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MULTI CRITERIA ANALYSIS FOR ASSESSMENT OF VULNERABLE AREAS TO FLOOD HAZARD IN THE UPPER RIVER KADUNA BASIN, NORTH-CENTRAL NIGERIA

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ABSTRACT
The study was conducted on multi criteria analysis for assessment of vulnerable areas to flood hazard in the upper river Kaduna basin, north-central Nigeria. Six (6) criteria; topography, slope, landuse and landcover, stream density, soil types and mean annual rainfall of the area were integrated for assessment of vulnerability of flood hazards in the basin. Data on each of the six (6) factors were acquired, processed, weighted (using Analytical Hierarchy Process (AHP)) and overlain using weighted sum module of ArcGIS 10.5 software. The output map was classified into four (4) classes of vulnerability, that is, highly vulnerable, vulnerable, marginally vulnerable, and safe zones. The result revealed that parts of Bauchi, Kano, Katsina and Plateau States that were within the basin were not much vulnerable to flood hazards. However, close to half of the land area (48.43%) in Kaduna State were found to fall in either highly vulnerable or vulnerable zones, while 88.9% of the land area of Niger State within the Basin was also either highly vulnerable or vulnerable. Kaduna metropolis (comprising of the entire Kaduna North and South LGAs as well as parts of Igabi and Chikun LGAs), which is the most populated town within the entire basin was found to be more vulnerable to floods than any of the other LGAs in the State. In Kaduna South, 86.87% were highly vulnerable, almost half (44.88) of the land area of Kaduna North were also highly vulnerable. It was concluded that rainfall, topography urbanization and land-use were the main factors responsible for flood hazards. Proper land-use management and monitoring as well as sustainable utilization of the entire River Kaduna basin were recommended to minimize the constant occurrence and effects of floods in the area.

Keywords: Analytical Hierarchical Process, Flood Hazards, Flood Vulnerability, Geospatial Techniques, Kaduna Basin, Multi-Criteria Analysis.

INTRODUCTION
Hazard is a phenomenon that posed a serious threat to life, environment and properties. It can occur naturally or induced by man; it is natural when it includes earthquakes, volcanic eruptions, avalanches, tsunamis, cyclones, floods, draughts, blizzards and wildfires which man cannot change, but can prepare for them in terms of warning systems, evacuation plans and aid organization. Man-made hazard on the other hand include toxicity of pesticides to fauna, accidental release of chemicals or radiation from a nuclear plant and collapse of dams (Burton *et al.,* 1993). When any of these hazards takes place in an area that is not habited or utilized, it causes no harm, and hence, not a disaster (Nils-Axel, 2015). Therefore, natural phenomenon that occurs in a populated area is called hazardous event and vulnerable to lives and properties.

Vulnerability refers to the way hazard or disaster affects human life and property. Vulnerability to a given hazard depends on: proximity to a possible hazardous event, population density in the area proximal to the event, scientific understanding of the hazard, public education and awareness of the hazard, existence or non-existence of early-warning systems and lines of communication, availability and readiness of emergency infrastructure, construction styles and building codes and cultural factors that influence public response to warnings (Indrajit and Tuhin, 2018). In general, less developed countries are more vulnerable to natural hazards than are industrialized countries because of lack of understanding, education, infrastructure, building codes, and poverty which leads to poor building structure, increased population density, and lack of communication and infrastructure. Risk Assessment involves not only the assessment of hazards from a scientific point of view, but also the socio-economic impacts of a hazardous event. Risk assessment involves; hazard assessment, location of buildings, highways, and other infrastructure in the areas subject to hazards, potential exposure to the physical effects of a hazardous situation, the vulnerability of the community when subjected to the physical effects of the event (Stephen, 2018). Risk assessment aids decision makers and scientists to compare and evaluate potential hazards, set priorities on what kinds of mitigation are possible, and set priorities on where to focus resources and further study.

Like most other basins in the world, River Kaduna which is the longest and the largest tributary to River Niger before the Benue confluence, has been subjected to numerous environmental hazards such as floods (Alayande and Agunwamba, 2010; and Ijigah and Akinyemi 2015), and soil erosion (Aliyu *et al.,* 2015; and Aliyu *et al.*, 2017), which usually result into disaster: that is, destruction of properties, displacement, migration or death of animals and people (Jeb and Agarwal, 2008; and Aliyu and Suleiman, 2016). A recent study on flooding and flood risk reduction in Nigeria by Nkwunonwo *et al.* (2015) revealed that between 1985 and 2014, flooding has affected more than 11 million lives, with a total of 1100 deaths and property damage exceeding US$17 billion. In 2012, Nigeria recorded the worst incidence of flood in over 40 years as it claimed 363 lives and displaced over 2.1 million people as at November 5, 2012. Records by the National Emergency Management Agency (NEMA) revealed that 30 of Nigeria’s 36 States were affected by the floods and affected an estimated total of seven million people. The estimated damages and losses caused by the floods were worth over ₦2.6 trillion. Specifically, in 2015, Kaduna State recorded flood menace resulting in the displacement of several families, and a similar situation arose in Benue State in 2017, which displaced over 100,000 people. In the findings of Nkwunowo *et al.* (2015) attempt to tackle the hazard, appear to be limited by lack of flood data and other remote causes, which are yet to be identified and therefore, concluded that experts in their search for a sustainable solution to the problem of flood have consistently argued that more robust and scientific approaches to flood risk reduction such as flood modeling and vulnerability assessment are lacking.

Several works have been carried out to assess the vulnerability and extent of flood hazard in the floodplains but mostly on Kaduna metropolis without taking into consideration the entire River basin where the causal factors, extent and impact of flood hazard can be assessed at a larger scale. Moreover, most of the existing works in the metropolis considers only one factor such as effect of urbanization, land-use and land-cover, topography among others at a time instead of integrating the several factors for flood hazards in the basin.

Therefore, in the study, multi-criteria analysis was used to integrate six flood hazards' criteria, that is, topography, soil, land-use and land-cover, rainfall intensity, stream density and slope, for modeling and investigation of vulnerable land and communities to flood hazard in the Basin. Therefore, the main objectives of the study were to: integrate natural and environmental factors for modeling vulnerable land and communities to flood hazard within the basin; assess the level of vulnerability of each of the riparian LGAs within the Basin; and identify the main factors that cause frequent flood hazard in Kaduna Metropolis

MATERIALS AND METHODS The Study Area

Upper River Kaduna is defined in this study as the catchment of River Kaduna from the upstream to Shiroro dam in Niger State, which covers 32,216.72 $km^2$with a perimeter of 6,634.88km. Within Kaduna State, though, 18 out of the 23 LGAs are either entirely or partly located within this basin, but, the catchment covers the entire land areas of only 10 out of the 23 LGAs in the State that is, Chikun, Giwa, Igabi, Kaduna North, Kaduna South, Kauru, Kudan, Sabon Gari, Soba and Zaria LGAs. Major land area of six (6) LGAs (Birnin Gwari, Kachia, Kajuru, Kuban, Lere and Makarfi) is also within the catchment. Finally, little portions of Ikara and Zango Kataf LGAs of the State only fall within the catchment. The Upper Kaduna Basin also extends beyond Kaduna State into the western parts of Torro and Bassa LGAs in Bauchi and Plateau States, respectively. In Niger State, the basin extends into some parts of Muya, Paikoro and Shiroro LGAs. A little portion of the land area of Rogo and Doguwa LGAs in Kano State also falls within the basin. In Katsina State, some parts of Sandume, Danja, Funtua and Gabuwa LGAs were within the catchment (Figure 1).

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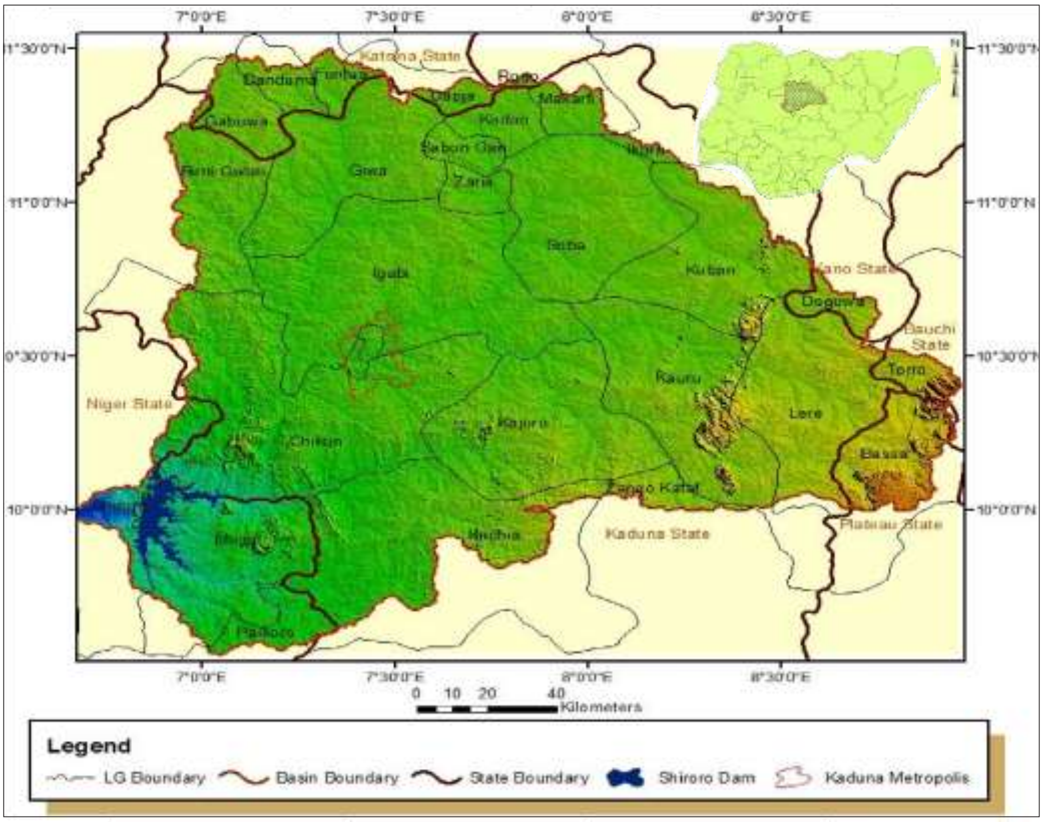

Figure 1: *The study area*

Further to Figure 1, the major parts of the basin are lowlands, that is, low floodplains (230-520 m) high floodplains (520.1-635 m) and the plains (635.1-729 m). The highland areas are found in Bassa and Torro LGAs in Plateau and Bauchi States, respectively, with a range of altitudes from 913 to 1582 m above sea level (Figure 1 and 2a). The plains are mainly found in Lere, Zango Kataf and Kachia LGAs. River Kaduna is the main river within the basin, joined by other tributaries such as Rivers Tubo, Galma and Karami from the north and Rivers Dinya and Sarkin Pawa from the south. River Kaduna is the only perennial among the existing rivers; several streams are also found within the basin. The basin has two distinct seasons; the wet season which starts in April and ends in October and the dry season from November to March (Ijigah and Akinyemi, 2015). This means that the area receives rainfall for at least six months annually. Using the rainfall data between 1950 and 2016, the pattern of mean annual rainfall was found to be latitudinal and ranging between 935 mm in the north to 1374 mm in the south, which is similar to that of Ijigah and Akinyemi (2015), Yunusa *et al.* (2017).

The total population of the 10 LGAs that are fully within the catchment in Kaduna State, based on the 2006 housing and population census were 1,557,894 people (NPC 2007), constituting more than half of the total population (51.53%) in the entire 23 LGAs of the State. This population figures suggest that millions of people are residing within the basin. The catchment also lies within the Guinea savanna in the south to the Sudan savanna in the north. Both vegetation belts are covered with woodlands and grasses, but that of the Guinea savanna in the south are more wooded with taller grasses than the Sudan in the north. Riperian forest are also found mainly along river valleys, though mostly deforested due to human activities like farming, fuel wood harvesting, bush burning and animal grazing. All these activities expose the land to serious land degradation.

Generation of the Basin's Topography

ASTERGDEM v2 dataset was obtained online from United State Geological Survey (USGS) for the purpose of generating the DEM of the basin. A Triangulated Irregular Network (TIN) of the basin using contour 50 m was generated using the TIN management module of ArcGIS 10.5 software (Figure 2a). The TIN map was rasterized and classified into five (5): highly vulnerable (which comprises the low floodplains and the depressions within the high floodplains), vulnerable (remaining land areas of high floodplains) marginally vulnerable (plains), low safe zones (uplands: which can be utilized for rescue missions and temporary camps) and high safe zones (mountain and highland areas).

Slope Mapping

The DEM of the basin was also processed to generate the slope of the catchment. The slope module of ArcGIS was run on the DEM, using percentage method. The output slope was classified into five, based on the steepness of the slope and each of the classes was in turn assigned values according to the vulnerability to flood based on the facts that the steeper the slope, the safer from flood hazard and vice versa.

Land-use and Land-cover Classification

The following four (4) Landsat images covering the catchment and which was captured within the same season (dry season) were obtained online (USGS earthexplorer.usgs.gov). The details of each of the images are presented in Table 1.

Table 1: Source and Ccharacteristics of Landsat Images

Images	Source	Path	Row	Date
Landsat 8	earthexplorer.usgs.gov	188	052	25th Nov. 2018
Landsat 8	earthexplorer.usgs.gov	188	053	27th Dec. 2018
Landsat 8	earthexplorer.usgs.gov	189	052	19th Jan. 2019
Landsat 8	earthexplorer.usgs.gov	189	054	20th Feb. 2019

Source: USGS (2019)

Preprocessing activities such as mosaicking of the four images, extraction of the catchment area and image filtering were performed. The extracted image was then classified into the following: (i) built-up areas (ii) forest (iii) grassland (iv) water body (v) bare surface (vi) farmland. Accuracy assessment was performed using the confusion matrix in ENVI environment which shows 91.2346% overall accuracy and Kappa co-efficient of 0.8427. Since the coefficient is close to 1 with a high overall percentage, the classification output was accepted and integrated for the study. The classified image was part of the integrated data for modeling flooding within the basin (Figure 5).

Soil Mapping

The shape file of the catchment was used to extract the soil units from "dominant soils in Nigeria obtained from FAO/UNESCO/ISRC (1997). Each of the soil units within the catchment was digitized and rasterized for overlay operations Figure 6.

Rainfall Mapping

The mean annual rainfall of the catchment was derived from online climatic data obtained from Tropical Applications of Meteorology Using Satellite Data and Ground-Based Observations (TAMSAT) rainfall data from 1983 to 2016- a period of 34 years. The mean annual rainfall that was generated from the online data was compared to the in-situ mean annual rainfall values of Kaduna and Zaria towns (1983-2016) obtained from NIMET in 2017. The mean annual rainfall (1983-2016) was computed for the two towns and 1228.52 mm and 994.39 mm were arrived at for Kaduna and Zaria towns, respectively.

From the rainfall map in Figure 6. Kaduna falls within the range of 1180 and 1254 mm, which means the 1228.52 mm obtained on ground falls within the online class where Kaduna falls. For Zaria, the 994.39 mm in-situ mean annual rainfall also falls within the class of 905 and 1026 mm of the online class as shown in Figure 6. This shows that there is a close relationship between the two data sets. Online climatic data are now becoming popular because of their reliability and consistencies which are sometimes lacking in in-situ data that are prone to human errors, incomplete data, and negligence among others (Karthika, 2015; Tufa, 2018; and Ikusemoran *et al.,* 2019). Moreover, online climatic data are now globally been used by researchers for modeling and prediction of climatic elements (Olusina and Odimade, 2012; Luis *et al.*, 2015; Clement *et al.*, 2018; and Ikusemoran *et al.*, 2019).

Mapping Stream Density

Streams and rivers in the catchment were delineated from the DEM data. The flow accumulation of ArcGIS software was run on the direction of flow of the streams; the generated streams were merged together as a single layer. The stream density module of ArcGIS was used to map the stream density of the basin. The generated map was finally classified into five based on the numbers of the streams as shown in Figure 5.

Modeling Flood Vulnerability Areas

The six (6) criteria; topography, land-use and land-cover, rainfall intensity, stream density, soil and slope were integrated using Multi-Criteria Decision Analysis (MCDA) method. Each of the criteria was classified and assigned values that were proportional to their intensities such as 5 for very high impact, 4 for high impact, 3 for marginal impact 2 for low impact and 1 for very low impact. The criteria were weighted using AHP methods of weighting (Saaty, 2012) as summarized in Table 2.

Table 2: AHP of the Six Criteria for the Study

Landuse/Landcover	Priority	Weights	Average	Sum
Rainfall	0.34	34.22	376.37	11.00
Topography	0.23	23.16	213.10	9.20
Stream Density	0.17	16.68	123.42	7.40
Landuse	0.12	12.04	67.45	5.60
Slope	0.08	8.43	32.04	3.80
Soil	0.05	5.47	10.93	2.00

Source: Researcher's work (2019)

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The Eigen value was arrived at by dividing the total sum of 39 by the number of criteria (6). Therefore, Eigen value is 6.50. To obtain the Consistency Index (CI);

$CI = (\lambda_{max}-n)/(n-1)$ …(1)

where;

λ_{max} = eigen value = 6.50 n

= number of criteria = 6

Therefore, CI = (6.50-6)/(6-1) = 0.1; The Random Index (RI) for six (6) criteria is 1.24 (Saaty, 2012); and; therefore, to obtain the Consistency Ratio (CR); CR = CI/RI where;

CI = 0.10, RI = 1.24. Therefore, CR = 0.10/1.24 = 0.08

According to Saaty (2012), when the CR of AHP is equal to or less than 1, the weights (Table 2) can be used for the criteria for AHP analysis, but if the value is more than one, the weights cannot be used. The weighted outputs of all the criteria (Table 2) were integrated using weighted sum method of overlay in ArcGIS environment. Finally, the output map was reclassified into four: highly vulnerable, vulnerable, marginally vulnerable, and free zones classes as shown in Figure 8.

Calculation of Vulnerable Areas

Each of the five vulnerability classes was clipped to each of the riparian LGAs in the basin. The area of each class was calculated in kilometers square in ArcGIS environment as presented in Table 3.

RESULTS AND DISCUSSION

The six (6) criteria that were integrated for modeling the flood hazards are shown in Figures 2 to 6. The final vulnerability map is also presented in Figure 8. Table 3 shows the land vulnerability in each of the riparian LGAs of the Upper River Kaduna Basin.

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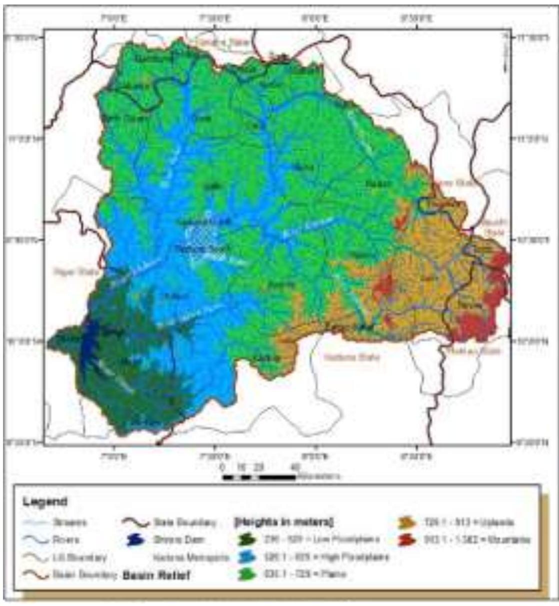

Figure 2a: *Relief of the basin*

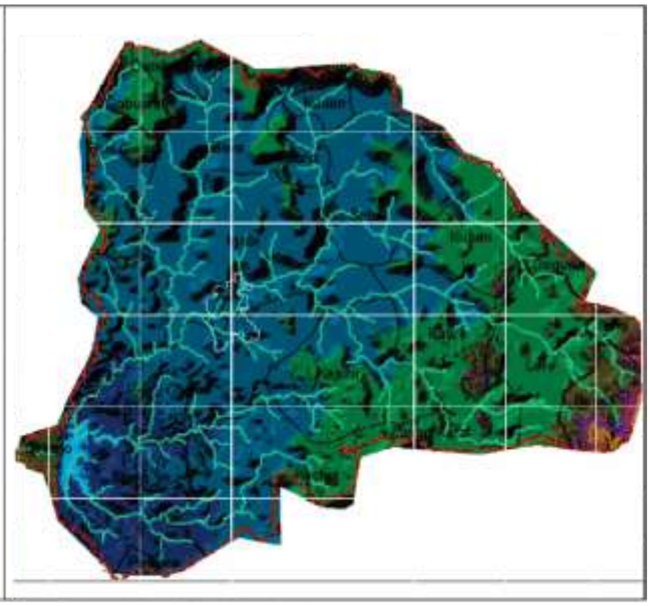

Figure 2b: *TIN of the basin*

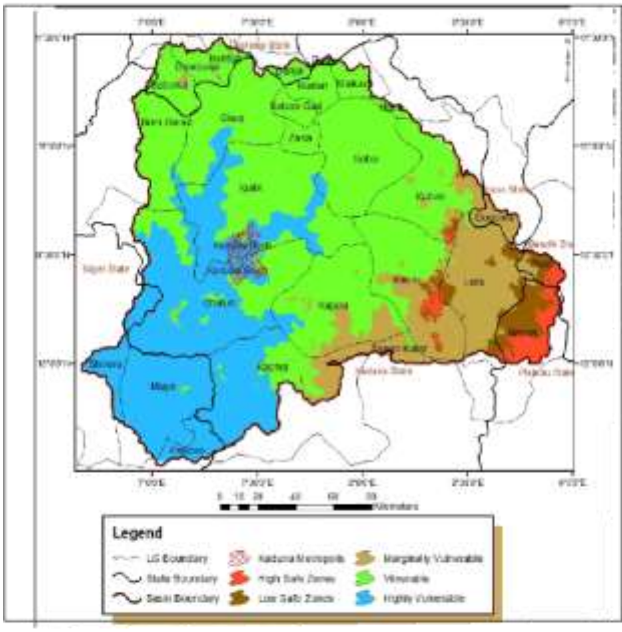

Figure 2c: *Flood vulnerability due to topography*

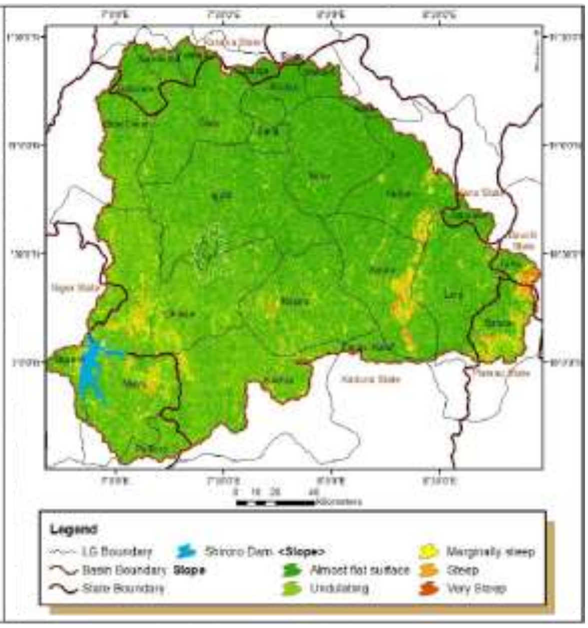

Figure 3: *Slope of the basin*

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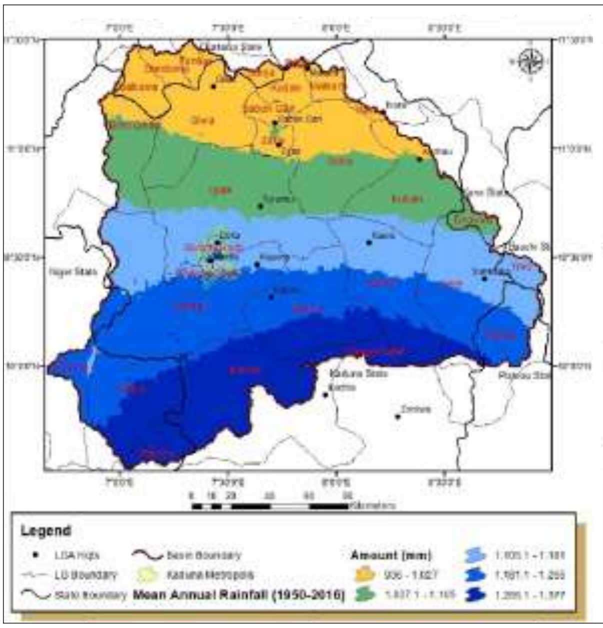

Figure 4: *Mean annual rainfall of the basin (1920-2000)*

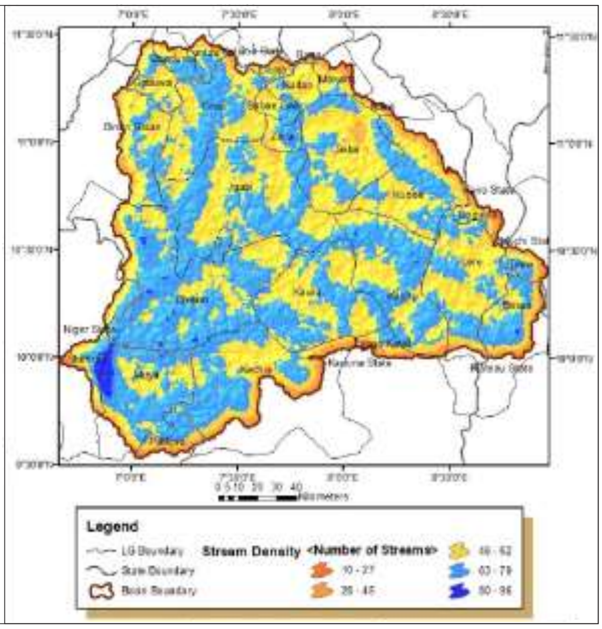

Figure 5: *Stream density of the basin*

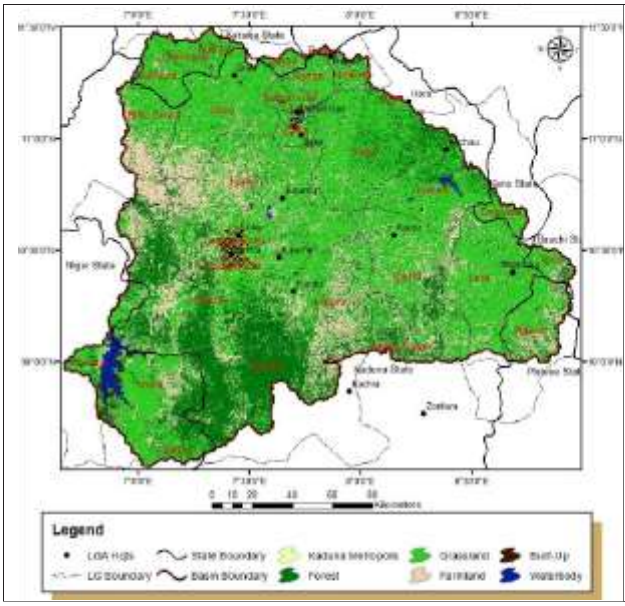

Figure 6: *Land-use and land-cover of the basin*

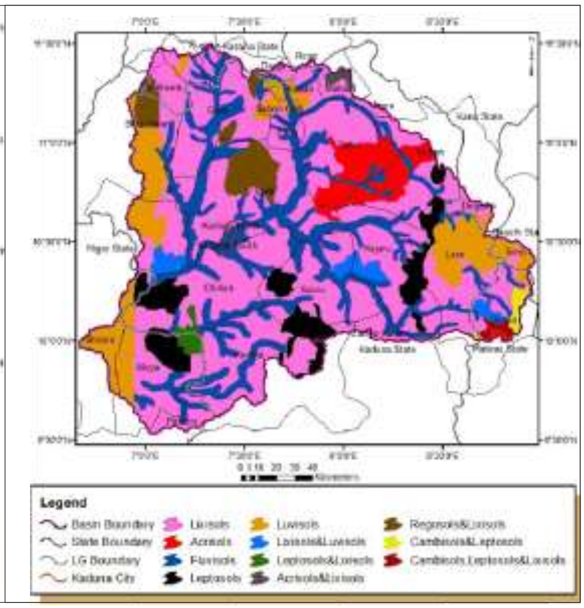

Figure 7: *Soil units in the basin*

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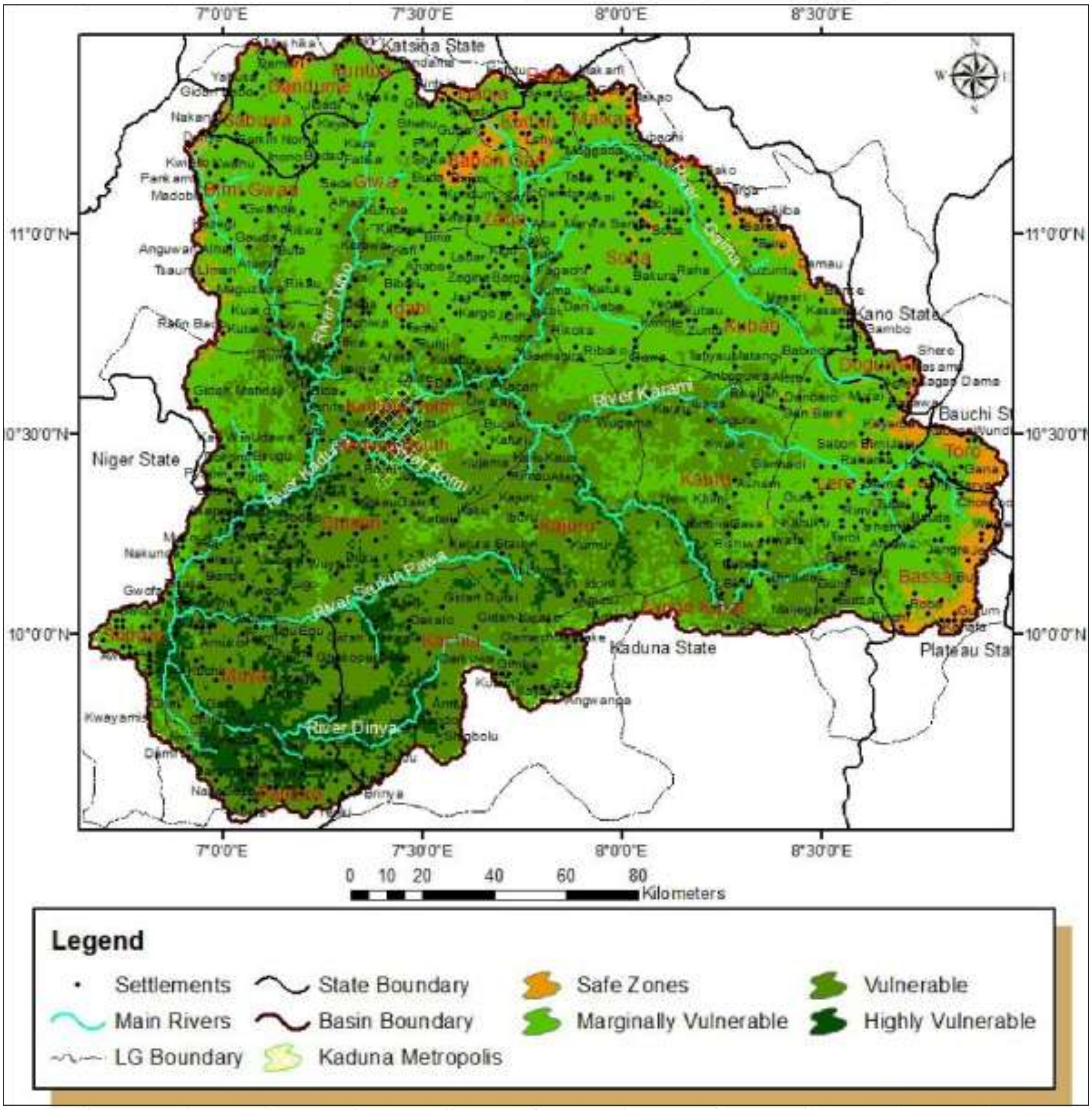

Figure 8: *Upper Kaduna basin flood vulnerability zones* **Table 3:** Flood Hazard Vulnerability of each Riparian LGAs of the Basin

S/N	LGAs	Land Area (km²)	Basin Area (km²)	Basin % of LGA	Highly Vulnerable Area (km²)	Highly Vulnerable %	Vulnerable Area (km²)	Vulnerable %	Marginally Vulnerable Area (km²)	Marginally Vulnerable %	Safe Zones Area (km²)	Safe Zones %
Kaduna State												
1	Birnin Gwari	6187.89	1215.32	19.64	1.03	0.08	118.03	9.71	997.63	82.09	98.63	8.12
2	Chikun	4646.43	4135.18	89.00	525.79	12.72	2669.17	64.55	940.22	22.74	-	-
3	Giwa	2066.27	2066.27	100	-	-	272.16	13.17	1748.17	84.61	45.94	2.22
4	Igabi	3727.48	3727.48	100	232.74	6.24	1803.56	48.39	1691.18	45.37	-	-
5	Ikara	852.98	83.76	9.82	-	-	-	-	77.83	92.92	5.93	7.08
6	Kachia	4652.78	2598.61	56.10	560.77	21.58	1857.92	71.50	179.92	6.92	-	-
7	Kaduna North	72.42	72.42	100	32.50	44.88	36.2	49.99	3.72	5.14	-	-

8	Kaduna South	59.34	59.34	100	51.55	86.87	7.79	13.13	-	-	-	-
9	Kauru	2810.18	2387.48	84.96	49.00	2.05	1478.06	61.91	860.42	36.04	-	-
10	Kajuru	2464.39	2464.39	100	267.63	10.81	1866.12	75.72	330.64	13.42	-	-
11	Kuban	2504.9	1876.09	74.90	21.47	1.14	175.16	9.34	1540.33	82.10	139.13	7.42
12	Kudan	399.85	399.85	100	-	-	4.13	1.03	291.63	72.93	104.09	26.03
13	Lere	2157.25	2041.62	94.64	1.40	0.07	410.85	20.12	1494.82	73.22	134.55	6.59
14	Makarfi	540.59	309.28	57.21	-	-	-	-	249.94	80.81	59.34	19.19
15	Sabon Gari	263.84	263.84	100	-	-	21.30	8.07	171.8	65.12	70.74	26.81
16	Soba	2232.89	2232.89	100	-	-	139.04	6.23	2067.39	92.59	26.46	1.19
17	Zango Kataf	2667.34	290.61	10.90	22.60	7.78	169.25	58.24	98.76	33.98	-	-
18	Zaria	299.83	299.83	100	-	-	50.98	17.00	248.85	83.00	-	-
Total		38606.65	26524.26	68.70	1766.48	6.66	11079.72	41.77	12993.25	48.99	684.81	2.58
Bauchi State					-	-						
19	Toro	7067.46	289.64	4.10			1.40	0.48	145.15	50.11	143.09	49.40
Kano State												
20	Doguwa	1439.12	272.06	18.90	-	-	-	-	224.61	82.56	47.45	34.34
21	Rogo	811.00	27.81	3.43	-	-	-	-	22.30	80.19	5.51	19.81
Total		2250.12	299.87	13.33					246.91	82.34	52.96	17.66

Source: Researcher's work (2019)

Flood Hazard Vulnerability Analysis

Figure 8 and Table 3 show the flood vulnerability zones and the vulnerable land area and communities in the riparian LGAs of Upper River Kaduna Basin, respectively. The vulnerability map revealed that the major highly flood vulnerable areas are mainly along the major Rivers within the Basin as well as the low floodplains region of the Basin. The valleys of River Kaduna and its six main tributaries (Rivers Dinya, Galma, Karami, SarkinPawa, Tubo, and Romi) were found to be highly vulnerable (Figure 8). The low floodplains of the catchment (Figure 8) which covers major land area of Muya LGA, western part of Chikun as well as almost the entire land of Paikoro and Shiroro LGAs within the Basin and the western side of Kachia LGA were all found to be highly vulnerable to flood hazard. From Table 3, only 8.6% of the entire basin was found to be highly vulnerable. The vulnerable areas are areas that are though, also vulnerable but with lower frequency and intensity. The vulnerable areas are mainly found along the valleys of the main Rivers as well as the low and high floodplains areas. A large area covering 39.7% of the basin is within the vulnerable zone. The marginally vulnerable areas are regions that are only occasionally flooded. The zone covers almost half of the entire basin (47.68%). Safe zones are mainly on mountains and highland areas such as Jos plateau at the eastern extreme and the watershed areas between Kaduna and Bauchi, Katsina and Kano States.

Table 3: Flood Hazard Vulnerability of each Riparian LGAs of the Basin **Cont'd.**

S/N	LGAs	Land Area (km^2)	Basin Area (km^2)	Basin % of LGA	Highly Vulnerable Area (km^2)	%	Vulnerable Area (km^2)	%	Marginally Vulnerable Area (km^2)	%	Safe Zones Area (km^2)	%
Katsina State												
22	Funtua	480.37	198.08	41.23	-	-	3.74	1.89	185.44	93.62	8.90	0.04

23	Dandume	427.15	285.53	66.85	-	-	5.09	1.78	245.15	85.89	35.29	12.36
24	Danja	464.35	213.37	49.95	-	-	0.50	0.23	184.85	86.63	28.02	13.13
25	Sabuwa	663.28	522.51	78.78	-	-	4.06	0.78	506.38	96.91	12.07	2.31
Total		2035.15	1219.49	59.92	-	-	13.39	1.10	1121.82	92.00	84.28	6.91
Niger State												
26	Muya	2314.73	1914.6	82.71	785.91	41.05	1090.28	56.95	38.41	2.01	-	-
27	Paikoro	2190.97	409.14	18.67	137.29	33.56	271.85	66.44	-	-	-	-
28	Shiroro	5295.22	646.79	12.21	85.30	13.19	270.09	41.76	291.4	45.05	-	-
Total		9800.92	2970.53	30.31	1008.5	33.95	1632.22	54.95	329.81	11.11	-	-
Plateau State												
29	Bassa	1664.75	957.88	57.54	-	-	80.90	8.45	547.02	57.11	329.96	34.45
Grand total		61425.05	32261.67	52.52	2774.98	8.60	12807.63	39.70	15383.96	47.68	1295.1	4.01

Source: Researcher's work (2019)

In Kaduna State, Table 4 revealed the top eight (8) LGAs within the Basin that are either highly or vulnerable to flood hazard. The LGAs comprises: Chikun, Igabi, Kachia, Kaduna North, Kaduna South, Kajuru, Kauru and Zango Kataf. Lere and Zaria LGAs also have 20% and 17%, respectively, of their land area vulnerable to flood hazard. These eight (8) LGAs are the same LGAs that have been frequently reported to have been excessively affected by floods (NEMA 2003; Jeb and Aggarwa, 2008; and Ijigah and Akinyemi, 2015). Communities that are located either in highly vulnerable or vulnerable areas are bound to be given more attention than those in the other vulnerable zones. Table 4 shows some of the communities that are found in highly vulnerable or vulnerable zones in seven (7) out of the eight (8) LGAs that are found to be more prone to flood hazard. Major land area of ZangoKatafLGA within the basin was found to be largely uninhabited and therefore not included in Table 4. In the work of Akintayo (2015), parts of Barnawa, Tudun-wada, Kigo Road, Gonin Gora, Karatudu and Rafinguza, Ramat Road, in Haliru Dantoro, Kabala Costain, Kabala West, UnguwanDosa, all in Kaduna metropolis were all almost submerged. Parts of Lere, Kachia, Chikun, Kaduna North, Kaduna South, Igabi, Soba and Zaria council areas were also affected by the flood. All these communities were also found to be either highly vulnerable or vulnerable in this study as shown in Table 4.

Table 4: Some of the Communities that are Highly Vulnerable or Vulnerable to Flood Hazard in the Basin

LGAs	**Highly Vulnerable**		**Vulnerable**		**Total (%)**
	%	**Communities**	**%**	**Communities**	

Chikun	12.72	Goni Gora, Kupari, Kosewa, Galbi, Kabema, Garu, Shepi, Kugos, Bwashishi, Kwafa, Shekalafu, Chagwa, Ungwan Galadima,Ungwan Pama, Kura, Chidinu, Ungwan Tanko etc	64.55	Chikuri, Gwazunu, Kashega, Kabai, Kakau, Kurada, Ligari, Chikun, Nafao, Kafako, Katerma, Kwapi, Wuya, Kaserami, Gidan Makeri	77.27
Kachia	21.58	Audi, Gidan Makama, G/Dala, G/Alkali, G/Dan Biki, G/Busa, G/Agata, G/Hassan, RafinDinya, Rando, Rishi, Old Dudu, Gamachua etc	71.50	Mai Ido, GidanBako, G/Kwaso, G/Dutsi, Dawodu, Achi, Doka, Shigbolu, Amfu, Kuderietc	93.08
Kaduna North	44.88	Ungwan Shanu, Kawo, Ungwan Rimi, Kabala, Birnawa and Tundun Wada	49.99	SabonGida, Resa, Rafin Kura	94.87
Kaduna South	86.87	Abakpa, Badiko, Tudun Nupawa, Namiya and Kudenda	13.13		100
Kajuru	10.81	Station Iri, IriArna	75.72	Kajuru, Kufana, Kurmi, Katura Station, Idon, Agunu, Ruwau, Kalla, Wugama	86.53
Igabi	6.24	Rigassa, Kakura, Gwazo, Zato, Ungwan Liman, Rumana, Buruku, Burkorno	48.39	Katabu, Fan Shanu, Sobawa, Zaure, Ungwan Ma Aji, Sanda, Turu Kawa, Yalwa, Tuba, Kawara, Pagachi, Kankurmi, Ifira, Gidan Bawa, Kusharki, Kwate, Gudu Gaya	54.63
Kauru	2.05	Bikal, Kabele, Kusheka	61.91	Kauru, Makami, Wufana, Kagura, Ibada, Galadimawa, Kaguta, Kusamani, Zamfaru, Geshare, Binawa	63.96

Factors Responsible for Flood Hazard in Kaduna Metropolis

The analysis of each of the criteria for modeling flood hazard vulnerable areas was used in this paper to identify the factors that makes Kaduna metropolis to be prone to frequent flooding. The following factors were identified:

(i) Low Terrain/Topography

The location of Kaduna metropolis which comprised of Kaduna North and South as well as parts of Chikun and Igabi LGAs was found to be in a low terrain, that is, in high floodplains (Figure 2a). This general low terrain of the area allows easy flow of water whenever it floods. Moreover, Fig. 2b also revealed that Kaduna metropolis is located in a depression of three Rivers: Rivers Kaduna, Tubo and Romi. This makes water from the high elevated places to accumulate in these depressions and therefore, result into serious flood. The topography, as revealed in this study is an important determinant of vulnerable areas to flood in Kaduna metropolis which has also been noted by several authors (Ijigah and Akinyemi 2015; and Aliyu *et al.*, 2015).

(ii) High Rainfall

Figure 4 shows that mean annual rainfall (1950-2016) in the central part of Kaduna metropolis is higher than the surrounding areas, while rainfall within the latitudes of the location of Kaduna ranges from 1104-1180mm. The mean annual rainfall of Kaduna metropolis ranged from 1180-1254mm. Therefore, since the metropolis receives more rainfall than the immediate environment, flood hazard is naturally bound to be more in the metropolis. Moreover, the trend

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of mean annual rainfall between 1982 and 2016; a period of 35 years (Figure 9) shows that rainfall in the metropolis is increasing as supported by the positive trend line equation of y = 8.9808x+1069.3.

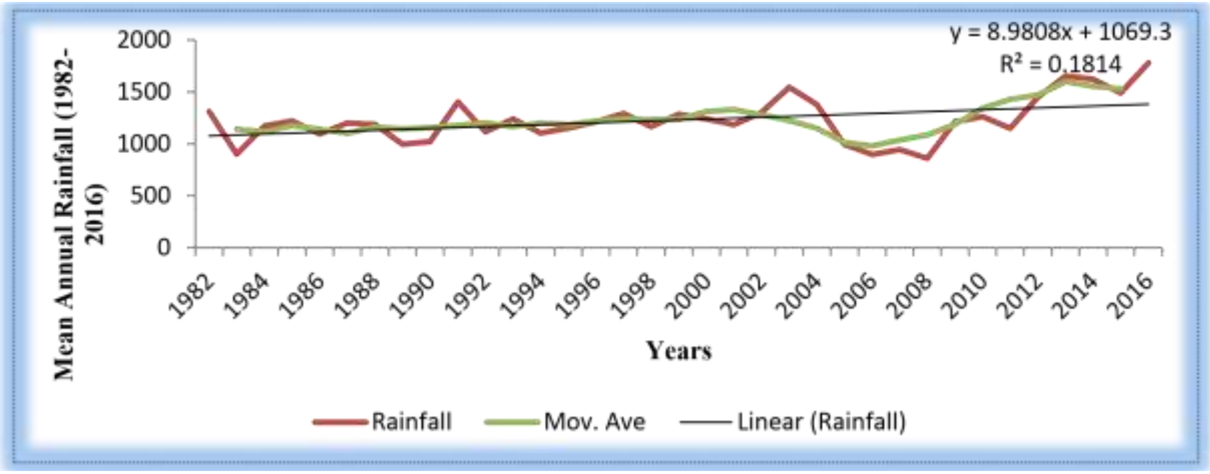

Figure 9: *Rainfall trends in Kaduna metropolis (1982-2016)*

The trend line also revealed high rainfall in 2003 which resulted into the widely reported 2003 Kaduna flood (National Emergency Management Agency [NEMA], 2003) which was reported to have washed away thousands of houses and rendering up to 100,000 homeless, figures of the death toll was put at 50. The increasing flood hazards in the metropolis especially since 2012 could also be attributed to the rising rainfall trends in the metropolis since 2012 as observed in Figure 9.

(iii) Drainage

Kaduna metropolis as revealed in Figures 2a, lies almost at the confluence of three Rivers: Kaduna (from the east), Tubo (from the north) and Romi (from the south). To worsen the situation, the confluence is a depression which makes runoff to accumulate in the depression instead of flowing downstream as revealed in Figure 2b Therefore the metropolis suffers flood from these three major rivers and due to accumulation of water in the depressions.

(iv) Soil

Kaduna metropolis generally falls within Fluvisols soil unit, while Lixisols is the main soil unit in the extreme Kaduna North LGA (Figure 6). FAO (2017) described Luvisols soil unit as *the soil type that is* found typically on level topography that is flooded periodically by surface waters or rising groundwater, as in river floodplains and deltas and in coastal lowlands. Lixisols was also said to have the presence of a subsurface layer of accumulated Kaolinitic clays and the absence of an extensively leached layer below the surface horizon, that is, the uppermost layer. These two soil units encourage the occurrence of flood hazard. This is unlike Hawul Basin for instance where Fluvisols covers only 0.41% with no presence of Lixisols, hence the basin is subjected to minimal flood occurrence (Ikusemoran *et al*., 2018).

(iv) Slope

The slope of the metropolis as presented in Figure 3 is the undulating and almost flat slope areas. This slope characteristic enables water to spread over a large land area since no highlands or mountains will serve as obstacles to their spread.

(v) Urbanization

Several studies have proved that the land area of Kaduna metropolis is rapidly increasing (Opatoyinbo *et al.,* 2015; and Aliyu *et al.,* 2015). In the work of (Opatoyinbo Opatoyinbo *et al.,* 2015), the built-up area of Kaduna metropolis which occupied 2156 ha in 1976, increased to 5506 ha in 2010. Thus, between 1976 and 2010, the built-up area increased by almost 3,350 ha, or nearly 155%. Aliyu *et al.* (2015) also reported similar trends of 3234.40 ha in 2001 to 4032.66 in 2010. Both portray rapid expansion of the metropolis. Urbanization has so much indirect effect on flooding as natural land areas are always altered, modified or converted into other land-use types especially into cultivated land and built-up. The findings of Aliyu *et al.* 2015) revealed that the trend of change in the metropolis indicates a progressive conversion of natural vegetation areas into farmlands and finally into built up lands. Ndabula *et al.* (2012) also observed that the highest rates of encroachment on River Kaduna floodplains in Kaduna metropolis were recorded by communities in the proximity of the Central Business District (CBD) such as Tundu Wada, Ungwan Rimi, Barnawa, Doka and the industrial layouts of Kakuri and Kudenda. Ndabula *et al.* (2012) concluded that 48.55km^{2}of the floodplains have been encroached by built-up. Associated problems of urbanization to flood hazard include lack, inadequate or non-functional drainage networks, dumping of wastes/refuse in drainage and water channels, overflowing of river banks, increased runoffs, and climate change (Aliyu and Suleiman, 2016).

CONCLUSION AND RECOMMENDATIONS

Multi criteria analysis has been applied in this paper to investigate the land and communities that are vulnerable to flood hazard in the Upper River Kaduna Basin in Nigeria. Most of the existing researches are concentrated on possible causes and remedy of flood hazard only in Kaduna metropolis using single criterion such as topography, rainfall, land-use, urbanization among others. In this study, these criteria were integrated to assess the land and communities that are vulnerable to flood hazard in the entire basin and identify the major factors that cause flood hazard in Kaduna metropolis.

The output map reflects the current situations of flood hazard within the basin which proves the capability and reliability of geospatial techniques for flood hazard monitoring. The techniques, no doubt, other than the reliability is also considered to be time saving, cheaper, cover large area among others than the manual methods. Though geospatial technique has been regarded as better than manual techniques, but it has some shortcomings such as inadequate data, the expertise of the analyst, and data resolution among others. It was pointed out in this study that if flood hazard will be ameliorated in Kaduna metropolis, the physical and environmental factors in the entire basin must be put into consideration. Therefore, flood hazards in the metropolis are not limited to urbanization and its side effects of Kaduna metropolis alone but also depend on the influence of some natural and environmental factors such as topography, drainage, soil, slope, rainfall and land-use and land-cover. The study recommended as follows:

1. Assessment of flood disaster in the highly vulnerable and vulnerable communities in the basin is recommended for further studies.
2. Remotely sensed data and technique should be adopted in monitoring flood hazards for quick, cheaper and reliable results.

3. The physical and environmental conditions of the entire Upper River Kaduna Basin must be taken into consideration in ameliorating flood hazard in Kaduna metropolis.
4. The land area and communities which have been found in the study to be highly vulnerable or vulnerable to flood hazard (and others in the same conditions but not listed) should be given higher priority in flood hazard monitoring and control.
5. Other highly vulnerable and vulnerable flood zones in the other LGAs outside the metropolis should be properly monitored against flood disaster.
6. Urban planners, Ministry of Environment and other agencies responsible for urban development and planning must ensure adequate adherence to regulations regarding residential development, waste disposal, and environmental sanitation for flood hazard control.
7. If all attempts to control flood disaster fail, the residents in the highly and frequently flooded areas especially along the banks of the rivers should be relocated

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