ASSESSMENT OF FLOOD VULNERABILITY IN LOKOJA METROPOLIS, KOGI STATE, NIGERIA

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Abstract
This study assessed flood vulnerability in Lokoja metropolis, Kogi State. The Geographic Information Systems analytical technique was used to assess the flood vulnerability zones of Lokoja metropolis by exploring the benchmark minimum and maximum water level sourced from the National Inland Water Ways Authority (NIWA), Lokoja area office for years 2006 to 2015. Data on Land-use/land-cover and flood vulnerability maps were generated from digitized satellite imageries sourced from Google earth imageries and the Gumbel's frequency distribution method. The study ascertained that the maximum water levels records corresponds with the area extent of flood coverage in Lokoja. The highly and most inundated areas are actually recorded in 2012 with area coverage of 3,638.19 ha, 3,011.2 ha in 2015 and least 1966.05 ha in 2011. By extension, more impact of flooding phenomena were felt more in years 2012, 2015 and less in 2011. Furthermore, the farmlands/ open spaces are most inundated areas e.g. 3,542.13 in 2012, 81.43ha of residential land use, 10.15ha of commercial land use, 4.38ha. of public and industrial 0.1 ha. The agricultural areas, and residential areas are the most vulnerable to high flooding while the industrial areas the least vulnerable. The study therefore recommends the preparation of flood management plan using the mapping of the flood areas done by the study and ensure enforcement by a joint task force that should consists of the Planning Authorities, Ministry of Environment, National Inland Waterways Authority and Ministry of Environment with each a clear cut role in ensuring safer floodplains management.

Keywords: Flood, Land use, Land cover, Inundation, Vulnerability.

INTRODUCTION

Historically, flood plains have served as attractive sites for settlements due to its advantage of fertile land, freshwater supply and transportation. This perceived advantages attracted the beginning of modern settlement (Bue, 1967). In the world today, floods are among the most devastating natural disasters that are responsible for the loss of lives and properties every year (Wang, 1999 and Dilley et-al., 2005). In Nigeria, floods hazard is only second to drought. In terms of the natural hazard directly or indirectly affecting of the 90% of damages resulting from natural hazards (Adeoye et-al. 2009). Floods that occur in Nigeria are as a result of intensive rainfall, drainage blockages and dam failures (Jeb and Aggarwal, 2008). Flood is among the most devastating natural hazards in the world claiming lives and properties more than any other natural phenomena (Ologunorisa, 2006; Alcira and Martha, 1991). In the past decade in Nigeria, thousands of lives and properties worth millions of Naira have been lost directly or indirectly from flooding every year. In most urban centers of the country most especially in fast growing towns like Gwagwalada town of the Federal Capital Territory, population increase, landscaping in paved areas, streams and channel obstruction due to bad waste disposal and other human activities at floodplains were considered to be the major causes of floods (Ishaya, Ifatimehin and Abaje, 2009). Flooding are common features in Nigeria, and it usually occurs in locations of flat or low- lying terrain, especially cities that have little or poor provision surface drainage system, or where drainages are blocked with municipal waste, refuse and eroded soil sediments (Folorunsho and Awosika, 2001). Adeoye (2009) reported that floods have caused over 10,000 deaths in the United States since 1900. According to Asian Development Bank (2007), floods have affected over nine (9) million people in Bangladesh and about thirty (30) million people in India. With these

characteristics, the occurrence of flood remains unstoppable especially on its destructive consequences on people who reside along its plain. In the United States of America, 80% of disaster occurrences are caused by flood, between the periods of 1988 and1994 four (4) billion dollars' worth properties are lost annually as a result of flood (Wadsworth1999). A flood occurrence in many regions of the world are in the increase (Drogue et-al, 2004). It is reported that flood disasters account for about a third of all natural disasters by number and economic losses. This however shows how disastrous flood can be if not checked. Ziervogel (2008) states that, though floods cannot be stopped, but, control of its damaging effects and the vulnerability of risk prone communities is possible.

In recent years, the increase in population and expansion of settlements in flood prone areas has fostered the impact of the floods worldwide. Gilbert (1991) asserted that urban encroachment into floodplain alters the integration of surface- runoff with the main channel, reduces surface water storage and conveyance capabilities, and reduces water quality of receiving waters and adjacent lands, in addition to other secondary effects such as depletion of water resources, cumulative impact on wetlands and pollution of downstream surface waters. Across the globe, floods have posed tremendous danger to people's lives and properties. In Nigeria, the pattern is similar with the rest of world. Flooding in various parts of Nigeria have forced millions of people from their homes, destroyed properties, polluted water resources and increased the risk of diseases (Baiye, 1988; Akinyemi, 1990; Nwaubani, 1991; Edward-Adebiyi, 1997). In Kogi State, many urban dwellers reside mostly in relatively low lying areas of Rivers Niger and Benue due to their large resource bases on natural resource. This attraction has led to fast and exponential increase in urban development and other activities in the area. Flooding has been one of the major natural disasters in Kogi, during the disaster lots of lives and properties were lost, inundation of institutions, farmlands, destruction of roads, bridges and especially the major road to gain entrance from southwest into the northern area. Etuvnobe (2011) reported that flooding in Kogi State occurs like wildfire

with ninety communities of over 500, 000 persons including Lokoja displaced form theire abodes, and farmlands completely swept away. According to the reports from the Nigeria Emergency Management Agency, NEMA, (2012), five districts, namely, Adankolo/ Kabawa, Sarkin Noma/Galilee, Phase1– Old Poly quarters, Ganaja and Gadumo of Lokoja were flooded in August and early September, 2012 when River Lagdo burst its banks. Several studies on flood dwelled more on the effects flood on lives and properties, yet there remain lacunas in the subject matter that will foster a strong mechanism towards addressing the problem from the perspective of mapping that forms baseline information for predicting the vulnerability of the flood plains, this is a gap this study attempts to fill in. The study aim is to assess the vulnerability of human settlement along flood plains of Lokoja metropolis via the identification of the causes of flood in Lokoja, mapping of the areas where flooding had occurred and examining the vulnerable areas of flood hazards for the sake of management purposes.

Backdrop of Flooding

Flood is an overflowing or irruption of a great body of water over land not usually submerged (Oxford English Dictionary). It is an extreme weather event naturally caused by rising global temperature which results in heavy downpour, thermal expansion of the ocean and glacier melt, which in turn result in rise in sea level, thereby causing salt water to inundate coastal lands. Flooding is the most common of all environmental hazards and it regularly claims over 20,000 lives per year and adversely affects around 75 million people world-wide (Ologunorisa, 2006; Alcira and Martha, 1991). Previous studies also reported that communications and traffic are interrupted while many land areas are inundated, and industrial plants and commercial establishment are paralyzed during floods. Besides, untold hardship is experienced, especially by the most vulnerable groups (women and school children) whenever there is flood disaster (Oluduro, 1988; Durotoye, 1999; Folorunsho and Awosika, 2001). Flooding is a normal phenomenon that occurs from a river in many catchment areas or drainage outlet). The drainage out let can be a stream or a river, the

wider the catchment area, the more the quantity of runoff getting into the drainage outlet. For instance, the catchment area of River Niger extends far beyond Nigeria; hence it carries the highest volume of water. River Ogun on the other hand extends only into Oyo and Osun States and hence carries smaller volume of water compared with the River Niger. Thus, if the catchment area is large, the inflow into any dam built on the drainage outlet will be heavy and if the inflow is greater than the out flow that the drainage channel can carry, leading to a retention, that forms some reservoir lake and its boundary extending to areas previously dried. Otherwise, there will be an outflow into the adjoining land area. This extension of retained water boundary or the out flow into the adjoining dry land is what is called floods or flooding.

Causes of Flooding in Nigeria

Nwigwe and Emberga (2014) identified that the following causes of flood in Nigeria could be natural as well as human (anthropogenic). The natural cause could be in form of heavy or torrential rains/rainstorm, oceans storms and tidal waves usually along the coast. While, the human causes could be via non-provision of drainage lines or silting of same with solid waste. It could also be via the burst water main pipes, dam burst that results to dam spills. Flooding occurs throughout Nigeria in following forms: Coastal flooding, River flooding, flash floods, urban flooding, Dam burst leaves failures and Dam spills. They further claim that Coastal flooding occurs in the low-lying belt of mangrove and fresh water swamps along the coast river flooding occurs in the flood plains of the larger rivers flash floods are associated with rivers in the inland areas where sudden heavy rains can change them into destructive torrents within a short period. Urban flooding occur in towns located on flat or low lying terrain especially where little or no provision has been made for surface drainage, or where existing drainage has been blocked with municipal waste, refuse and eroded soil sediments, extensive urban flooding is a phenomenon of every rainy session in Lagos, Maiduguri, Aba, Warri, Benin and Ibadan. Virtually every Nigerian is vulnerable to disasters, natural or man-made. Every rainy season, wind gusts arising from tropical storms

claim lives and property worth millions of naira across the country. Flash floods from torrential rains wash away thousands of hectares of farm land. Dam bursts are common following such flood. In August 1988 for instance, 142 people died, 18,000 houses were destroyed and 14,000 farms were swept away. When the Baguada Dam collapsed following a large flood. Urban flooding such as the Ogunpa disaster which claimed over 200 lives and damaged property worth millions of naira in Ibadan, are common occurrence (Edward-Adebiyi, 1997). Flood occurrences inhibits economic activities in many towns and cities in the country. Some of the Major roads that link when flooded causes hardship to motorists. When these roads were constructed, the flooding problems were not there, and the companies that constructed the roads probably did not anticipate the problem.

Cause of flooding in Lokoja between 2006 and 2015

The River Niger runs from Guinea through Mali, Benin, Niger and empties into the ocean through Nigeria. The rainy season in West Africa where the River Niger exists is the same, spreading mainly between April and November. The peak of the rainy season is July /August. This peak flow implies that the River Niger runs full all across its length for the rainy season. But the flow also takes time to travel. The peak flow coming from Fouta D'jalon mountain where the River Niger takes its source travels all the way until it arrives in Nigeria. The time it floods Nigeria is, therefore, different from the time the rains fall upstream of its basin. This explains why the River Niger floods Nigeria yearly starting from September and at its peak in November but receding to its lowest discharge of about 500m^3/s in May. The authorities managing the Kainji and Shiroro dams would normally open the floodgates only when the peak flow of the River Niger arrives in September in order to ensure adequate impoundment. When the opening of such flood gates coincides with high precipitation in Nigeria, the flooding of the downstream becomes inevitable. And if such opening coincides with discharges due to the opening of floodgates on Lagdo dam on upper River Benue , the flooding is accentuated (NEMA, 2012). The opening of the floodgates of the Kainji, Shiroro on River Niger and Lagdo dams and

their attendant discharges of excess flows coincided with heavy rainfall thus causing the large scale flooding ever recorded in Nigerian history in 2012. Had the floodgates of these dams been opened at various times such that the discharges did not arrive at the confluence in Lokoja simultaneously, the extent of flooding would have been reduced.

Sgarma & Sharma (2002) and Douglas, Gasiorek, and Swaffield (1985) claimed the foregoing issue on causes of floods in Lokoja can briefly be illustrated with some equations. If the catchment area (or drainage basin) available to be A_a, rainfall intensity or storm I, then the quantity of flow available (Q_a) in a drainage basin outlet at any time (t) can be given by:

$$Q_a = 2.78CIA_a \qquad (1)$$
(Sgarma & Sharma, 2002: pp. 200-427)

Where C is a constant that depends on surface/soil characteristics of the catchment area, and its values range from 0 to 1 (i.e. $0 < C <= 1$). The Value of C=1 implies non-permeability while C=0 implies full permeability or sinking into the ground of all precipitation.

The critical condition for C is when the value approaches unity (i.e. C=1).This condition occurs when:
(1) The ground becomes fully saturated due to past rainfall and can no longer soak any other water,
(2) When every portion of the catchment area is paved, and
(3) When the affected area is underlain with impervious rock or clay soil.

On the other hand, if the carrying capacity of a drainage outlet is Q_c, the cross-sectional area of the drainage or river channel is A, slope of the drainage or river bed is S, then

$$Q_C = A[R^{(2/3)} S^{(1/2)}]/n \qquad (2)$$

Where R =hydraulic mean radius = wetted perimeter/ sectional area, and ―n‖ is Manning's constant which depends on surface characteristics of the channel, and ―^‖ is an exponential power.

Flooding occurs when ―Q_a‖ in equation (1) is more than ―Q_c‖...in equation (2) or simply put:

$$Q_a > Q_c \qquad (3)$$

This can be written as:

$$2.78CIA_a > A[R^{(2/3)}S^{(1/2)}]/n \qquad (4)$$

Or

$$I > k(A/A_a) [R^{(2/3)}S^{(1/2)}] \qquad (5)$$

Where: k = 1/(2.78nC)

Equation (4) provides that if the rainfall intensity is higher than the value on the right hand side, flooding occurs. This can occur due to a sudden increase in rainfall intensity (I) either within a short time frame or over a long time frame. The causes of floods in recent times in China, Russia, America, Africa and Europe have all been associated with high precipitation or rainfall intensity (I) factor.

Similarly from equation (4):

$$A > 2.78nCIA_a/ [R^{(2/3)}S^{(1/2)}] \qquad (6)$$

It follows from equation (ivb) that if A_a, C, I, or―n‖ is high (or their combination is high), then a higher cross-sectional area is required for the same flow. Thus, the excess water above the drainage channel available inundates the surrounding causing ponding and flooding.

The river catchment area of the River Benue basin begins before the Lagdo dam in northern Cameroun and extends westwards up to Lokoja, Kogi State, Nigeria. That of the River Niger starts from the Volta region in Mali. Thus the catchment area, A_a, is large for both River Niger and River Benue. This is another reason why we have floods. Another condition that can cause flood in Lokoja is when there is a hydraulic jump and energy is dissipated. Upstream of any hydraulic jump is a region of rapid flow and shallow depth while its downstream is an area of sluggish flow with high depth of water. The high depth of water in this case can be taken as flooding. This is

governed by the following equations put forward by Douglas, Gasiorek, and Swaffield (1985: 462-465);

$$D_2 = \frac{1}{2} D_1 [-+\sqrt{(1+8v_1^2/gD_1)}] \qquad (7)$$

Where: D1 and D2 are conjugate depths upstream and downstream of the hydraulic jump location. For instance, if:
D1 = 2m; v1 = 0.5m; g = 9.81m/s^2; then D2 = 0.35m.

Thus, relatively shallow depth of approximately 1foot (i.e.0.35m) at the upstream region could generate a depth of 2m in the downstream region. The loss of head associated with any such hydraulic jump is given by:

$$E = (D_1 + v_1^2/2g) /(D_2 + v_2^2/2g) \qquad (8)$$

In examining the terrain traversed by both the R. Benue and R. Niger drainage basins, it is discovered that the most flooded areas occurred in flat areas downstream of sloppy critical flow areas that were associated with energy dissipation (hydraulic jump). In Lokoja, the confluence zone is a spot of hydraulic jump and energy dissipation.

The third condition that can cause flooding occurs when maximum discharges from Lagdo dam, Kainji dam and Shiroro dam coincides with peak rainfall runoff from the adjoining catchment areas. The River Niger is 4,180km long while, the River Benue is about 1,400km long (Douglas, Gasiorex and Swaffield, 1985). If we assume that both Rivers Niger and Benue flow at an average velocity (V) of 1.1m/s, then the time required for a full discharge, T, is governed by:

$$S = VT \qquad (9)$$

Where S=distance or length,

V = velocity and T=Time of travel.

From equation (9), we obtain:

$$T = S/V \qquad (10)$$

Thus, for River Niger (with distance converted to meters), the time required taken as T$_1$is:

T$_1$= 4,180 x1000 / 1.1
= 3,800,000 seconds or 43.98 days

The peak period of flow from Fouta Djalon, the source of River Niger in Guinea, will arrive in about one and a half months after peak flow begins. And for the River Benue, the time required taken as T$_2$ is:

T$_2$ = 1400 x1000 / 1.1
= 1,272,272.3 seconds or 14.7 (15 days)

This shows that the peak flow from the source of the River Benue is about two (2) weeks after the peak flow begins. If the rivers run full in early July, we should expect that higher flow from Lagdo area will arrive at the confluence zone in mid-July while that of the River Niger will arrive in mid-August. During this period of July to August, is the peak of the rainy season. Thus, the opening of floodgates from any dam upstream of confluence point at Lokoja, Kogi State, between July and November will accentuate flooding of the Niger Delta. Such a condition must never be allowed to take place. But in 2012, the floodgates of the Kanji, Shiroro and Lagdo dams coincided with torrential rainfall in the middle and southern parts of Nigeria. That was a human error, and of course a human flooding cause.

From the aforementioned therefore, the following factors can be inferred to be responsible for flooding in Lokoja metropolis: the status of Lokoja as a confluence point/ town fuels the inevitability of flood occurrence, rapid urban sprawl along the floodplains/areas, high rate of precipitation, and the low lying terrain of the metropolis.

MATERIALS AND METHODS
Study Area
Lokoja is the headquarters of Kogi State; it is located between Latitude 7^0 45'N to 7^0 51'N and Longitude 6^0 41'E to 6^0 46'E with an area cover of 3,180km² (Britannica Encyclopaedia), it is located between the confluence of Rivers Niger and Benue in Nigeria. It has a population of 195,261 at the 2006 census (NPC, 2006). Lokoja lies in the Koppen Aw-warm continental type (Olatunde and Ukoje, 2016) characterised by tropical wet and dry seasons with a mean annual rainfall of about 1,000mm and Relative Humidity of about 30% (dry season) and 70% (wet season) (Olivera et. al, 1995). Lokoja has a mean annual temperature of 30.7^0 C with the hottest months of February and March

(Ifatimehin, Ishaya and Ujoh, 2010), the It is underlined by igneous and metamorphic rocks of the basement complexes with a rough terrain and mountainous landscape, forsts and valleys, and the soils are generally characterized by a sandy texture overlying a weakly structured clay accumulation (Atoyebi, 2013) with the soils of flood plains of the aforesaid rivers hydromorphic in nature with mixture of alluvial and colluvial deposits (Areola, 2004). The vegetal cover is predominanty Guinea or Parkland savanna with tall grasses, shrubs and some trees (Luca, 2012). Lokoja is a cosmopolitan town with mix of various Nigerian ethnic tribes such as Igala, Tiv, Idoma, Hausa, Egbira, Yoruba, Igbo and Gbagyi just to mention a few (Olatunde and Adejoh, 2017). The people are largely involved in fishing, farming, lumbering and trading activities. The land use is about

556.5 sq. km residential, 1, 510.50 sq.km open spaces (partly farmlands), 467.46 sq. km for roads, 295.74 sq. km water bodies, 73.14 sq. km commercial, 6.36 sq.km industrial, 143.10 sq.km for schools, hospitals, offices and other public uses and 127.20 recreational land use coverage (Lokoja master plan, 2009).
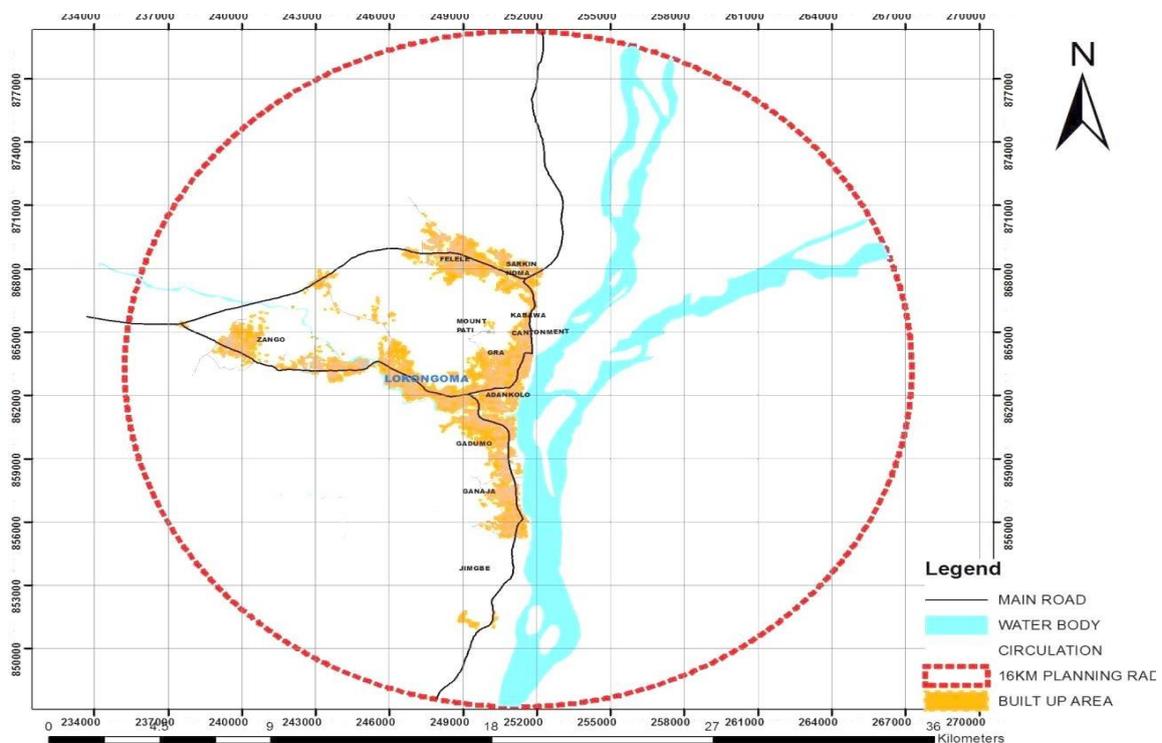

Figure 1 Lokoja Metropolis: 16km Planning Radius.
Source: GIS Analysis by Authors 2016

The study uses Remote Sensing and GIS analysis tool and technique for assessing the flood vulnerability zones of the Lokoja metropolis by exploring the benchmark minimum and maximum water level from the year 2006 to 2015 sourced from the National Inland Water Ways Authority, Lokoja area office. Land-use/land-cover and flood vulnerability maps were generated from digitized satellite imageries sourced from Google earth imageries and the Gumbel's frequency distribution method. The data on record of flood coverage, yearly discharge record of Niger River, areas affected, contour and Digital Elevation Model (DEM) of the study area were acquired from NIWA as well. Flood vulnerability maps for the study areas were prepared by intersecting/ overlay of the land use map of the floodplains with the flood area polygon for each of the flood event being modeled. This helped in determining the vulnerability and flood risks of the areas, particularly, in terms of the presence or the absence of flooding of a particular return period

as a binary model. Also, record of property/houses lost, farmlands and number of people affected were also collected in the study area form NEMA. The data on water levels on the pattern of flooding from 2006– 2015, from the annual maximum water gauge levels at Adankolo (NIWA Dock Yard) gauge site located in the catchment area analysed via flood frequency analysis and overlay with the Digital Elevation Model with the aid of Arc GIS10.0 Raster Calculator to determine the vulnerable areas and mapping. Descriptive analysis was done on the data collected where necessary.

RESULTS AND DISCUSSION
Flood vulnerability mapping of Lokoja metropolis
Annual maximum water level from 2006-2010

Tables 1a and 1b show the maximum water level from year 2006-2015. Year 2012, had the highest maximum water level height 13.42m, followed by year 2015 with a maximum height of 9.79m, the year with least water level is 2011 with maximum height of 6.65m. this implies that the year with the highest water level seem to be the year that unprecedented inundation was experienced in Lokoja followed by year 2015 when so many houses where submerged, settlements dislodged, farmlands swept off and loss of properties. But year 2011, with the lowest value 6.65m had a minimal experience of inundation and submergence of settlements along the floodplain. This table provides strong baseline information on planning, managing and mapping of vulnerable areas of flooding in the metropolis.

Table 1 Annualwater level from 2006 to 2010

ANNUAL WATER LEVEL FOR 10 YEARS RETURN PERIOD														
STATION: Lokoja						RIVER: Niger			MILE: 581.3km					
DATE ESTABLISHED:1914									AREA OFDRAINAGEBASIN:					
ELEVATION OFGAUGE AT ZERO ABOVE DATUM:13.40m														
ELEVATION OFGAUGE AT ZERO ABOVEM.S.L:32.37m														
2006			**2007**			**2008**			**2009**			**2010**		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
2.32	6.75	3.65	2.26	8.77	4.88	2.84	9.36	4.02	2.11	9.44	3.82	2.05	9.34	4.04

Table 1 Contd. Annual water level from 2011 to 2015

ANNUAL WATER LEVEL FOR 10 YEARS RETURN PERIOD														
STATION: Lokoja					RIVER: Niger			MILE: 581.3km						
DATE ESTABLISHED:1914								AREA OF DRAINAGE BASIN:						
ELEVATION OF GAUGE AT ZERO ABOVE DATUM:13.40m														
ELEVATION OF GAUGE AT ZERO ABOVE M.S.L:32.37m														
2011			**2012**			**2013**			**2014**			**2015**		
Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
2.02	6.65	3.44	1.37	13.42	4.77	2.09	8.22	4.17	2.13	8.75	3.21	2.81	9.79	3.62

Source: National Inland Waterways Authority, Lokoja Area Office 2015

Pattern of Flooding, 2006-2015
Table 2 shows that the highest water level recorded over the years under study is year 2012 with 13.42m maximum water level, and the least 6.65m in years 2006 and 2011. Between years 2011 and 2012 there was a sharp increase in water level/height meaning an unprecedented inundation in the study area. This water levels height corresponds with

higher inundation of if the increasing land use/ activity areas as shown in figure 2. Less inundated areas were in 2006 and corresponding less development as shown in figure 2. The highly and most inundated areas were actually recorded in 2012 with area coverage of 3,638.19 ha (Plate 3), 3,011.2 ha in 2015 and least 1966.05 ha in 2011 (see plate 2). By extension, more impact of flooding

phenomena should be felt more in years 2012, 2015 and less in 2011. Furthermore, the farmlands/ open spaces are most inundated areas e.g. 3,542.13 in 2012, 81.43ha of residential land use, 10.15ha of commercial land use, 4.38ha. of public and industrial 0.1 ha.

It is worthy to note that, year 2012 was the only year that had the industrial land use inundated. Perhaps, the highest water level recorded within that year. So increase in flooding would affect the industrial hub of the Lokoja metropolis.

Table 2 Pattern of flooding from 2006 −2015 (inundated areas)

YEARS	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Maximum Water	6.65m	8.77m	9.36m	9.44m	9.34m	6.65m	13.42m	8.22m	8.75m	9.79m
Landuse	Area	Area	Area	Area	Area	Area	Area	Area	Area	Area
Residential	39.32	42.34	52.23	59.49	61.01	47.22	81.43	55.34	53.56	65.44
Commercial	4.87	5.33	6.45	6.71	7.6	3.23	10.15	6.92	7.21	8.12
Public	1.34	2.31	3.34	3.41	3.82	2.87	4.38	3.98	3.18	3.83
Industrial	0	0	0	0	0	0	0.1	0	0	0.10
Farmland/	2084.32	2562.12	2662.43	2683.78	2676.12	1912.73	3542.13	2408.43	2518.21	2933.71
TOTAL	2129.85	2612.1	2724.45	2753.39	2748.55	1966.05	3638.19	2474.67	2582.16	3011.2

Source: KSTPDB (2012) and GIS Analysis by Authors, (2016).
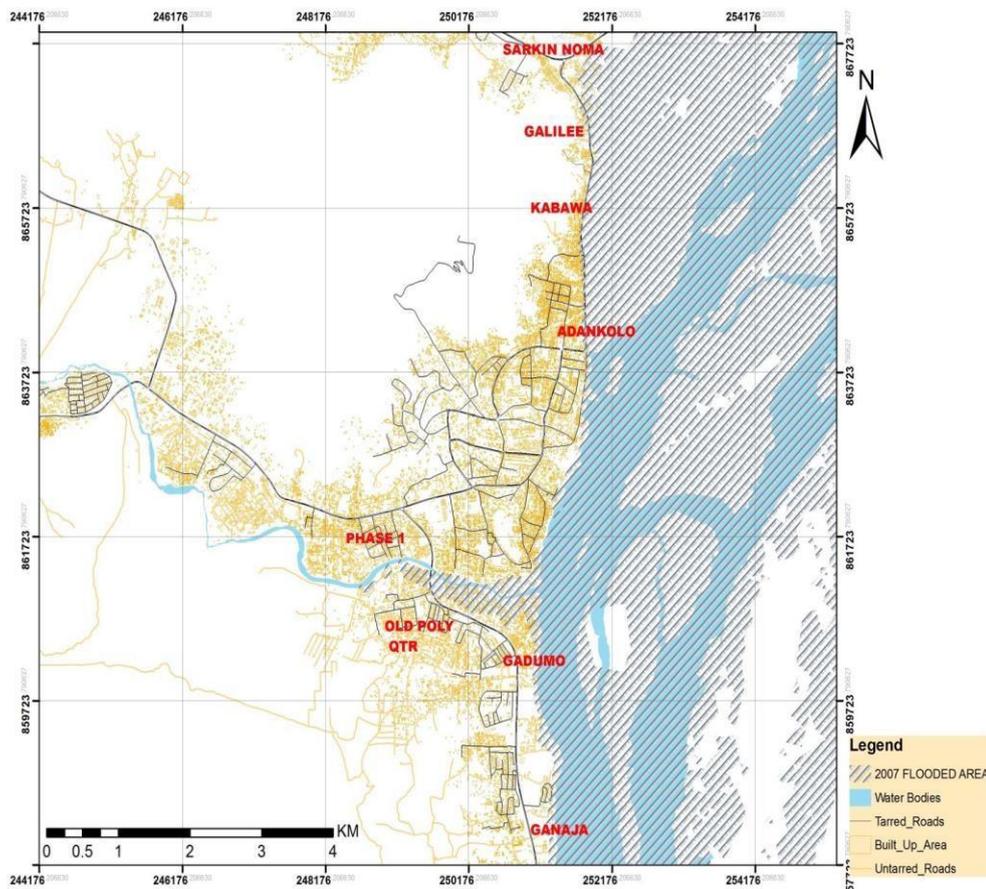

Figure 2 Lokoja Metropolis Flooded Areas in 2006.

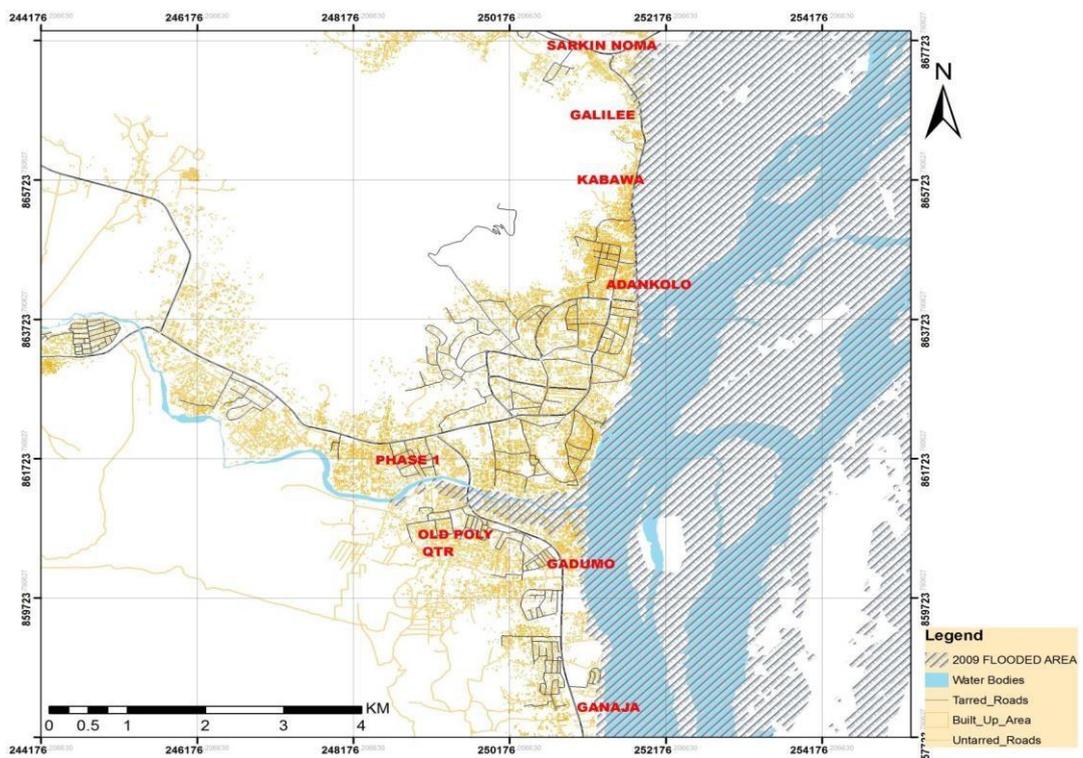**Figure 3** Lokoja Metropolis Flooded Areas in 2007.

Figure 3 Lokoja Metropolis Flooded Areas in 2009

Figure 4 Lokoja Metropolis Flooded Areas in 2012

Structures Affected by the Flood

Table 3 shows that inundated areas are the areas with higher water levels and height in year 2012, year 2015 and the least in 2006. They had structures (property) affected by flood with about 1,792 houses in 2012, followed by 1,434 houses in 2015 and the least 437 houses in 2006 as shown in Table 3. This means whenever the maximum values are recorded area extent of inundation increases, at the same time more properties will be affected, but whenever low values are recorded, the areas shall remain safe from flooding hazards.

Table 3 Structures affected

LOCATION	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Sarkin	201	213	231	236	268	193	345	234	222	276
Kabawa-Adankolo	120	131	143	158	533	385	707	481	457	566
Phase1–oldpolyquarters	15	28	30	39	73	60	112	76	64	90
Gadumo	34	36	42	45	273	201	364	247	231	291
Ganaja	67	71	76	80	192	146	264	178	181	211
TOTAL	437	479	522	558	1339	985	1792	1216	1155	1434

Source: Kogi State Town Planning Board (2012), and GIS Analysis (2016)

Population Affected by the flood

The estimated population affected by the flood varies from one year to another, Table 4, reveals an increasing population at years with higher area extent/ coverage by inundation. The number hitherto, follows the trend of years 2012, 2015 and the least in 2006 with affected population estimates at 15,232 persons, 12,189 persons and 3,715, persons respectively. So the higher the inundated areas the more the likelihood to have many persons affected by the phenomenon**.**

Table 4 Estimated population affected

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
POPULATION	3715	4072	4437	4743	11382	8373	15232	10330	9818	12189

Source: KSTPDB (2012) and GIS Analysis by Authors (2016)

Flood Vulnerability in Lokoja Metropolis

Table 5 shows that a high vulnerable areas are with more than 8 meters water level gauge, and the areas with the highest coverage are the farmlands/open spaces falls with a land area of 2,754.21 ha, followed by residential land uses with land area/ coverage of 64.23 ha. Commercial 6.79 ha and Public land uses 3.56 ha. Therefore it can be deduced that in the 10 years flood period of 2006-2016 in Lokoja metropolis 2,754.21 hectares of farmland/open space lies in high hazard zone. By implication, the impact of flooding and proneness of areas to flooding is at an increasing trend, though, with some disparity of vulnerability when compared with the tables 1 and 2 on the maximum water levels recorded in Lokoja. In addition, residential areas susceptibility increases geometrically into the vulnerable conditions with 64.23 hectares of residential land use under higher hazard zone in 10 years flooding (figure 6)

Table 5 Flood vulnerability

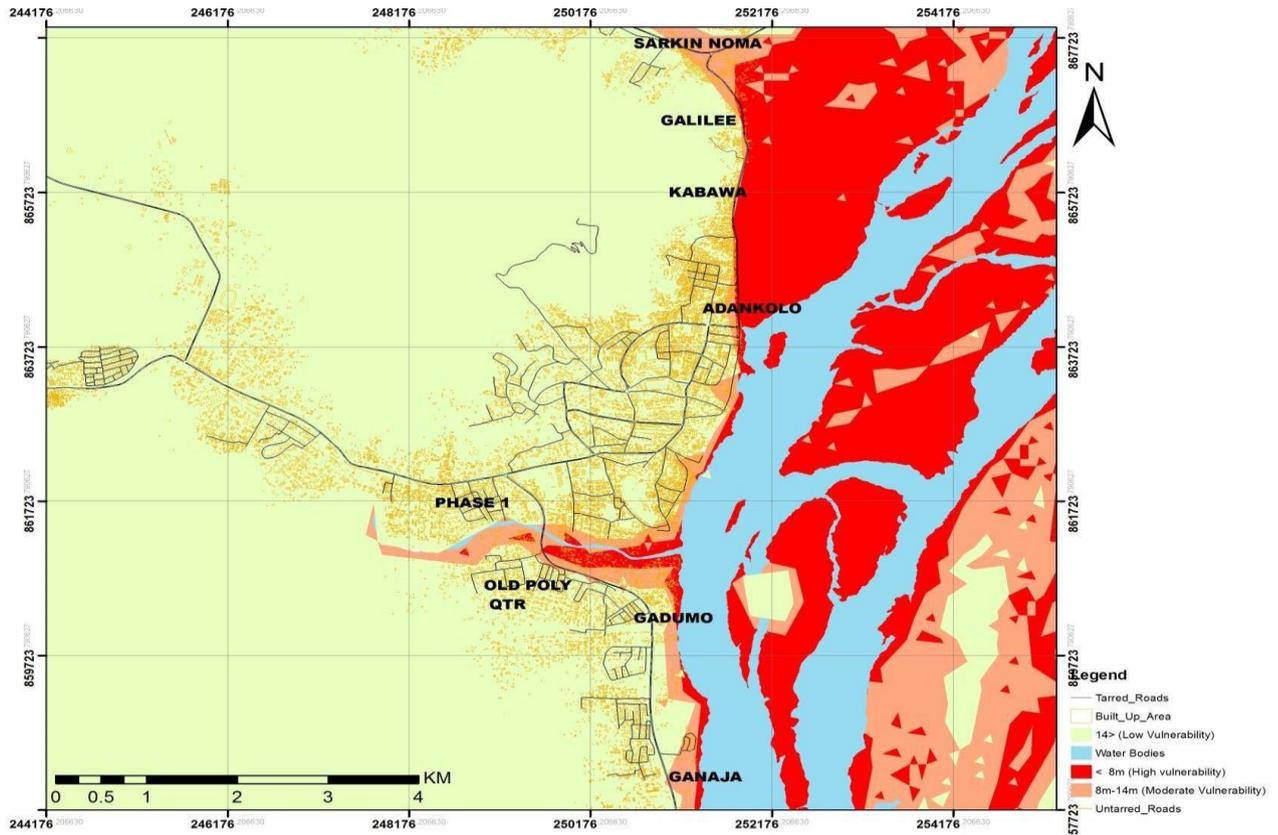| Water Level	Land Use					Total	%
	Residential	Commercial	Public	Industrial	Farmland/ Open Space		
< 8m (High Vulnerability)	64.23	6.79	3.36	0	2754.21	2828.59	13.64
8 - 14m (Moderate Vulnerability)	81.43	10.15	4.38	0.23	3756.34	3852.53	18.57
> 14 m (Low Vulnerability)	2619.1	8.12	46.6	0.22	11389.22	14063.26	67.79
Grand Total						20744.38	100

Source: GIS Analysis, 2016

Figure 6 Flood Vulnerable area of Lokoja Metropolis in Ten Years.
Source: Field survey, 2015

CONCLUSION

The study established that flood occurs in Lokoja metropolis and the water levels recorded at the area influences the inundation of areas under the hazard with most houses submerged and the properties destroyed. The study also revealed that the most affected land uses under the threat of flood in the metropolis are the agricultural producing areas meaning threats to food production and subsequently the living areas (residences). The metropolis is really under the threat of flood hazards, which agrees with the initial position of the causes of flooding in the study area as calculated/ estimated using Sgarma and Sharma (2002) formulas for an increasing flooding in the area. The study only achieved mapping of the high flood vulnerable areas and areas where flood occurs in ten years in regards to already occurred flood but further studies can explore this technique to simulate the situation and predict areas of flooding effects and vulnerabilities to help policy formulation and management. However, the study provides a strong baseline and benchmark for policy formulation and management of flood in Lokoja metropolis. The National Inland Water Authority should collaborate with the Planning Authority, State Emergency Management Authority and the Ministry of Environment to ensure enforcement of standards in relation to setbacks on water ways, and the Government should prepare a flood management plan and risk assessment that will lead to a policy to be jointly enforced by the institutions aforementioned.

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