaluating the importance of catchment & Impact hydrological parameters for urban surface water flood modelling using a simple hydro- inundation model. *Journal of Hydrology* 524, 385-400.

Dadhwal, V. K., Mishra, N., & Aggarwal, S. P. (2010). Hydrological Simulation of Mahanadi River Basin & Impact of L & Use / L & Cover Change on Surface Runoff Using a Macro Scale Hydrological Model. *ISPRS TC VII Symposium – 100 Years ISPRS, Vienna, Austria*, *XXXVIII*(7B), 165–170.

Dalil, M., Nda, H. M., Yamman, U. M., Husaini, A., & Mohammed, S. L. (2015). An assessment of flood vulnerability on physical development along drainage channels in Minna , Niger State, Nigeria. *African Journal of Environmental Science & Technology*, *9*(January), 38–46. http://doi.org/10.5897/AJEST2014.1815

Das, P., Mahmud, K., & Karmaker, S. (2013). Surface-Runoff Characteristics Under Simulated Rainfall Conditions. *Progress Agriculture*, *1 & 2*(24), 219–227.

de Almeida, G. A., Bates, P., Freer, J. E., & Souvignet, M. (2012). Improving the stability of a simple formulation of the shallow water equations for 2-D flood modeling. *Water Resources Research*. 48, 1–14.

de Moel, H., Van Alphen, J., & Aerts, J. . (2009). Flood Maps in Europe – Methods, Availability & Use. *Natural Hazards & Earth System Sciences*, *9*(77), 289–301.

Demir, V., & Kisi, O. (2016). Flood Hazard Mapping by Using Geographic Information System & Hydraulic Model : Mert River , Samsun, Turkey. *Advances in Meteorology*, *2016*, 1–9.

Dukiya, J. J. (2012). Remote Sensing & GIS Assessment of Flood Vulnerability of Nigeria’s Confluence Town. *Journal of Research in National Development*, *1*(3), 123–129. http://doi.org/10.1017/CBO9781107415324.004

Ejemma, E., Sunday, V. N., Eluwah, A.N., Onwuchkwa, I. S. (2014). Mapping Flood Vulnerability arising from L & use / L & covers Change along River Kaduna , Kaduna State , Nigeria. *IOSR Journal of Humanities & Social Sciences*, *19*(7), 155–160. Retrieved from http://iosrjournals.org/iosr-jhss/papers/Vol19-issue7/Version-4/Y01974155160.pdf

Ejikeme, J. O., Igbokwe, J. I., Ojiako, J. C., Emengini, E. J., & Aweh, D. S. (2015). Modelling the Impact of Flooding Using Geographic Information System & Remote Sensing. *Internation Journal of Technical Research & Application*, *3*(4), 67–72.

Elias, M. (2010). GIS & Remote Sensing for Natural Resource Mapping & Management. *Geospatial World*. 2(3), 36-51.

ESRI. (2011). ESRI authorized course Introduction To ArcGIS 9.

Etuonovbe, A. K. (2011). The Devastating Effect of Flooding in Nigeria The Devastating Effect of Flooding in Nigeria. *Hydrography & the Environment,* 1–15.

Eze, J. N. (2004). *Vulnerability & Adaptation to Climate Variability & Extremes: A Case Study of Flooding in Niger State, Nigeria*. Student Number : 0413447J - MSc research report. School of Geography Environmental Studies, Faculty of Science University of Witwatersr & , Johannesburg, South Africa.

Foody, G.M. (2002) status of L & cover classification Accuracy Assessment. *Remote Sensing of Environment,* 80(5), 185-201

Fosu C., Forkuo E. K., & Asare M. Y. (2013). River Inundation & Hazard Mapping – a Case Study of Susan River – Kumasi Proceedings of Global Geospatial Conference Québec City, Canada, 14-17.

Garba, H., Ibrahim, A., Ahmed, S., & Faustinus, B. (2013). Hydrological Modeling of the Impact of Climate Change on A Tropical Perennial River Flooding. *International Journal of Engineering & Science*, *3*(6), 30–35.

Garg, V., Nikam, B. R., Thakur, P. K., & Aggarwal, S. P. (2013). Assessment of the Effect of Slope on Runoff Potential of a Watershed Using NRCS-CN Method. *International Journal of Hydrological Science & Technology*, *3*(2), 141–159. http://doi.org/10.1504/IJHST.2013.057626

GFDRR. (2016). *The making of a riskier future: How our decisions are shaping future disaster risk*. Washington, D.C.

Gharbi, M., Soualmia, A., Dartus, D., & Masbernat, L. (2016). Comparison of 1D & 2D Hydraulic Models for Floods Simulation on the. *CODEN: Journal of Engineering & Material Science (JMESC)*, *7*(8), 3017–3026.

Hassaballah, K., Mohamed, Y., Uhlenbrook, S., & Biro, K. (2017). Analysis of Streamflow Response to L & use L & Cover Changes using Satellite Data & Hydrological modelling : Case Study of Dinder & Rahad Tributaries of the Blue Nile (Ethiopia / Sudan). *Hydrology & Earth System Sciences*, *128*(March), 1–22. http://doi.org/10.5194/hess-2017-128

Huong, H., & Pathirana, A. (2011). Urbanization & Climate Change Impacts on Future Urban Flood Risk in Can Tho City, Vietnam. *Hudrology & Eath System Sciences Discussions*, *8*, 10781–10824. http://doi.org/10.5194/hessd-8-10781-2011

IIRS. (2017). Flood Hydrology, Risk Zone Mapping & Damage Assessment With RS & GIS. Indian Institute of Remote Sensing, MSc lecture series, Dehradun, India.

Ikusemoran, M., Kolawole, M. S. & Martins, A. K. (2014). Terrain Analysis for Flood Disaster Vulnerability Assessment : A Case Study of Niger State , Nigeria. *American Journal of Georaphic Information System*, *3*(3), 122–134. http://doi.org/10.5923/j.ajgis.20140303.02

ISDR. (2005). Hyogo Framework for Action 2005-2015. *Strategy*, (January), 1–25. http://doi.org/10.1017/CBO9781107415324.004

Isioye, O. A., Enebeli, I., Alademomi, S. A., & Akomolafe, E. (2012). Terrain Analysis in GIS & Its Significance to Surface Runoff Analysis (A Study of Basawa Community in Sabon Gari L.G.A. of Kaduna State, Nigeria). *International Journal of Advanced Scientific Engineering & Technological Research, IJASETR*, *1*(1), 72–92.

Isioye, O. A., & Jobin, P. (2012). An assessment of digital elevation models (DEMs) from different spatial data sources. *Asian Journal of Engineering, Sciences & Technology*, *2*(1), 1–17.

James, G., Shaba, H., Zubair, O., Teslim, A., Nuhu, A., & Yusuf, G. (2013). Space-Based Disaster Management in Nigeria : The Role of the International Charter " Space & Major Disasters " Space-Based Disaster Management in Nigeria : Journal *Environment for Sustainability*, 1–16. Abuja, Nigeria.

Jayasinghe, A., Mahanama, P. K. ., Senanayake, L., B & ara, L., & Seifert, I. (2013). Participatory GIS (PGIS) as a tool for Flood Mapping in Climate Change Adaptation ; A study of Batticaloa City , Sri Lanka. In *Europian Climate Change Adaptation Conference (ECCA).*

Jenson, S. & Domingue, J. (1988) Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis. *Photogrammetric Engineering & Remote Sensing*, 54, 1593-1600.

Jha, A., Lamond, J., Bloch, R., Bhattacharya, R., Lopez, A., Papachristodoulou, N., … Barker, R. (2011). Five Feet High & Rising Cities & Flooding in the 21 st Century. World Bank *Policy Research Working Paper*, Technical Report, 5648 .

Jinadu, M. A. (2014). Rural Hazards & Vulnerability Assessment in the Downstream Sector of Shiroro Dam , Nigeria. In *Global Risk Forum Davos Planet@Risk* 2(1), 370–375. Retrieved from http://www.planet-risk.org

Jung, Y., Kim, D., Kim, D., Kim, M., & Lee, S. O. (2014). Simplified Flood Inundation Mapping Based on Flood Elevation-Discharge Rating Curves Using Satellite Images in Gauged Watersheds. *Water*, 6(5), 1280–1299. ISSN 2073-4441. doi:10.3390/
w6051280,

Jung, Y., Merwade, V., Yeo, K., Shin, Y., & Lee, S. O. (2013). An approach using a 1D hydraulic model, l & sat imaging & generalized likelihood uncertainty estimation for an approximation of flood discharge. *Water, 5*(4), 1598–1621. http://doi.org/10.3390/w5041598

Kab & a, T.H. & Palamuleni, L.G. (2013). L & Use/Cover Changes & Vulnerability to Fooding in the Harts Catchment, South Africa. *South African Geographical Journal, 2013* , *95*(1), 105–116. http://dx.doi.org/10.1080/03736245.2013.806165. Routledge Taylor & Francis Group

Karamage, F., Zhang, C., Fang, X., Liu, T., Ndayisaba, F., Lamek, N., Nsengiyumva, J. B. (2017). Modeling Rainfall-Runoff Response to L & Use & L & Cover Change in Rw & a (1990–2016). *MDPI Water, 9*(147), 1–24. http://doi.org/10.3390/w9020147

Khosroshahizadeh, S., Pourkermani, M., & Almasian, M. (2016). Lineament Patterns & Mineralization Related to Alteration Zone by Using ASAR-ASTER Imagery in Hize Jan-Sharaf Abad Au-Ag Epithermal Mineralized Zone (East Azarbaijan-NW Iran). *Open Journal of Geology, 6(4),* 232–250. Retrieved from http://www.scirp.org/journal/ojg

Kindl, L. (2012). *Exploring the benefits of satellite remote sensing for flood prediction across scales*. University of Iowa.

Komolafe, A. A., Adegboyega, S. A., & Akinluyi, F. O. (2015). A Review of Flood Risk Analysis in Nigeria. *American Journal of Environmental Sciences*, *11*(3), 157– 166. http://doi.org/10.3844/ajessp.

Kumar, M. (2017). *Digital Image Processing Image Enhancement Techniques*. IIRS lecture series, Dehradun, India. Retrieved from www.iirs.gov.in

Kute, S., Kakad, S., Bhoye, V., & Walunj, A. (2014). Flood Modeling of River Godavari Using Hec-Ras. *International Journal of Research in Engineering & Technology*, *3*(9), 81–87. Retrieved from http://www.ijret.org

Laks, I., Sojka, M., Walczak, Z., & Rafał, W. (2017). Possibilities of Using Low Quality Digital Elevation Models of Floodplains in Hydraulic. *Water*, *9*(283), 1–19. http://doi.org/10.3390/w9040283

Langhammer, J., & Vilimek, V. (2008). L & scape changes as a factor affecting the course & consequences of extreme floods in the Otava river basin, Czech Republic. *Environmental Monitoring & Assessment*, *144*, 53 – 66.

Ngen, V. & Lankreijer, H. (2016). Hydrographs & the Gumbel distribution. *Hydrology, 5(2), 155-176.*

Lawal, D. U., Matori, A. N., Hashim, A. M., Ch & io, I. A., Sabri, S., Balogun, A. L., & Abba, H. A. (2011). Geographic Information System & Remote Sensing Applications in Food Hazards Management: A Review. *Research Journal of Applied Sciences, Engineering & Technology*, *3*(9), 933–947.

Le & ro, J. (2008). A Dynamic-Objective-Function algorithm to calibrate a 1D/1D Coupled Hydraulic Model Versus a 1D/2D Model. In *11th International Conference on Urban Drainage* (pp. 1–11). Edinburgh, Scotl & , UK,.

Lee, J. E., Heo, J., Lee, J., & Kim, N. W. (2017). Assessment of Flood Frequency Alteration by Dam Construction via SWAT Simulation. *Water*, *9*(264), 1–19. http://doi.org/10.3390/w9040264

Li, T., & Gao, Y. (2015). Runoff & Sediment Yield Variations in Response to Precipitation Changes: A Case Study of Xichuan Watershed in the Loess Plateau, China. *Water*, *7*, 5638–5656. http://doi.org/10.3390/w7105638

Machado, M. S., & Ahmad, S. (2007). Flood hazard Assessment of Atrato River in Colombia. *Water Resources Management*, *21*(2), 591–609.

Mamodu, A., Kor, J. D., Chukwu, N. J., Waziri, S. H., Ofor, N. P., & Alhassan, D. U. (2015). Geospatial Science Flood Vulnerability Assesseement Using Field Observation & Geospatial Techniques ; A Case Study of Makurdi, Benue State, Nigeria. *Geospatial Science*, *1*(1), 9–16.

Maniyar, F. A., & Bhatt, J. P. (2015). Literature Study on Hydraulic Modelling of Floodplain Mapping. *International Journal of Research in Engineering & Technology IJRET*, *4*(11), 272–276. Retrieved from http://www.ijret.org

Manta, I. H., & Ahaneku, I. E. (2009). Flood frequency analysis of Gurara River catchment. *Scientific Reserach & Essay*, *4*(6), 636–646. Retrieved from http://www.academicjournals.org/SRE

Marfai, M. A. (2003). GIS Modelling of River & Tidal Flood Hazards in a Waterfront City Case Study: Semarang City, Central Java, Indonesia. *The Environmentalist* , 28, 237–248.

Mayomi, I., Anthony, D., & Maryah, U. . (2013). GIS Based Assessment of Flood Risk
& Vulnerability of Communities in the Benue Floodplains, Adamawa State ,

Nigeria. *Journal of Geography & Geology*, *5*(4), 148–160. http://doi.org/10.5539/jgg.v5n4p148

McCall, M. K. (2008). *Participatory Mapping & Participatory GIS (PGIS) for CRA, Community DRR & Hazard Assessment. Consortium, CRA Toolkit, Participation Resources,* (Vol. 12). Retrieved from http://drm.cenn.org/Trainings/Multi Hazard Risk Assessment/Lectures_ENG/Session 04 Elements at risk/Background/PGIS for Disaster Risk Assessment.pdf

McCall, M. K. (2014). Mapping Territories , L & Resources & Rights : Communities Deploying Participatory Mapping / PGISs In Latin America. *Revista Do Departamento de Geografia – USP*, *Especial C*, 94–122.

Merz, B., Thieken, A. H., & Gocht, M. (2007). Flood Risk Mapping at the Local Scale: Concepts & Challenges. In S. et al. Begum (Ed.), Flood risk management in Europe *Springer*, 231–251. Springer International Publishing.

Moore, M. R. (2011). *Development of a High-Resolution 1D/2D Coupled Flood Simulation of Charles City, Iowa*. The University of Iowa Iowa City, Iowa, U.S.A. Retrieved from http://ir.uiowa.edu/etd/1032/

Mujere, N. (2011). Flood Frequency Analysis Using the Gumbel Distribution. *International Journal of Computer Science & Engineering (IJCSE)*, *3*(7), 2774–2778.

Mukherjee, M. K. (2013). Flood Frequency Analysis of River Subernarekha, India, Using Gumbel's Extreme Value Distribution. *International Journal of Computational Engineering Research*, *3*(7), 12–19.

Muller, A., & Reinstorf, F. (2011). Exploration of L & -Use Scenarios for Flood Hazard Modeling-The Case of Santiago de Chile. *Hydrology & Earth System Sciences Discussions*, *8*, 3993–4024. http://doi.org/10.5194/hessd-8-3993-2011

Musa, J. Yunusa, M.B. Adamu, M. & Mohammed, A. (2016). Flood Risk Analysis & Hazard Assessment in Gusoro Community Downstream of Shiroro Dam Using Geospatial Approach. *Academia Journal of Environmetal Science*, *4*(2), 20–27. http://doi.org/10.15413/ajes.2015.0111

Musa, J., Adenle, A. A., & Adebayo, M. A. (2015). Vulnerability Assessment of Communities along Oil Pipeline Area using Geospatial Technique : A Case Study of Izom Community 1. In *57th Annual Conference of the Association of Nigerian*

Geographers (UNILAG ANG- 2016) (pp. 1–15). Lagos.

Musungu, K., Motala, S., & Smit, J. (2011). A Participatory Approach to Data Collection for GIS for Flood Risk Management in Informal Settlements of Cape Town. *AfricaGEO Conference*. Retrieved from http://hdl.h & le.net/10625/48590

Naikoo, M. W., Rihan, M., & Ishtiaque, M. (2020). Analyses of l & use l & cover (LULC) change & built-up expansion in the suburb of a metropolitan city: Spatio-temporal analysis *of Delhi NCR using l & sat datasets. Journal of Urban Management, 9(3),347-359*

Ndanusa, A. B., Dahalin, Z. M., & Ta'a, A. (2018). Topographic-Based Framework for Flood Vulnerability Classification: A Case of Niger State, Nigeria. *Journal of Information System & Technology Management*, 3(9), 27-38

Nicholas, J. E. (2014). Assessment of the 2012 Flooding in Mararaba Karu local government area of Nasarawa State, Nigeria. An unpublished MSC thesis, Department of Geograhpy, ABU Zaria, Nigeria.

Niger State. (2012). Facts & Figures About Niger State, 52. Retrieved from http://nigerstats.ni.gov.ng/uploads/docs/FACTS & FIGURES 2012.doc 2.pdf

Nkwunonwo, U.C, Whitworth, Malcolm, Baily, B. (2015). Flooding & Flood Risk Reduction in Nigeria: Cardinal Gaps. *Journal of Geography & Natural Disasters, 5*(1), 1–12. http://doi.org/10.4172/2167-0587.1000136

Nyombo, D., & Aggarwal, S. . (2008). Flood Inundation Hazard Modelling of the River Kaduna Using Remote Sensing & Geographic Information Systems. *Journal of Applied Sciences*, *4*(12), 1822–1833.

Obeta, M. C. (2014). Institutional Approach to Flood Disaster Management in Nigeria : Need for a Preparedness Plan. *British Journal of Applied Science & Technology*, *4*(33), 4575–4590. http://doi.org/10.9734/BJAST/2014/11844

Odufuwa, B. O., Adedeji, O. H., Oladesu, J. O., & Aloysius, B. (2012). Floods of Fury in Nigerian Cities. *Journal of Sustainable Development*, *5*(7), 69-82. http://doi.org/10.5539/jsd.v5n7p69

Ogba, C. O., & Utang, P. (2008). Integrated Approach To Urban Flood Adaptation In The Niger Delta Coast of Nigeria. *Natural Disaster Management*, 1–10.

Ojigi, M.l., Abdulkadir, F.I. & Aderoju, M. O. (2013). Geospatial Mapping & Analysis of the 2012 Flood Disaster in Central Parts of Nigeria. *8th National GIS Symposium. Dammam. Saudi Arabia. April 15-17, 2013th*, 1–14.

Olajuyigbe, A. E., Rotowa, O. O., & Durojaye, E. (2012). An assessment of flood hazard in Nigeria: The case of mile 12, Lagos. *Mediterranean Journal of Social Sciences*, *3*(2), 367–375. http://doi.org/10.5901/mjss.2012.v3n2.367

Olang, L. O., Kundu, P. M., Ouma, G., & Fürst, J. (2012). Impacts of L & Cover Change Scenarios on Storm Runoff Generation : A Basis for Management of the Ny
& o Basin, Kenya. *L & Degradation & Development*, John Wiley & Sons, Ltd., 1–11. http://doi.org/10.1002/ldr.2140 IMPACTS

Olukanni, D. O., & Salami, A. W., (2012). Assessment of Impact of Hydropower Dams

Reservoir Outflow on the Downstream River Flood Regime–Nigeria's Experience. Chapters, in: Hossein Samadi-Boroujeni (ed.), *Hydropower - Practice & Application*, *IntechOpen.*http://doi.org/10.5772/33180

Onwuka, S. U., Ikekpeazu, F. O., & Onuoha, D. C. (2015). Assessment of the Causes of 2012 Floods in Aguleri & Umuleri, Anambra East Local Government Area of Anambra State, Nigeria. *British Journal of Environmental Sciences*, *3*(1), 1689–1699. http://doi.org/10.1017/CBO9781107415324.004

Orok, H. I. (2011). A GIS-Based Flood Risk Mapping of Kano City, Nigeria. Unpublished M.Sc., School of Environmental Sciences, University of East Anglia University Plain, Norwich. http://www.akamaiuniversity.us/PJST.htm

Palm, F. (2015). Urban Vegetation Mapping using Remote Sensing Techniques A comparison of methods. *Sensors*, *21*(14), 4738; https://doi.org/10.3390/s21144738

Parker, R., & Silke, H. (2010). Responding to Floods in West Africa : Lessons from Evaluation. World Bank Report.

Patel, D. P. (2010). Flood Assessment by Integrated Hydrological Modeling with RS & GIS. *Water Resources*, 3(1), 131-168.

Patrick, G. (2009). Linking rural community livelihoods to resilience building in flood risk reduction in Zimbabwe. *Jamba: Journal of Disaster Risk Studies*, *2*(1), 71–89. Retrieved from http://www.ndmc.gov.za/LinkClick.aspx?fileticket=n_5rPYFPsgc%3D & tabid=267

Paudel, M. (2010). An examination of distributed hydrologic modeling methods as compared with traditional lumped parameter approaches. An unpublished Ph.D. thesis. Brigham Young University, Provo, Utah.

Pechlivanidis, I. G., Jackson, B. M., Mcintyre, N. R., & Wheater, H. S. (2011). Catchment Scale Hydrological Modelling : A Review of Model Types , Calibration Approaches & Uncertainty Analysis Methods In the Context of Recent Developments *Technology & Applications. Global NEST*, *13*(3), 193–214.

Pedzisai, E., Manatsa, D., Mukwada, G., Taru, P., & Paper, O. (2015). A participatory approach in GIS data collection for flood risk management , Muzarabani district, Zimbabwe. *Arabian Journal of Geoscience* *8*(2), 12–15. http://doi.org/10.1007/s12517-014-1265-6

Pincott-Miller, D., McGarry, D., Fairweather, H., & Srivastava, S. K. (2012). Review & framework development for addressing flash flood potential using GIS assisted spatial-hydrologic modelling. *Papers & Presentations of Queensl & Surveying & Spatial Conference 2012*, 1–16. Retrieved from http://research.usc.edu.au/vital/access/manager/Repository/usc:8848

Qi, H., Altinakar, M. S., & Jeon, Y. (2006). A decision support tool for flood management under uncertainty using GIS & remote sensing technology. In *The 7th Int. Conforence on Hydroscience & Engineering (ICHE-2006)* 2006, 1–17. Philadelphia.

Rahmati, O., Zeiniv & , H., & Besharat, M. (2016). Flood hazard zoning in Yasooj region, Iran, using GIS & multi-criteria decision analysis. *Geomatics, Natural Hazards & Risk*, 7(3), 1000–1017.

Ramírez, J. A. (2000). Prediction & Modelling of Flood Hydrology & Hydraulics. (E. Wohl;, Ed.) *Inl & Flood Hazards: Human, Raparian & Aquatic Communities*. Cambridge University Press.

Reis, S. (2008). Analyzing L & Use & l & Cover Changes Using Remote Sensing & GIS in Rize, North-East Turkey. *Sensors*, *8*, 6188–6202. http://doi.org/10.3390/s8106188

Renyi, L., & Nan, L. (2002). Flood area & damage estimation in Zhejiang, China. *Journal of environmental management* 66: 1-8.

Reynaud, A., Aubert, C., & Nguyen, M.-H. (2013). Living with Floods: Protective Behaviours & Risk Perception of Vietnamese Households. *The Geneva Papers on Risk & Insurance - Issues & Practice*, *38*(3), 547–579. http://doi.org/10.1057/gpp.2013.16

Richter, B. D., Postel, S., Revenga, C., Scudder, T., Lehner, B., Churchill, A., & Chow, M. (2010). Lost in Development's Shadow: The Downstream Human Consequences of Dams. *Water Alternatives*, *3*(2), 14–42. http://doi.org/10.1007/s11195-009-9131-2

Rogelis, M. C. (2016). Operational Flood Forecasting , Warning & Response for Multi-Scale Flood Risks in Developing Cities. Deflt University of Technology, Netherl & s.

Rongrong, W., & Guishan, Y. (2007). Influence of l & use /cover change on storm runoff – A case study of Xitiaoxi river basin in upstream of Taihu lake watershed. *Chinese Geographical Science*, *17*(4), 349 – 356.

Saghafian, B., Farazjoo, H., Bozorgy, B. & Farhad, Y. (2008). Flood Intensification due to Changes in L & Use. *Water Resour Manage*, 22, 1051–1067 (2008). https://doi.org/10.1007/s11269-007-9210-z

Salami, A. W., Mohammed, A. A., Adeyemo, J. A., & Olanlokun, O. K. (2015). Modeling Reservoir Inflow for Hydropower Dams Using Artificial Neural Network. *Nigerian Journal of Technology (NIJOTECH)*, *34*(1), 28–36. Retrieved from http://www.ajol.info/index.php/njt/article/viewFile/124000/113518

Salami, A. W., & Sule, B. F. (2010). An overview on Reservoir Operational Impact of Kainji , Jebba & Shiroro Dams on the Environment. *One Day Seminar on Reservoir Operation, Federal Ministry of Water Resources, Dams & Reservoir Operation, Nigeria*, 1–12. Retrieved from https://www.unilorin.edu.ng/publications/salamiaw/30 An overview on Kainji,Jebba & Shiroro Dams FMWR Abuja Seminer Salami & Sule Abuja.pdf

Saleh, F., Flipo, N., Habets, F., Ducharne, A., Oudin, L., Viennot, P., & Ledoux, E., (2011). Modeling the impact of in-stream water level fluctuations on stream-aquifer interactions at the regional scale. *Journal of Hydrolology*, 400 (3–4), 490–500.

Salihu, M. (2014). Discussion Paper: Highlights of Recent Floods In Nigeria. *Technical Workshop On: Toward a Consensus on Flood Risk Hotspots in Nigeria Under a*

Changing Climate, World Bank Office, Abuja, 1–5.

Samson, S. A., Eludoyin, A. O., Ogbole, J., Alaga, A. T., Oloko-Oba, M., Okeke, U. H., & Popoola, O. S. (2016). Drainage Basin Morphometric Analysis for Flood Potential Mapping in Owu Using Geospatial Techniques. *International Journal of Geography, Environment & Earth Science*, *4*(3), 1–8. http://doi.org/10.9734/JGEESI/2016/22223

S & ers, B. F., (2007). Evaluation of on-line DEMs for flood inundation modeling. *Advances in Water Resources*, 30 (8), 1831-1843, ISSN 0309-1708.

SFDRR 2015-2030. (2015). *Sendai Framework for Disaster Risk Reduction 2015 - 2030*.

Shaari, A. B., Ali-Khan, M. M., Muchtar, A., Bahar, A., & Nazaruddin, A. . (2016). Estimation of infiltration rate in major soil types of Kota Bharu , Kelantan , Malaysia. *Geological Society of Malaysia*, *62*, 7–11.

Sarhadi, A., Soltani, S. & Modarres, R. (2012). Probabilistic flood inundation mapping of ungauged rivers: Linking GIS techniques & frequency analysis, *Journal of Hydrology*, 458-459, 68–86,

Singh, P. (2010). Environment & Ecology (As Per the New Syllabus, B.Tech. 1 Year of U.P. Technical University).

SLG. (1999). *The potentiality of Industries & Agriculture in Shiroro Local Government Area of Niger State , Nigeria*.

Strupczewski, W. G., Kochanek, K., & Bogdanowicz, E. (2014). Flood Frequency Analysis Supported by the Largest Historical Flood. *Natural Hazards & Earth System Sciences*, *14*, 1543–1551. http://doi.org/10.5194/nhess-14-1543-2014

Subramanya, K. (2013). *Engineering Hydrology* (2nd ed.). TataMcGraw-Hill, New Delhi.

Suleiman, Y.M. & Ifabiyi, I. (2014). The Role of Rainfall Variability in Reservoir Storage Management at Shiroro. *An International Journal of Science & Technology Bahir Dar, Ethiopia*, *3*(2), 18–30. http://doi.org/http://dx.doi.org/10.4314/stech.v3i2.2

Takara, K. (2014). Free FLow, Reaching Water Security Through Cooperation. Japan. Retrieved from http://www.comaqua.org/comaqua-TakaraRijiUNESCO-FreeFlow.IMG_NEW.pdf

Tarboton, D. . (2003). Rainfall-Runoff Processes. In *A workbook to accompany the Rainfall-Runoff Processes Web module* (p. 159). Uttah U.S.A. Retrieved from http://ceefsl.engr.usu.edu/cee6400/TarbotonRainfallRunoffProcesses.pdf

Tawari-Fufeyin, P., Paul, M., & Godleads, A. O. (2015). Some Aspects of a Historic Flooding in Nigeria & Its Effects on some Niger-Delta Communities. *American Journal of Water Resources*, *3*(1), 7–16. http://doi.org/10.12691/ajwr-3-1-2

Thakur, S., Singh, A., & Suraiya, S. (2012). Comparison of Different Image Classification Techniques for L & Use L & Cover Classification : An Application in Jabalpur District of Central India. *International Journal of Remote Sensing & GIS*, *1*(1), 26–31. Retrieved from

http://rpublishing.org/Journal/IJRSG/Vol1Issue1/RSG1103.pdf

Tymkow, P., Karpina, M., & Borkowski, A. (2016). 3D GIS For Flood Modelling in River Valleys. In *ISPRS - International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences* (Vol. XLI, pp. 175–178). Prague, Czech Republic. http://doi.org/10.5194/isprsarchives-XLI-B8-175-2016

UN. (2012). *Summary of the UNFCCC Climate Change Conference in Doha, Qatar, 26 November – 7 December 2012*.

UN-HFA. (2005). *Hyogo Framework for Action, Building Resilience of Nations & Communities to Disaster: An Introduction to the Hyogo Framework for Action*.

UN-Water. (2006). *World Water*. Retrieved from http://www.unesco.org/water/wwap

UNISDR. (2011). *I*nternational Strategy for Disaster Reduction Statement of Commitment by the Private Sector for Disaster Prevention , Resilience & Risk Reduction International Strategy for Disaster Reduction.

UNISDR. (2012). Australian Multilateral Assessment March 2012 United of the United Nations International Strategy for Disaster Reduction Secretariat (UNISDR).

UNOOSA. (2011). United Nations International Conference on Space-based Technologies for Disaster Risk Management " Best Practices for Risk Reduction & Rapid Response Mapping ."

Usman, A. & Ifabiyi, I. P. (2012). Socio-Economic Analysis of the Operational Impacts of Shiroro Hydropower Generation in the Lowl & Areas of Middle River Niger. *International Journal of Academic Research in Business & Social Sciences*, *2*(4), 57–76. Retrieved from www.hrmars.com/journal

Uyigue, E. (2006). *Dams are unrenawable: A discussion Paper*.

Vijayalakshmi, D. P., & Babu, J. K. (2010). Floodplain Modelling Materials & Methodology. In *Proceedings of International Conference on Advances in Civil Engineering 2010* (pp. 1–4). India. http://doi.org/DOI: 02.ACE.2010.01.17

Vivekan & a, G. N., Swathi, R., & Sujith, A. V. L. N. (2020). Multi-temporal image analysis for LULC classification & change detection. *European Journal of Remote Sensing*, 1-11.

Wagesho, N. (2014). Catchment dynamics & its impact on runoff generation: Coupling watershed modelling & statistical analysis to detect catchment responses. *International Journal of Water Resources & Environmental Engineering*, *6*(2), 73–87. http://doi.org/10.5897/IJWREE2013.0449

Wagner, P. D., Kumar, S., & Schneider, K. (2013). An Assessment of L & Use Change Impacts on The Water Resources of the Mula & Mutha Rivers Catchment Upstream of Pune, India. *Hydrology & Earth System Science*, *17*, 2233–2246. http://doi.org/10.5194/hess-17-2233-2013

Wahab, S. A., & Adeola, A. A. (1999). Flood Control Structure : Influences on the Bacita Sugar Cane Plantation at Downstream of Kainji & Jebba Dams in Nigeria, 1–8.

Waheed, A. A., & Ogunwamba, J. C. (2010). The impacts of Urbanisation on Kaduna

River Flooding. *Journal of American Science, 6*(5), 28–35.

WMO. (2011). *Manual on flood forecasting & warning*.

World Bank. (2016). 2016 World Population Data Sheet: With a Special Focus on Human Needs & Sustainable Resources. World Bank. Retrieved from http://www.prb.org/pdf16/prb-wpds2016-web 2016.pdf%5Cnhttp://www.prb.org/pdf15/2015-world-population-data-sheet_eng.pdf

Yakubu, G. Z. (2012). An Assessemnt of Socio-Economic impacts of flood on the Inhabitantants of Galadima Kogo in Shiroro Local Government Area, Niger State, Nigeria.An unpublished Mtech. thesis, Department of Geography, Federal University of Technology, Minna, Niger State, Nigeria.

Yangbo, C Peng D, & Yang, X. (2017). Improving L & Use/Cover Classification with a Multiple Classifier System Using AdaBoost Integration Technique. Remote Sensing. 9. 1055. 10.3390/rs9101055.

Yin, J., He, F., Xiong, Y. J., & Qiu, G. Y. (2017). Effects of L & Use / L & Cover & Climate Changes on Surface Runoff in a Semi-Humid & Semi-Arid Transition Zone in Northwest China. *Hydrology & Earth System Sciences*, *21*, 183–196. http://doi.org/10.5194/hess-21-183-2017

Yuan, Y., & Qaiser, K. (2011). *Floodplain Modeling in the Kansas River Basin Using Hydrologic Engineering Center (HEC) Models Impacts of Urbanization & Wetl & s for Mitigation*.

Zhang, H., Ma, W., & Wang, X. (2011). Rapid urbanization & implications for flood risk management in Hinterl & of the Pearl River delta, China: The Foshan study. *Sensors*, *8*, 2223–2239.

Zhang J., Gong Q. Li, H., Song X. Li, L. & Huang, J. (2010). Hydrologic Information Extraction Based on archydro tool & DEM 2010 *International Conference on Challenges in Environmental Science & Computer Engineering, Wuhan, China, 2010*, pp. 503-506, doi: 10.1109/CESCE.2010.169..

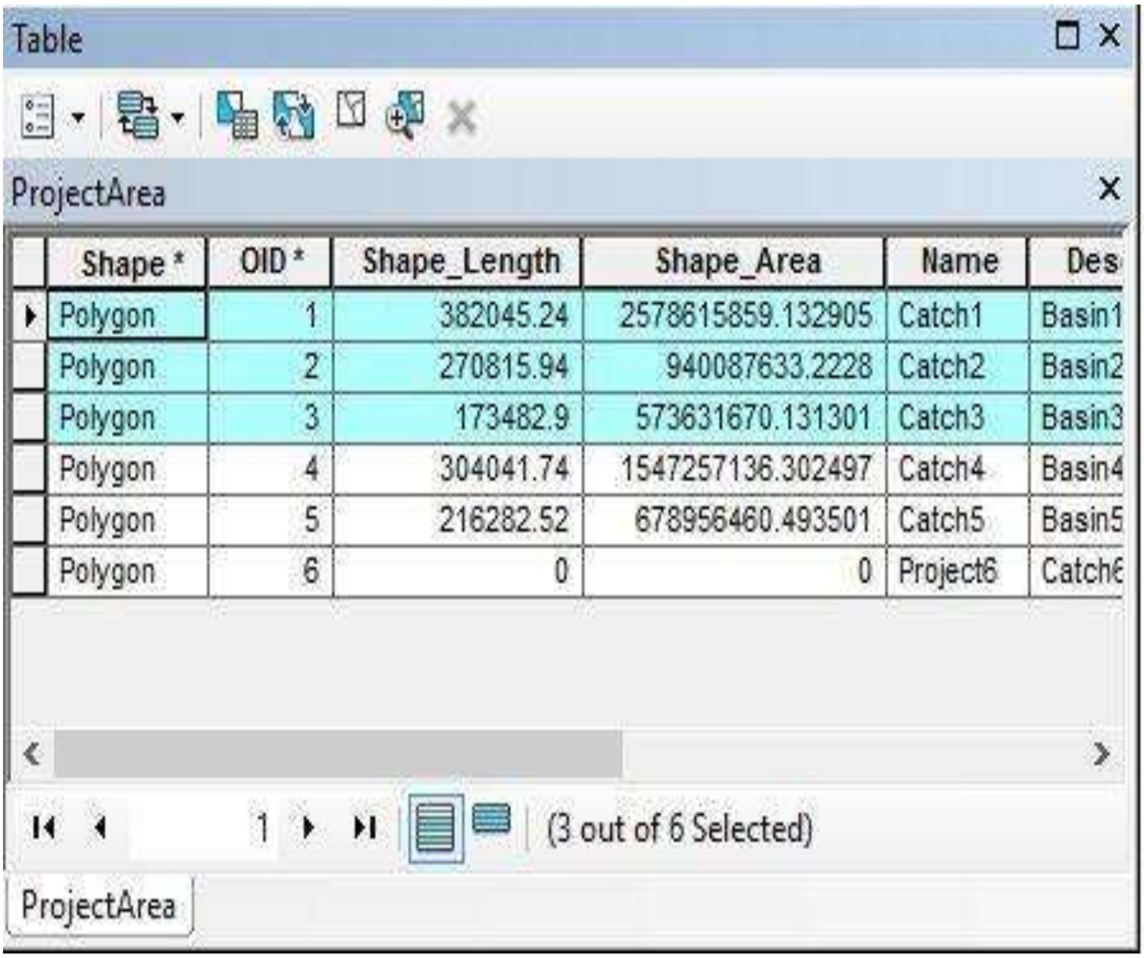
APPENDIX A

Table : Rational Method of Runoff Coefficients

	Runoff Coefficient, C											
	Soil Group A			**Soil Group B**			**Soil Group C**			**Soil Group D**		
Slope:	**< 2%**	**2-6%**	**> 6%**	**< 2%**	**2-6%**	**> 6%**	**< 2%**	**2-6%**	**> 6%**	**< 2%**	**2-6%**	**> 6%**
Forest	0.08	0.11	0.14	0.10	0.14	0.18	0.12	0.16	0.20	0.15	0.20	0.25
Meadow	0.14	0.22	0.30	0.20	0.28	0.37	0.26	0.35	0.44	0.30	0.40	0.50
Pasture	0.15	0.25	0.37	0.23	0.34	0.45	0.30	0.42	0.52	0.37	0.50	0.62
Farmland	0.14	0.18	0.22	0.16	0.21	0.28	0.20	0.25	0.34	0.24	0.29	0.41
Res. 1 acre	0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.40	0.31	0.35	0.40
Res. 1/2 acre	0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.42	0.34	0.38	0.42
Res. 1/3 acre	0.28	0.32	0.35	0.30	0.35	0.39	0.33	0.38	0.45	0.36	0.40	0.45
Res. 1/4 acre	0.30	0.34	0.37	0.33	0.37	0.42	0.36	0.40	0.47	0.38	0.42	0.47
Res. 1/8 acre	0.33	0.37	0.40	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.49
Industrial	0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.90	0.89	0.89	0.90
Streets: ROW	0.76	0.77	0.79	0.80	0.82	0.84	0.84	0.85	0.89	0.89	0.91	0.95
Parking	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97
Disturbed Area	0.65	0.67	0.69	0.66	0.68	0.70	0.68	0.70	0.72	0.69	0.72	0.75

Source: (Shaari *et al.*,2016)

APPENDIX B

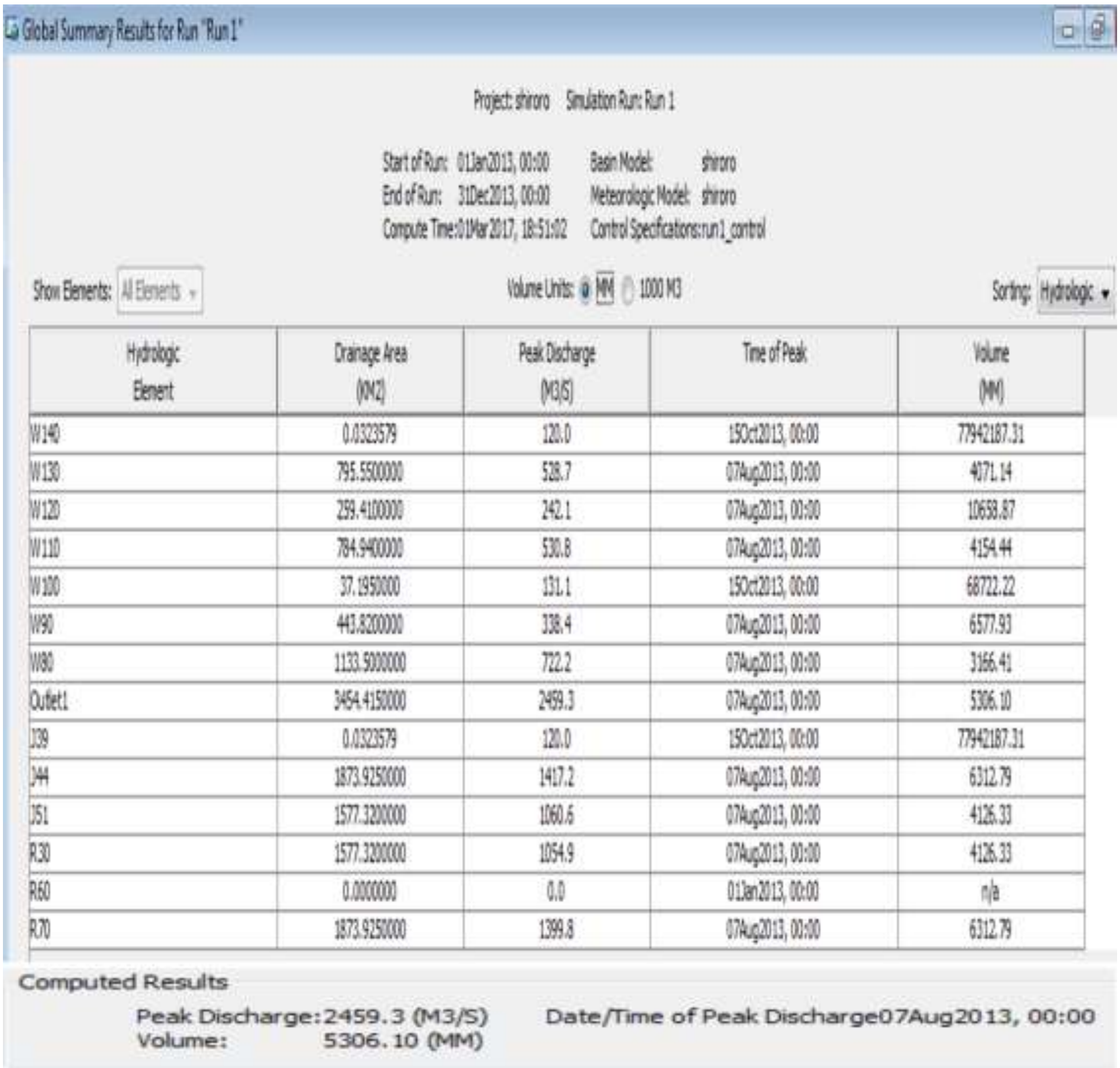


Shape *	OID *	Shape_Length	Shape_Area	Name	Des
Polygon	1	382045.24	2578615859.132905	Catch1	Basin1
Polygon	2	270815.94	940087633.2228	Catch2	Basin2
Polygon	3	173482.9	573631670.131301	Catch3	Basin3
Polygon	4	304041.74	1547257136.302497	Catch4	Basin4
Polygon	5	216282.52	678956460.493501	Catch5	Basin5
Polygon	6	0	0	Project6	Catch6

(3 out of 6 Selected)

Atrtributes of the 3 delineated basins.

APPENDIX C



Project: shiroro Simulation Run: Run 1

Start of Run: 01Jan2013, 00:00 Basin Model: shiroro
End of Run: 31Dec2013, 00:00 Meteorologic Model: shiroro
Compute Time:01Mar2017, 18:51:02 Control Specifications:run1_control

Show Elements: All Elements Volume Units: ● MM ○ 1000 M3 Sorting: Hydrologic

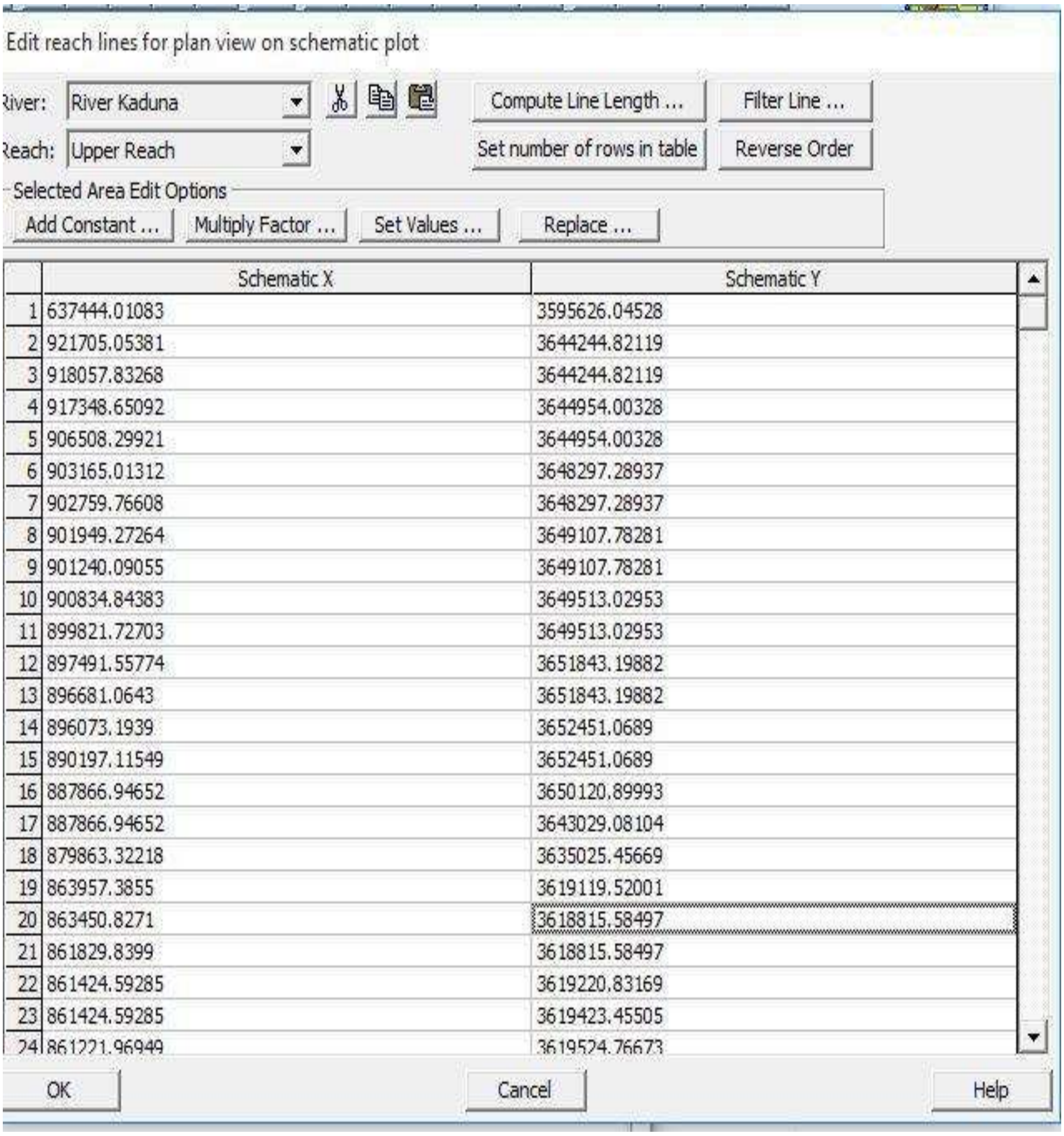
Hydrologic Element	Drainage Area (KM2)	Peak Discharge (M3/S)	Time of Peak	Volume (MM)
W140	0.0323579	120.0	15Oct2013, 00:00	77942187.31
W130	795.5500000	528.7	07Aug2013, 00:00	4071.14
W120	259.4100000	242.1	07Aug2013, 00:00	10658.87
W110	784.9400000	530.8	07Aug2013, 00:00	4154.44
W100	37.1950000	131.1	15Oct2013, 00:00	68722.22
W90	443.8200000	338.4	07Aug2013, 00:00	6577.93
W80	1133.5000000	722.2	07Aug2013, 00:00	3166.41
Outlet1	3454.4150000	2459.3	07Aug2013, 00:00	5306.10
J39	0.0323579	120.0	15Oct2013, 00:00	77942187.31
J44	1873.9250000	1417.2	07Aug2013, 00:00	6312.79
J51	1577.3200000	1060.6	07Aug2013, 00:00	4126.33
R30	1577.3200000	1054.9	07Aug2013, 00:00	4126.33
R60	0.0000000	0.0	01Jan2013, 00:00	n/a
R70	1873.9250000	1399.8	07Aug2013, 00:00	6312.79

Computed Results

Peak Discharge:2459.3 (M3/S) Date/Time of Peak Discharge07Aug2013, 00:00
Volume: 5306.10 (MM)

Result of Simulation of Koriga Sub-basin Model to Calculate surface runoff

APPENDIX D



Edit reach lines for plan view on schematic plot

iver: River Kaduna

each: Upper Reach

	Schematic X	Schematic Y
1	637444.01083	3595626.04528
2	921705.05381	3644244.82119
3	918057.83268	3644244.82119
4	917348.65092	3644954.00328
5	906508.29921	3644954.00328
6	903165.01312	3648297.28937
7	902759.76608	3648297.28937
8	901949.27264	3649107.78281
9	901240.09055	3649107.78281
10	900834.84383	3649513.02953
11	899821.72703	3649513.02953
12	897491.55774	3651843.19882
13	896681.0643	3651843.19882
14	896073.1939	3652451.0689
15	890197.11549	3652451.0689
16	887866.94652	3650120.89993
17	887866.94652	3643029.08104
18	879863.32218	3635025.45669
19	863957.3855	3619119.52001
20	863450.8271	3618815.58497
21	861829.8399	3618815.58497
22	861424.59285	3619220.83169
23	861424.59285	3619423.45505
24	861221.96949	3619524.76673

Appendix D is the X and Y Schematics of River Kaduna from field Survey