



Spatial Vulnerability Assessment of Flood in Niger State

Abiodun Olufemi Adebola¹, Emmanuel Ajayi Olofin² & Suleiman Abdul-Azeez Adegboyega¹

¹ Department of Remote Sensing and GIS, Federal University of Tehnology, Akure

² Department of Geography, Bayero University Kano.

Corresponding author: collinola@gmail.com

Received: March 2016

Accepted: May 2016

Abstract

This study used remote sensing applications in Flood Vulnerability Assessment of Flood in Niger State. Shuttle Radar Topographic Mission Satellite Image, Soil analysis, curve number flood model and Quantum GIS software were used to provide baseline information for the monitoring of flood disaster in Niger State. The SRTM image was used to analyse proximity of Niger State to rivers and create a Digital Terrain Model of Niger State based on elevation. Soil analysis was conducted to determine the types of soil in different locations in the state, using integrating curve number model to calculate run-off values. The research revealed two major causes of flood in Niger State namely primary causes such as soil type, rainfall intensity and duration; and secondary causes which include reservoir operations and building of structures along flood plains. Out of about 76,000km² covered by Niger State, 40% (30,000km²) was found to be highly vulnerable, 45% (34,000km²) was moderately vulnerable and the remaining 15% (11,400km²) had low vulnerability to flood. The study advocates evolvment and enforcement of an environmental policy to curtail unstainable agricultural activities on and discourage wanton destruction of environmental sensitive areas for unapproved developments.

Keywords: *Flood Vulnerability Map; Digital Terrain Model; SRTM Image; Curve number; Model and Quantum GIS*

1.0 INTRODUCTION

River and coastal floodings are the most frequently occurring natural disasters and are increasing in occurrence more rapidly than any other natural disaster. World Bank report has shown that flooding is not only the most frequent natural hazard – it is also the disaster with the greatest economic and humanitarian impacts that affect buildings, transport infrastructure, utility infrastructure and other assets (Shi and Wang, 2010). The vulnerability of the inhabitants of the developing countries is alarming and the mitigating measures are not forthcoming.. A cornerstone of Disaster Risk Reduction is the consensus reached in developing Hyogo framework that aimed to strengthen the resilience of nations and

communities for Disaster Risk Reduction (UNBCPR, 2005).

The problem of flood is a global problem that has no boundaries. Though, the extent of destruction is cushioned from country to country, depending on her level of technological advancement, developing nations are ill-prepared and thus more affected. Floods occurrence is not peculiar to Nigeria, but the 2012 floods was considered the worst in the nation's history. The heavy rains precipitated overflow of river banks due to blocked drains which led to flood disasters across the country in 2012. This incidence had further exposed Nigeria and Nigerians to flood vulnerability and also showed the level of

preparedness in states and the nation as a whole.

Preparation for flood emergencies in Niger State is grossly inadequate. Consequent upon this, the overall risk to society, the economy and the environment is high because every year lives are lost and properties worth

millions of Naira are destroyed. This study therefore attempts to develop a flood vulnerability map for the whole of Niger State with a view to generating baseline information for effective control and monitoring of flood disaster in the study Area.

2.0 RESEARCH AREA GEOLOGY

2.1 Research locale

The latitudinal and longitudinal locations of the study area are 8°20'N, 11°30'N, 3°30'E and 7°20'E respectively as shown in Fig 1. It shares boundary with Zamfara State in the north, Kebbi State in northwest, Kogi State in the south and Kwara State in the southwest. Moreover, it is bordered to the northeast and southeast by Kaduna State and the Federal Capital Territory respectively (Niger State Bureau of Statistics, 2011b).

The strategic location of the State is reflected in sharing international boundary with Benin Republic at Babanna in Borgu Local Government Area (LGA). The areal extent of the study area is about 76,000 Km² (Niger State Bureau of Statistics, 2011c). River Niger flows through the area together with its other tributaries.

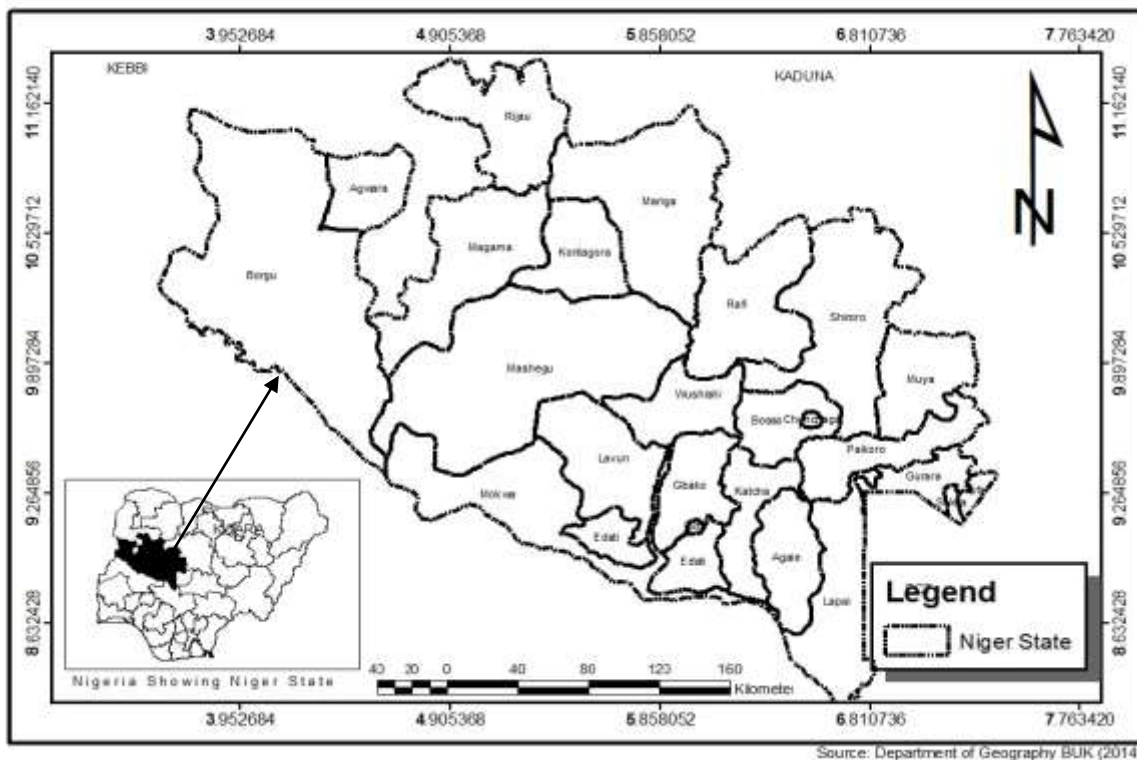


Figure 1: Niger State. Source: Adapted from Google map.

The study area is characterized by two major rock formations namely sedimentary and basement complex rocks. Sandstones and alluvial deposits are the major features of the sedimentary rocks in the study area and doubles as the area with extensive flood plains as well as the most fertile agricultural plains in the country. Basement complex, on the other

hand, is characterized by granitic outcrops or inselbergs that dominate the landscape in Rafi, Shiroro, Minna, Mariga and Gurara LGAs (Niger State Bureau of Statistics, 2011d).

Niger State has a tropical wet and dry climate; the two seasons are controlled by the interplay of the North-East trades, Monsoon moist

winds and the Inter-tropical Convergence Zone (ITCZ). Rainfall begins in April and terminates in October and total range is between 1000 – 1400mm. the duration of sunshine per day combined with solar-radiation intensity are two important parameters that determine the drying power of

the ambient air under low relative humidity values. Other elements of climate that affects flood in Niger State are discussed in details in this section (Adefolalu & Oguntoyinbo, 2005a). The mean annual rainfall and length of rainy season is shown in Figures 2 and 3 (Adefolalu, 1986).

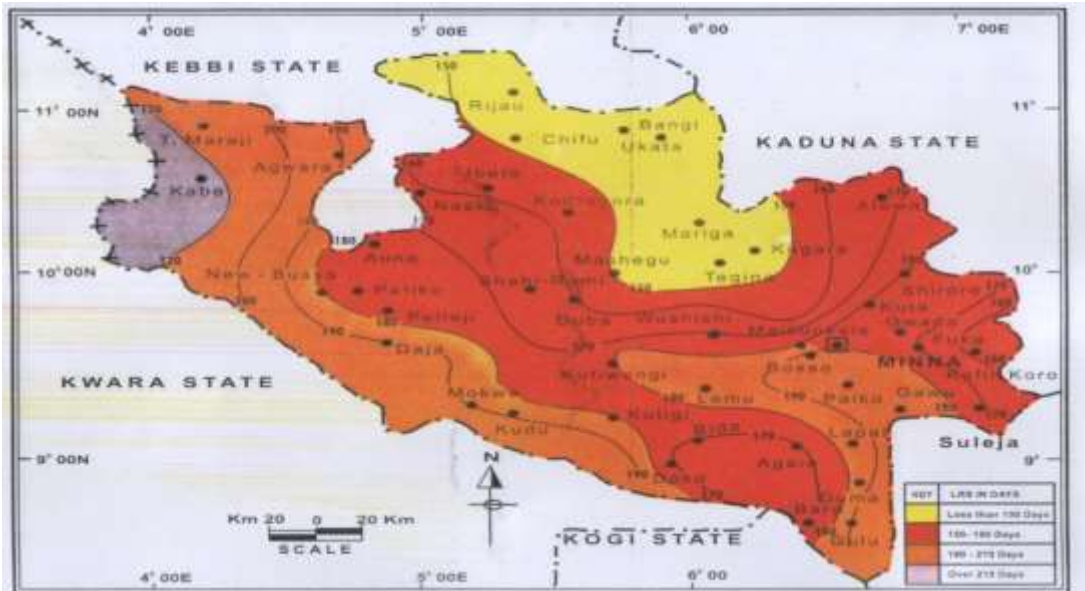


Fig 2: Mean Length of Rainy Season in Days. Source: CCCFWR, FUT, Minna (2009)

Onset of rains varies from place to place in Niger State, in some places, the rains start after 20th May, while others start before 20th April, as shown in Fig 4. Mean onset dates and Mean cessation Dates for rainfall are shown in Figures 4 and 5.

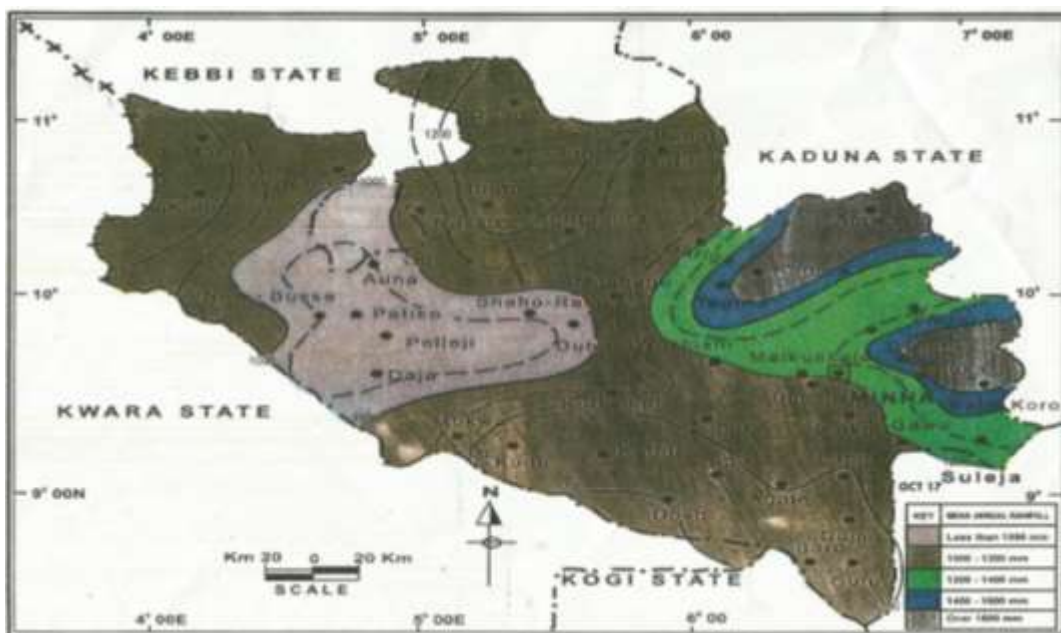


Fig 3: Mean Annual Rainfall. Source: CCCFWR, FUT, Minna (2009).

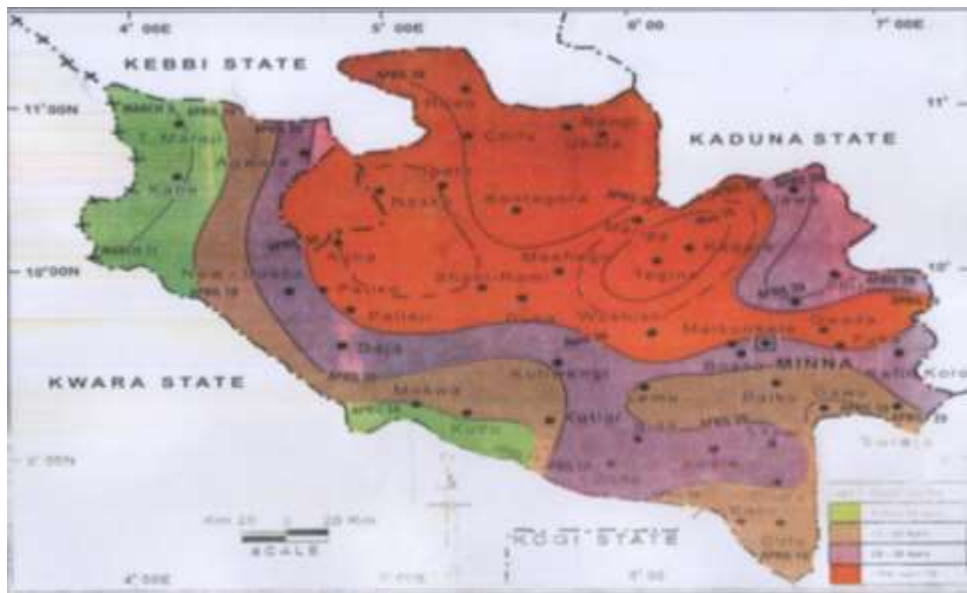


Figure 4: Mean Onset Dates for Rainfall. Source: CCCFWR, FUT, Minna (2009)

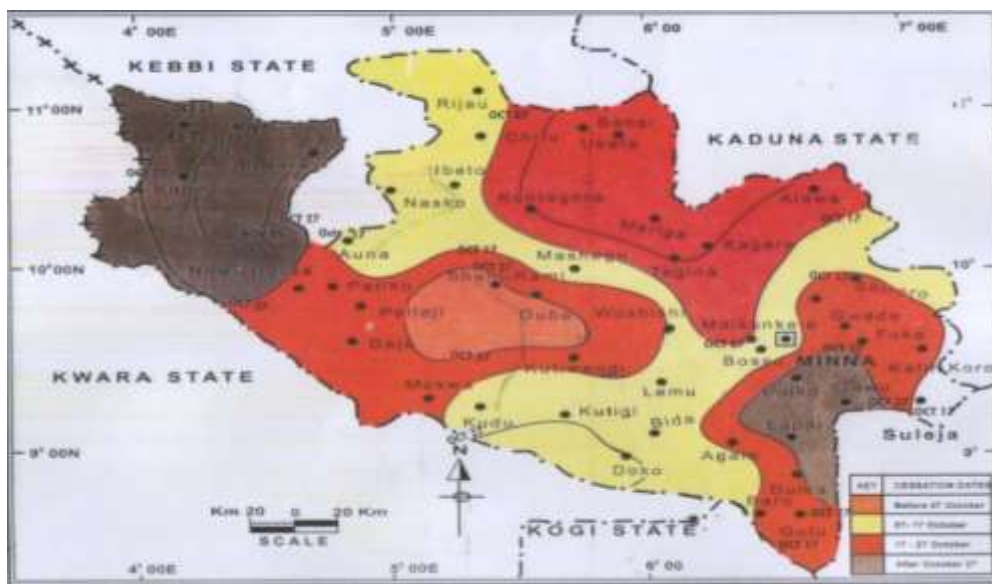


Figure 5: Mean cessation Dates for Rainfall. Source: CCCFWR, FUT, Minna (2009).

Mean maximum temperature remains high throughout the year, hovering about 32°C, particularly in March and June. However, the lowest minimum temperatures occur usually between December and January when most parts of the state come under the influence of the tropical continental air mass which blows from the north. Dry season in Niger State commences in October. (Adefolalu & Oguntoyinbo 2005b)

Three major soil types that can be found in the State include the ferruginous tropical soils, hydromorphic soils and ferrosols. The most predominant soil type is the ferruginous

tropical soils which are basically derived from the Basement Complex rocks, as well as from old sedimentary rocks. Such ferruginous tropical soils are ideal for the cultivation of guinea corn, maize, millet and groundnut (Adams, 1985).

Hydromorphic or waterlogged soils are largely found in the extensive flood plain of the Niger River. The soils are poorly drained and are generally greyish or sometimes whitish in colour due to the high content of silt. Ferrosols which developed on sandstone formations can be found within the Niger trough. Their characteristic red color enriched with a clay sub soil is noticeable in the landscape. Termite

hills dot the landscape, particularly between Mokwa, Bida and Kontagora. These can be seen along the major highways in the state. The Southern Guinea Savannah vegetation covers the entire landscape of the state. It is characterized by woodlands and tall grasses interspersed with tall dense species. However, the Niger trough and flood plain region accommodate tall trees and a few oil palm trees. In some areas, traces of rain forest species can be seen (Adams, 2000).

Niger State is one of the states being confronted with one form of ecological problem or the other since its creation in 1976. The situation has degenerated with the construction of dams at Jebba, Kainji and Shiroro, resulting in flood problems occurring virtually every year. This is also apart from some areas like Rijau, Nasko and Magama that are prone to desertification. The State Government has at different times, warned on the rate of desertification, noting that farming activities might soon be grounded. To combat this, tree planting projects has been aggressively embarked on. The state also

3.0 MATERIALS AND METHODS

Shuttle Radar Topography Mission Satellite Image

The Shuttle Radar Topographic Mission (SRTM) is an international research effort that obtains digital elevation models on a near-global scale from 56° S to 60° N, to generate the most complete high-resolution digital

experiences flooding as a result of the construction of the three hydro-electric dams in Niger State by the Federal Government, which have been causing flooding at the lower part of the state, and which incidentally accounts for about 60 per cent of the entire land area spread across the two of the state's geopolitical zones (Adams, 2000b).

On annual basis, several hectares of farmland and property are usually lost in addition to loss of lives to flood either from water releases from the dams or as a result of heavy rainfall. In the year 2010, over 250 communities were sacked from their communities. The area mostly affected is Muregi. Six people lost their lives, while several hundreds were rendered homeless as a result of the flood, the third to affect Muregi community in Bida Local Government Area of Niger State in a space of two years. According to Timothy (2012), it was realized that villagers had been fleeing the area in their hundreds while all economic activities had been dormant. Other places affected are Wuya Kede, Muye and Akere (NSEMA 2012b).

topographic database of digital elevation models around the globe. The Digital Terrain Model (DTM) of Niger State came in 90m resolution, so it was resampled to 50m to get a better result for the vulnerability zones. The re-sampling was done with Global Mapper. The resampled image downloaded from the site is shown in fig 6.

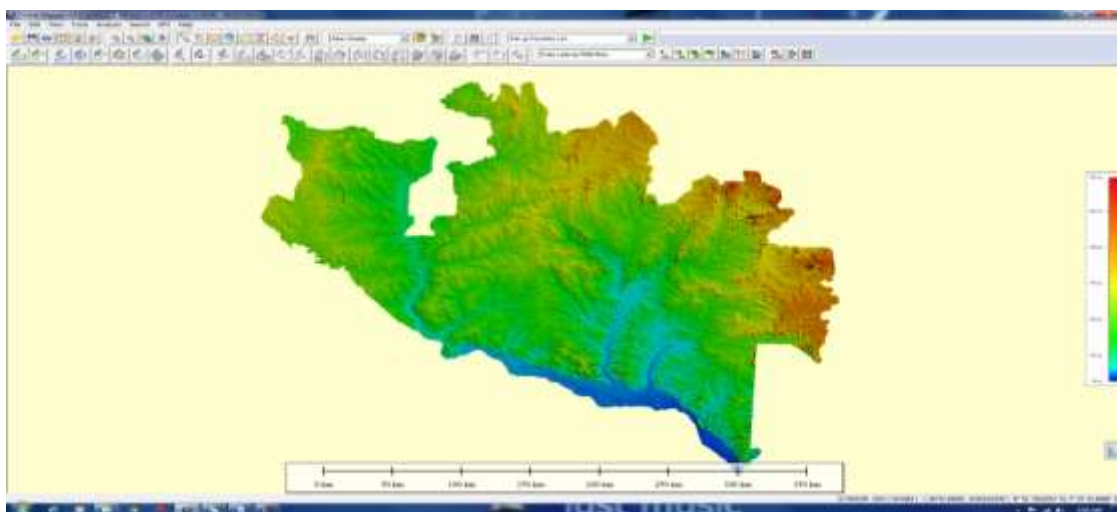


Figure 6: SRTM Image of Niger State.

From the DEM data loaded within the Global Mapper environment a contour map was generated, the contour was generated in polygon format so as to give an impression of the Area of Interest (AOI). The Digital Elevation Model was used to classify the state into vulnerable zones using height above lowest point in Niger State and proximity to water bodies in the state as basis for classification.

3.1 Rainfall data

Rainfall intensity, rainfall duration and mean annual rainfall were collected from different weather stations namely, Minna, Suleja, Bida, Rijau, Badeggi, Kontagora, Lapai, Shiroro, Mokwa, and Jebba. The data was used to determine which of the rainfall variables constituted the primary cause of flood in Niger state. Rainfall intensity, rainfall duration and mean annual rainfall map generated by the Center for Climate Change and Fresh water Resources Federal University of Technology, Minna, were also used as standard classification criteria for areas with different rainfall intensity, mean annual rainfall and duration. The essence of this was to group the causes of flood in Niger State into two major groups; the primary and the secondary causes of flood.

3.2 Reconnaissance survey and Field observation

An initial survey was carried out to get first-hand information on the study area concerning up-to-date flood situations in the state, and to interact with the people especially those affected by flood in 2012. A survey was carried out to ascertain which communities were affected by flood and to what extent they were affected and also to determine the agricultural land that was destroyed in the 2012 floods. Soil samples were taken during the field observation exercise and GPS readings were taken and recorded.

3.3 Run-off properties of soil using curve number

The curve number model developed by United States Natural Resources Conservation Service is an empirical parameter used in hydrological study for predicting direct run-off or infiltration from rainfall excess. Based on the rainfall intensity map of Niger State, the state was divided into 5 zones, soil samples was taken purposively from each area and test carried out on each to get infiltration rate using curve number. It is given by

$$Q = \frac{(P - I_a)^2}{P - I_a + S}$$

Where **Q** = Runoff

P = Rainfall

S = the potential maximum soil retention after runoff begins

I_a = the initial abstraction or the amount of water before runoff, such as infiltration or rainfall interception by vegetation. (USDA-SCS, 1972; Williams, 1995)

It is generally assumed that **I_a** = 0.2S

The runoff curve number CN is then related as

$$S = \frac{1000}{CN} - 10$$

CN has a range from 30 to 100; lower numbers indicate low runoff potential while larger numbers are for increasing runoff potential. The lower the curve number, the more permeable the soil is.

3.4 Computing Runoff volume

In computing the runoff volume, the following steps were followed:

- a) Compute the Surface Storage:
 $S = (1000 / CN) - 10$
- b) Compute the Initial Abstraction:
 $I_a = 0.2 \times S$
- c) Compute the runoff in Inches:
 $Q = (P - I_a)^2 / (P - I_a + S)$
- d) Convert from inches to millimeters

Rainfall intensity, soil type, land use type, rainfall duration, approximate distance from rivers and elevation above sea level are all input into the quantum GIS software and a vulnerability map was generated for Niger State based on the studied variables.

3.5 Laboratory Techniques

The laboratory techniques used in this study include standard procedures for determining particle size distribution of gravel, sand, silt and clay. This is to measure infiltration rate of each soil type in the state and relate it to rainfall intensity and duration to see at what point infiltration becomes zero.

3.6 Generation of Flood Vulnerability Map

The absolute location of the study area (Latitude and Longitude) was determined using a Global Positioning System. The latitude, longitude and height represented by X, Y and Z coordinates from the GPS and SRTM image were used to generate digital elevation model for the study area. The vulnerability of the study area based on height was determined from the digital elevation

model. Coordinates from GPS Garmin 75 and satellite image was imported into Global Energy mapper where the elevation values for different points in the state were extracted and a digital elevation model was generated from Quantum GIS software. A vulnerability map of Niger State was developed based on elevation above sea level, land use type and proximity to natural and man-made water bodies. The high, moderate and low vulnerability areas were digitized in the Quantum GIS environment.

4.0 RESULTS AND DISCUSSION

4.1 Rainfall intensity and soil type

According to the Centre for Climate Change and Fresh Water Resources Federal University of Technology, Minna, rainfall intensity in Niger State ranged from 0mm/hr to 70 mm/hr. Surface runoff, consequent on high intensity of above 50mm/hr which was aggravated by soil type, slope and settlement pattern, was one of the major causes of flood in Niger State. Niger State had five mean rainfall intensity levels as shown in (Fig 7). These places with different levels of intensity were associated with mean rainfall intensity of less than 36mm/hr, 36 – 40mm/hr, 40 – 50mm/hr, 50 – 60mm/hr, 60 – 70mm/hr. Apparently, rainfall intensity, infiltration rate of soil and topography (mainly slope) all contributed to runoff in Niger State.

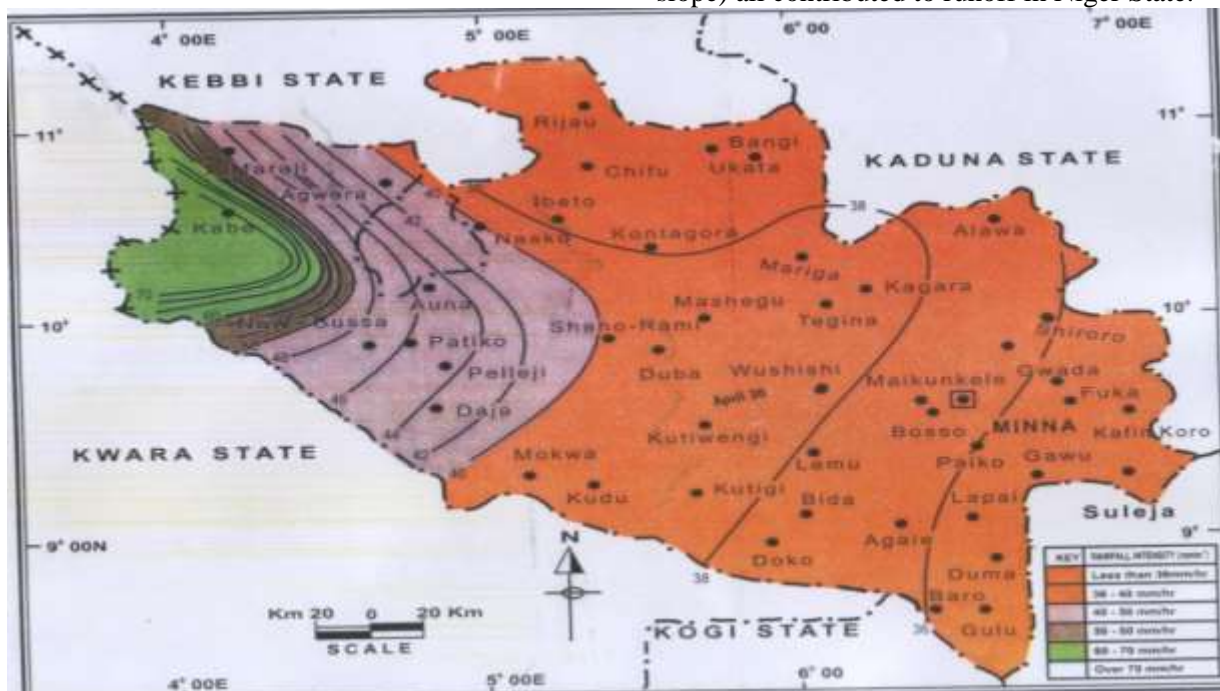


Figure 7: Rainfall intensity for Niger State. Source: Adapted from CCCFWR, 2009.

The result of the soil tests undertaken to determine the texture of the soils in the study area is given in Table 1. Soil texture was modelled after United States Department of Agriculture soil textural classification.

Table 1: Soil Texture in the Study Area.

Rainfall Intensity Area (mm/hr)	0 - 35	36- 40	40 - 50	50 – 60	60 - 70
Gravel (Laterites %)	14	0	11	0	0
Sand (%)	52	95	10	98	72
Silt (%)	13	5	18	2	13
Clay (%)	21	0	61	0	15
Soil textural class (USDA textural triangle)	GSC	S	GC	S	LS
GSC - Gravel, sand and clay					
S – Sand					
GC – Gravel and sand					
LS – Loam and sand					

Source: Field work, 2013.

Table 1 showed that the soils in the state contained more of sand, than clay and gravel. This means that infiltration and percolation is low. Little quantity of rainfall percolates into the soil and a large amount flows as runoff. Considering the intensity and duration of rainfall in the state and relating it to infiltration rate, it is obvious that places with high rainfall intensity tend to have higher runoff. However, there are other factors that aggravate flood problems in Niger State, these factors show that making a definite assumption that places with higher rainfall intensity have higher runoff and thus experience flood more than places with low rainfall intensity may not be correct for all times and conditions. Some secondary factors aggravate flood beyond the primary causes. These factors are land use type, construction of residential buildings on flood plains and reservoir operations. These secondary factors are products of the primary factors and thus cannot be studied in isolation,

hence the need to establish the secondary causes of flood in Niger State.

4.2 Land use type

The major land use types in Niger State are residential, commercial, agricultural and open land. The residential area is further divided into two based on population density. There is no place in Niger State with high population density, what is obtainable is medium and low population density. Soil type that was collected from each land use type in each rainfall intensity stratum was analysed using the curve number model, the results are presented in Fig 8.

The result from Fig 8 showed that land use type is one of the secondary factors that triggered runoff. The study identified rainfall and soil type as the primary causes of flood in Niger State. Relating rainfall intensity and soil type with land use types, helped to determine the rate of infiltration and runoff for each land use type.

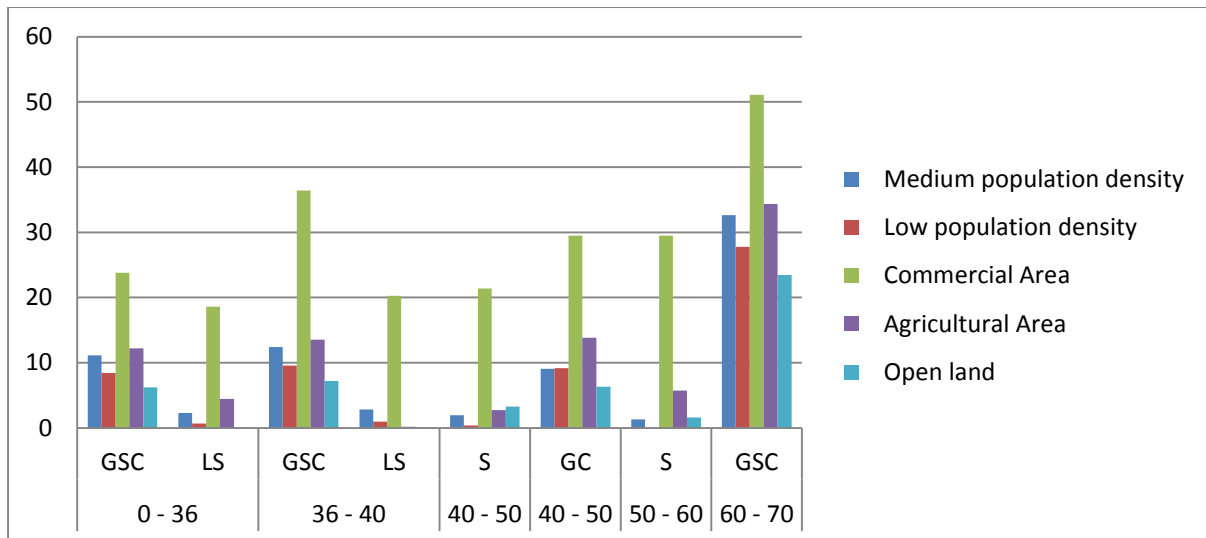


Figure 8: Runoff values for different land use types.

Figure 8 shows the difference in runoff for each land use type; firstly, there is difference in runoff for places with the same soil type and same rainfall intensity but different land use types. Areas with rainfall intensity of between 0-36mm/hr with soil type characterized by a mixture of gravel, sand and clay and infiltration of between 0-1.27mm/hr are places with actual runoff of 11.13mm/hr, while places with low population density even though they are both residential areas, have actual runoff of 8.44mm/hr. Commercial area have the highest amount of runoff of 23.78mm/hr, while open land has the lowest amount of runoff of 6.25mm/hr. The low amount of runoff for open land is because the flow pattern and drainages on the soil have not been tampered with. Agricultural area is next in high amount of runoff; this is caused by regular cultivation which has loosened the top soil thereby making the flow of water on the surface free especially along slopes. In contrast, places with soil type characterized by gravel, sand and clay to areas with loam and sand within the zone of 0-36mm/hr of rainfall intensity have different runoff rates. Though soil type in the commercial area has the highest runoff

rates, the runoff is less than that of the Medium Population Density areas. This shows that land use type affects runoff in Niger State. In other places in the state with different rainfall intensity and soil type, commercial areas have the highest runoff; places with medium population density area are next, while open area have the least runoff incidence. Agricultural land and low population density areas have runoff greater than open land. This is in tandem with the findings of Swaroop (2005), Munich Reinsurance (2002), NIOSH (2003) and Ologunorisa (2006), which states that land use type is a major factor that contributes significantly to flood problems in Nigeria and around the world.

4.3 Reservoir Operations

There are three major dams in Niger State, Nigeria. The Kainji Dam built in 1968, Jebba Dam built in 1985 and Shiroro Dam built in 1990. A fourth dam is being built at Zungeru, also in Niger State. These are all hydroelectric dams that generate a potential combined power output of 1,900 megawatts.

Table 2: Dams in Niger State and their Characteristics

Dam	Capacity (Million m3)	Surface Area	Primary Usage
Jebba	3600	35,000	HEP
Kainji	15000	130,000	HEP
Shiroro	2700	31,200	HEP

Source: (David & Adebayo, 2012)

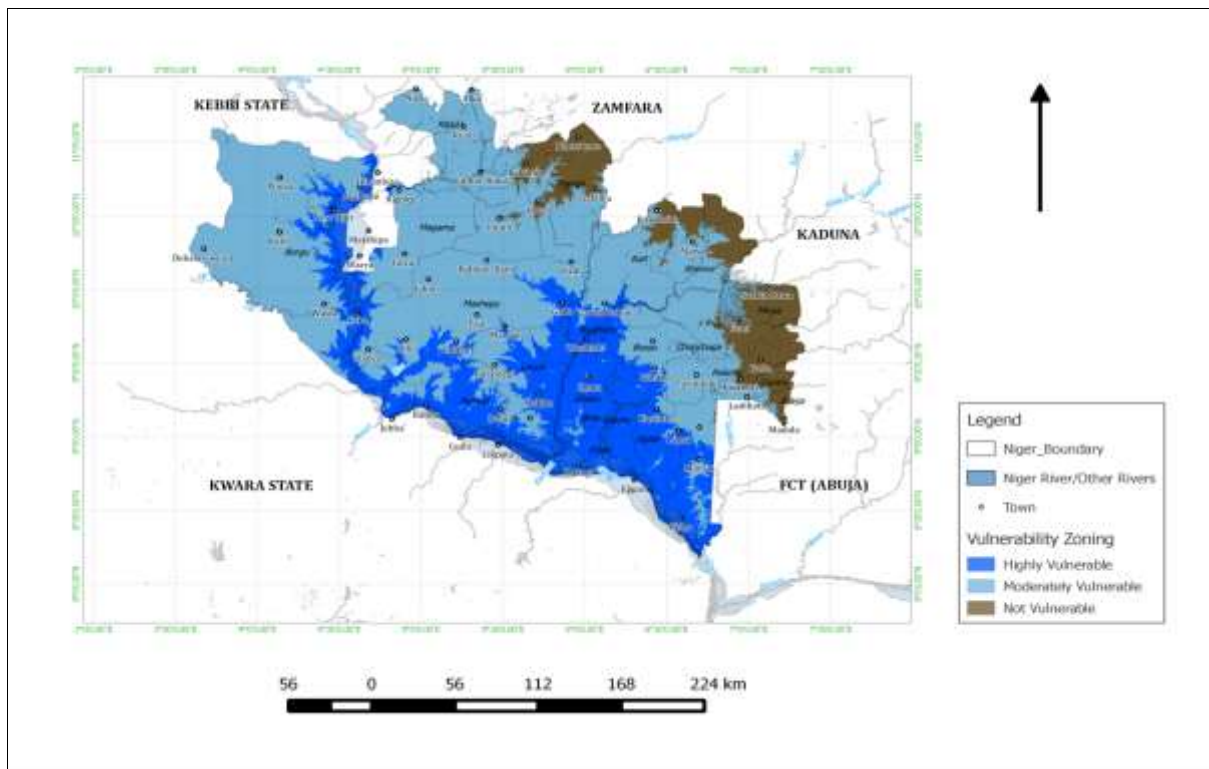


Figure 9: Flood Vulnerability Map of Niger State.

From the vulnerability map as shown in Fig 9, the highly vulnerable, moderately and low vulnerable areas to flood have been clearly established. The vulnerability map of the state also shows that 19 out of the 25 Local Government Area in the state are vulnerable to flood, while only six are not vulnerable to flood. Even at that, these six Local Government Areas (LGAs) are not completely free of flood events, a small part of these LGAs are vulnerable to flood. The LGAs are: Mariga, Munya, Shiroro, Rafi, Gurara and Suleja. Some of these areas are located in the highland regions in the state, and have never

5.0 CONCLUSION

The study revealed two major causes of floods in the State namely primary and secondary causes. The primary causes identified are soil type, rainfall intensity and rainfall duration while the secondary causes include reservoir operations and building of structures along the flood plains. It further established that highly vulnerable places were places with close proximity to the Rivers in the state, especially rivers Niger and Kaduna that coincided with the places that have been affected by flood in the past fall within these highly vulnerable

zones. The vulnerability map of the state also shows that 19 out of the 25 Local Government Area in the state are vulnerable to flood, while only six are not vulnerable to flood. Even then, these six LGAs are not completely free of flood events, a small part of these LGAs are vulnerable to flood. These LGAs are Mariga, Munya, Shiroro, Rafi, Gurara and Suleja. The study advocates evolvement and enforcement of an environmental policy to curtail unsustainable agricultural activities on and discourage wanton destruction of

environmental sensitive areas for unapproved

developments.

6.0 REFERENCES

Adams, W.M., (1985). *The Downstream Impacts of Dam Construction: A Case Study from*

Nigeria. Transactions of the Institute of British Geographers N.S. 10: 292-302

Adams, W.M., (2000a). *Social Impacts of Large Dams: Equity and Distributional Issues, Report to World Commission on Dams*. Thematic Review II Social Impacts of Large Dams; Equity and Distributional Issues.

Adams, W.M., (2000b). *Social Impacts of Large Dams: Equity and Distributional Issues, Report to World Commission on Dams*. Thematic Review II Social Impacts of Large Dams; Equity and Distributional Issues.

Adefolalu, D.O. (1986) Rainfall Trend in Nigeria, Theoretical Application to Climate Vol 3
205-209

Adefolalu, D.O. and Oguntoyinbo, J.S., (2005a). Rainfall Distribution and Agricultural Planning. *Journal of Tropical Geography*, vol. 1 (ii). Pp 9 – 13

Adefolalu, D.O. and Oguntoyinbo, J.S., (2005b). Rainfall Distribution and Agricultural Planning. *Journal of Tropical Geography*, vol. 1 (ii). Pp 9 – 13

Center for Climate Change and Freshwater Resources (2009): Eco-climatic Atlas of North-Central Nigeria, CCCFWR, Minna. Vol 1 No 1

David, O. O. and Adebayo W. S. (2012). Assessment of Impact of Hydropower Dams Reservoir Outflow on the Downstream River Flood Regime – Nigeria’s Experience, *Hydropower - Practice and Application*, Dr. Hossein Samadi-Boroujeni (Ed.), ISBN: 978-953-51-0164-2, InTech, Available

from: assessment-of-impact-of-hydropowerdams- reservoir-outflow-on-the-downstream-river-flood-regime-niger SEPT, 17th 2013

Munich Reinsurance, (2002) Topics: Annual review: Natural catastrophes 2002. Munich Reinsurance. 52 p. (<http://www.munichre.com>). Sept 2003

Niger State Bureau of Statistics (2011a). Facts and Figures about Niger State, Niger State Statistical Yearbook, 2011 Edition.

Niger State Bureau of Statistics (2011b). Facts and Figures about Niger State, Niger State Statistical Yearbook, 2011 Edition.

Niger State Bureau of Statistics (2011c). Facts and Figures about Niger State, Niger State Statistical Yearbook, 2011 Edition.

Niger State Bureau of Statistics (2011d). Facts and Figures about Niger State, Niger State Statistical Yearbook, 2011 Edition.

National Institute of Occupational Safety and Health (2003). Sand and gravel mining facts. Publication No 2003 – 134, July 1 – 2. [Online] Available: www.cdc.gov/niosh/mining/pubs/pubreference (November 20, 2008).

Ologunorisa, E.T., (2006) *Flood Risk Assessment and Management in Nigeria: Perspective from the Niger Delta*. Selfers Educational Books. Pp. 156.

Shi, P. and Wang, J. (2010): *Atlas of Natural Disaster System of China*. Science Press, Beijing.

Swaroop, R. (2005) Factors Influencing the Incorporation of Hazard Mitigation During Recovery from Disaster.” *Journal of Natural Hazards*. 22: 185-201.

Timothy, O. (2012). Flood Displaces 8 LG Residents in Bauchi Niger and Taraba States – NEMA. The Sun Newspaper, Thursday, September, 2012.

<http://www.sunnewsonline.com/webpages/news/national/2011/aug/29/national-29-08-2012-021.html>

United Nations. Bureau for Crisis Prevention and Recovery (2005). *Reducing Disaster Risk: A Challenge for Development*. Accessed at <http://www.undp.org/bcpr/disred/rdr.htm> on Sept. 21

United State Department of Agriculture-Soil Conservation Service (1972). National Engineering Handbook, Hydrology Section, Chapters 4 -10. Washington, D.C.

Williams, J.R. (1995). The EPIC Model. In Singh, V.P.(ed.): Computer Models of Watershed Hydrology. Water Resources Publication Pp 909-1000