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Spatial Multi-Criteria Evaluation of Proportional Accountability of Flood Causal Factors and Vulnerable Areas in Makurdi, Benue State, Nigeria

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Abstract
There have been considerable reports on flood frequency, vulnerability and risk especially on Makurdi. However, not much has been known about the proportional contribution of the causal factors and distribution among vulnerable areas. This aspect remains fundamental in flood disaster and risk management decisions and actions. It is on this premise that this study applied the spatial multi-criteria evaluation technique (SMCE). The four (4) broad categories of flood causative factors: Climatic (rainfall) , soil (textural distribution of clay and sand content), morphometric (slope, linear and areal) and Land Use / Land Cover (built-up land, bare land, farm land, vegetated land, wetland and water bodies/broad river) were used for the analytic hierarchy process and weighted sum overlay technique. The analysis revealed percentage contributions of the most effective flood causing factors as follows: Rainfall (44.89%), morphometry (34.02%), Landuse / Landcover (12.8%) and soil (6.28%). The weighted sum overlay result shows that low flood vulnerability areas occupy 43.11% (460.782 km^2), moderate flood vulnerability areas 31.13% (332.717 km^2) and high flood vulnerability 25.75% (275.238 km^2). Since this study identified rainfall as the major determinant of flooding it recommends that annual and seasonal rainfall predictions should be enhanced in Makurdi. Also, the area with high flood vulnerability which coincides with built-up area should drive the promotion of flood resilience city structures and enforced by relevant public institutions such as Federal Ministry of Environment, Urban Planning Departments, Works and Housing. Therefore, remediation actions can be applied for the high vulnerability areas while mitigation actions can be focused more on the moderate flood vulnerability areas.
Keywords: Spatial, Multi-criteria, Vulnerability, Flood, Mitigation
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1. INTRODUCTION

Flooding is one of the most common and widely distributed natural risks to life and property worldwide (Jebb, 2013). It has a special place in natural hazards and accounts for approximately one third of all natural disasters in both developed and developing worlds (UNISDR, 2012). Flooding is also responsible for more than half of all related fatalities and a third of the economic loss from all natural catastrophes (White, 2000). The reason for this as observed by Agusomu (2013) lies in the widespread geographical distribution of river flood plains and low lying coast, together with their long standing attraction for human settlement.

The observed escalation in magnitude, frequency, and intensity of flood events worldwide have led to a rise in global awareness for flood damage mitigation measures (Hall et al., 2014). According to Danumah *et al.,* (2016), assessing and predicting floods risk has become essential to offer appropriate solutions for flood and sustainable environmental management. Flood vulnerability mapping is a vital component for flood mitigation and appropriate land use planning. It provides accessible charts and maps which can be read easily and therefore, facilitates the identification of risk areas by planners and this enable them to prioritize their mitigation efforts (Bapalu and Sinha, 2005; Forkuo, 2011; Wang et al. 2011; Ajin *et al.,* 2013 cited in: Danumah *et al*., 2014). Flood management is necessary not only because flood imposes huge damages on the society, but for the optimal exploitation of the land and its proper management. This cannot become technically feasible without effective flood hazard and risk maps (Bhatt *et al.,* 2014).

Flood risk occurrence is a combination of natural and anthropogenic factors, which means that there is the need for knowledge about spatial extent of areas liable to flooding, using multi data as drivers becomes a potential source for more reliable flood management. For all that, Spatial Multi-criteria analysis (SMCA) approach has become widely used (Wang *et al.,*2011; Danumah *et al.,* 2014; Sowmya *et al.,* 2015) to solve complex problems and to assess flood risk. Many methods have been proposed for spatial multi-criteria decision making. Analytic Hierarchy Process (AHP) developed by Saaty (1980) is one of the best known and most widely used SMCA approaches (Orencio & Fujii, 2013; Yahaya *et al*., 2010). AHP is used to solve a broad range of multi-criteria decision-making problems, with the pairwise comparison matrix calculating the weights for each criterion considered (Yalcin, 2008; Orencio & Fujii, 2013; Pourghasemi *et al.,* 2014; Danumah *et al.,* 2014). AHP assumes complete aggregation among several criteria and develops a linear additive model. The uniqueness of applying AHP in different studies helps in modeling situations of uncertainty without losing subjectivity and objectivity of any evaluation measure.

According to Danumah *et al.,* (2014) considerable attention has been given to the use of AHP in natural hazard (earthquake and flood) assessment but more in flood management in various studies: (Savane *et al*., 2003; Yahaya *et al.,* 2010; Cozannet *et al*., 2013; Orencio & Fujii, 2013; Saley *et al.,* 2013; Chakraborty and Joshi, 2014; Pourghasemi *et al.,* 2014; Papaioannou *et al.,* 2015; Nejad *et al.,* 2015). It has been shown from these series of papers that AHP has the ability to assess and map flood vulnerability with good accuracy. However, it is based on expert opinions and thus may be subjected to cognitive limitations with uncertainty and subjectivity (Pourghasemi *et al.,* 2014).

There is paucity of research on flood vulnerability assessment using AHP in Makurdi. This has necessitated this research that is aimed at identifying and mapping areas that are vulnerable to flood in Makurdi based on several factors that are relevant to flood risks in Makurdi. For this purpose, assessment process of flood vulnerability was conducted under hazard and vulnerability concepts within analytic hierarchy process (AHP) framework.

2. STUDY AREA

2.1 Location of the Study Area

Makurdi is situated between latitude $07^0 43^1$N, $07^0 45^1$N and longitude $08^0 32^1$E and $08^0 38^1$E. Makurdi is the capital city of Benue state, traversed by the Benue River from which the state's name was derived. The river splits the town into North and South banks respectively. Benue state is found in the Middle belt region of Nigeria. See Figure 1, for the location of Makurdi. It is bounded by Tarka Local Government Area (L.G.A) to the East, Guma to the North, Gwer – West to the West and Gwer to the South. Makurdi is made up of eleven council wards which include: Agan; Ankpa/ Wadata: Bar; Central South Mission; Fiidi, Mbalagh; Market Clark; Modern Market; North Bank I; North Bank II and Walmayo (Oyatayo *et al.,* 2017).

2.2 Climate

The climate of Makurdi is the tropic Aw type with alternating wet and dry seasons which are also hot and cool. The climate is characterized by southwest (SW) and northeast (NE) monsoons. The north south annual movement of intertropical discontinuity (ITD), the convergence zone, SW and NE monsoons, synoptic weather systems (such as thunder storms and squall lines) and topography influences rainfall distribution in the region (Abah, 2012).

Abah (2012) observed that the rainy season in Makurdi is from April to October, with rainfall amount ranging from 900mm to 1200mm with the heaviest rain in June and September which declines with increasing latitude. Annual rainfall in Makurdi is consistently high, with an average annual total of approximately 1173 mm. The mean dates of onset and cessation of the rainy season are 15^{th} April and 14^{th} October respectively.

Tyubee (2005) identified three temperature periods that are being experienced in the study area which include:

i. The cool dry season, November- January (during the time of low sun)
ii. The hot dry season, February – April (just preceding the rain)
iii. The hot wet season, May – October (during the rain)

The temperatures are generally high, with mean annual temperatures of 32.5^0C. The atmospheric humidity varies with seasons from 80% during the wet season to 30% during the dry season. Wind speed is generally light to moderate except the squall lines that often gust at 66km/h (Benue State University Geography Dept. Field Work Manual, 2006).

2.3 Relief and Drainage

Makurdi is generally located in a plain that slopes up gently on either side of the river Benue at Makurdi. Thus, the elevation rises to the north about 154m above sea level at Daudu, and to the south about 216m above sea level at Ikpayongo (Benue State University Geography Department Field Work Manual, 2006).

The Benue River forms the major drainage channel in Makurdi. It flows east to west dividing the town into the north and south banks. Other drainage channels mostly first order streams and the tributaries of River Benue at Makurdi also drain the region. These include: Kpege, Adake, Asase, Idye, Urudu and Demekpe amongst others.

2.4 Geology and Soils

The geology of Makurdi consists mainly of sedimentary formation of sandstones. Low lying areas like Wadata are overlain by shale (BSU Geography Dept. Field Work Manual, 2006). The sandstone is divided into micaceous and feldsphatic sand-stones. The soils of the area are the tropical ferruginous soils that comprise of hydromorphics along flood plains and wetlands and lithosols of flood plains. The red ferrasols developed on sedimentary rocks are also found in the southern parts. The soils are a reflection of its parent materials developed by slope and climate. The sandy nature of the topsoil makes infiltration easy which explains the usage of shallow wells in the area. The first aquifer is unconfined with precipitation infiltration through porous sandy environment as water source. The second aquifer also referred to as the semi-confined has the formation of highly consolidated and geologically made of shales intercalated with sandstones of coarse grains exhibiting larger pores.

2.5 Vegetation

The vegetation of Makurdi is characterized by a mixture of trees and grasses of the guinea savanna specie. However, human activities have depleted the natural vegetation due to the increase in urbanization; the vegetation today is that of derived vegetation with patches of natural tree species along river courses and reserves. The trees in the study area include fruit trees such as *Anacardium Ocidentale* (Cashew), *Citrus X Sinesis* (Orange) and *Magnifera Indica* (Mango) alongside other economic trees like *Khaya Senegalensis*(Mahogany), *Triplochiton Scleroxylon* (Obeche), *Gmelina Arborea* (Gmalina) and *Milicia Excelsa* (Iroko). The grasses are of a mixture of shrubs which are useful for animal grazing and medication respectively.

2.6 Population

Makurdi is inhabited by many tribes with a population of 519,051 (NPC, 1991) made up of 271, 051 males and 247, 910 females. The population of the town makes up 7.01% of the state's population. The town has a population density of 380 persons per square kilometer.

2.7 Economic Activities

There are several economic activities that are carried out in Makurdi. These include teaching due to several primary, post primary and tertiary institutions. Administrative work as it houses the state capital and the local government headquarters as well as Federal Secretariat. Banking services are also available with banking houses all over. Trading is also carried out in the area due to the presence of markets; where there are shops with varying goods and services such as super markets, barbing and hair dressing saloons, computer centers, food vendors, meat shops, beer parlous, grinding mill operator, vulcanizers, automobile mechanics, street hawkers etc. also there are motor parks rendering transport services, as well as gas station.

Farming is practiced, most especially in the flood plains of River Benue. The crops produced include cereals and vegetables. Fishing activities also take place at the Benue River course as well as its tributaries. The presence of rest homes and sporting centers provide an avenue for hospitality and recreational activities.

3. MATERIALS AND METHODS

3.1 Types of Data

Data types used in this study are:

i. Rainfall
ii. Landcover
iii. Digital elevation model/ slope map
iv. Soil characteristics
v. Physical Characteristics (Morphometry)
vi. 2013 NigeriaSat-X satellite imagery

3.2 Sources of Data

3.2.1 The primary sources of data

i. NigeriaSat-X (NX) satellite imagery of 2013 with spatial resolution of 22 meters was acquired from the National Space Research and Development Agency (NASRDA) Abuja.
ii. The Shuttle Radar Topography Mission (SRTM 30 m) data were used to derive the DEM of the study area.

3.2.2 Secondary sources of data

i. Rainfall data for thirty five (35) years (1980 – 2014) was obtained from the Nigerian Meteorological Agency, Makurdi area office.
ii. Soil map of Makurdi was obtained from dominant soil of map of Nigeria (a nation-wide soil resource and land form inventory centre for World food studies, thirteenth west and central African soil correlation sub - committee meeting, Kumasi, Ghana, 1996).
iii. Morphometric characteristics of the sub basins were derived from topographical maps of Makurdi North west and south west sheet number 251 on a scale of 1:50,000, published by Federal Survey of Nigeria in 1965.

3.3 GIS Techniques of Data Collection

Satellite imagery of NigeriaSat X (2013) was scanned using Ao scanner and imported into AcGIS 10.3 environment for further GIS operations. All coordinate (X, Y) from GPS field mapping were entered into excel sheet, transferred to notepad and then ArcGIS 10.3 for plotting into maps.

3.4 Geo-referencing

Satellite Imagery of the study area was geo-referenced using ground control points (GCP's) obtained from GPS, using image to GPS techniques. A total of ten (10) GCPs were collected using GPS on the field. These points were distributed to ensure images are balanced on all the four axes and centralized at the center. The choice of images to GPS techniques is based on the fact that several data used were collected on the field using GPS and this reduced error during map composition and allowed points to fit in. The coordinates of these reference points were converted from geographic to UTM, in order to aid measurement later. Thus all images were of the same datum, the same map projection and in the same ground coordinate system. ArcGIS 10.3 Software was used for geo-referencing all the needed data.

3.5 Sub setting

Coordinates of the study area were picked from the topographic map sheets covering the study area and registered to create a box which defines the sub-set made up of the study area using ArcGIS 10.3 software. Satellite imagery covering Makurdi Town were extracted from full scene of NigeriaSAT X.

3.6 Techniques of Data Analysis

3.6.1 LU/LC Data Processing

Supervised classification in the maximum likelihood classifier was adopted. The full scene of the satellite imagery covering the study area was loaded onto the computer hard disc (C drive) and converted into ArcGIS 10.3 format. The combine process of visual image interpretation of tones/colours, patterns, shape, size, and texture of the satellite image processing were used to identify homogenous groups of pixels, which represent various land use classes of interest. This process as observed by Adeoye (2012) is commonly referred to as training sites because the spectral characteristics of those known areas were used to train the classification algorithm for eventual landuse classification of the image.

To validate the tonal values recorded on the satellite image with features obtained on ground and also to know what type of landuse was actually present, the study engaged in ground truthing as suggested by Adeoye (2012). Before the ground truthing, map of the study area was printed and was used as guide to locate and identify features both on ground and on the image data. The geographical locations of the identified features on the ground were clearly defined. These were used as training samples for supervised classification of the satellite data. Six (6) landuse were clearly identified during ground truthing, which were used to classify the image data. These are Water body, vegetation cover, farmland, wetland, buildup and bare surface. All classification results were delineated as polygons using on screen digitization with the aid of ArcGIS 10.3 software. Layers were topologised and saved as themes or coverage for use in map composition.

3.6.2 *Morphometric Analysis of Sub Basins*

For the purpose of this research, drainage map of the river basin was prepared with the help of topographical maps of Makurdi North West and South West sheet number 251 on a scale of 1:50,000, published by Federal Survey of Nigeria in 1965. The topographic maps are large scale maps which are highly recommended for a study of this nature (Ebisemiju, 1976; Adejuwon, *et. al.,* 1984; Ifabiyi, 2004 cited in: Ajibade, Ifabiyi, Iroye and Oguntеru, 2010). All streams were digitized with the help of ArcGIS 10.3 software, the stream ordering method adopted was that of Strahler (1964). The stream numbers of various orders were counted, while the stream segment length, total basin length, area and perimeter were measured with the help of Arc GIS 10.3 software. The study area was segmented in to eight river sub-basins, which include: Guma, Ake, Aso, Ahukum, Kereke, Walmayo, Mu and Ukoghor. The idea of segmentation of river basin was to address the hydrodynamic character of the sub basins in the study area as suggested by Ajibade, Ifabiyi, Iroye and Oguntеru (2010).

The choice of morphometric variables that were examined in this study was based on the result obtained from previous studies, which have been found to correlate highly with peak discharge, runoff volumes and sediment delivery (Morisawa, 1962; Gregory and Walling, 1973; Oyegun).

3.6.3 Development of Catchment Morphometry Ranking Matrix

The hydrological responses of the eight (8) sub basins in the study area were inferred based on the results of linear, area and relief morphometric parameters analysed. Catchment morphometry ranking matrix for each of the eight (8) sub basins in Makurdi was achieved based on the work of interpretation of the potential hydrological responses of the parameters. In the catchment morphometry ranking matrix Table, each of the eight sub basin was ranked 1 to 8 where 1 represents least and 8 represents highest vulnerability. All the matrix score for each sub basin were aggregated to obtain a total matrix score for each sub basin. The eight sub basins based on their relative total matrix

score were further classified into three flood vulnerability levels using the approach of Farhan and Anaba (2016). The range of the total matrix scores of the least (26) and highest (53) was divided by three to obtain an equal interval of the vulnerability classes as presented here:
50 and above: High vulnerability
35 – 49: Moderate vulnerability
20 – 34: Low vulnerability
Further to this, a flood vulnerability map was produced in ArcGIS 10.3 environment showing areas with low, moderate and high vulnerability.

3.6.4 Spatial Multi Criteria Evaluation SMCE

Mapping flood vulnerability using spatial multi criteria evaluation (SMCE) involves analyzing a series of alternatives or objectives with a view to ranking them from the most preferable to the least preferable using a structured approach. The end product of SMCE is often a set of weights linked to the various alternatives. Malczewski (1996) observed that of the various methods used in assigning weights to criteria the pairwise comparison method (PCM) and Trade-off analysis method (TAM) are overall the best options. He noted that other SMCE methods include fuzzy, ranking methods. Pairwise comparison method (Analytical Hierarchy Process-AHP) was adopted as contained in both IDRISI Selva17.0 and ArcGIS 10.3 software.

3.6.5 Selection and Evaluation of Criteria

The selection of criteria that has a spatial reference is an important step in spatial multicriteria decision analysis (Malczewski, 1996). The following selected criteria were used in this study due to their relevance in the study area:

i. Mean annual rainfall (precipitation) – this has a direct relationship with flood incidences.
ii. Soil types- soils with heavy textures have a high flood incidence probability as compared to soils with light textures.
iii. Land use- urban and settled areas have a high flood incidence probability as compared to the parks and gardens.
iv. Physical (morphometric) characteristics of the eight (8) sub basins (slope of the basin- this has a converse relationship with flood incidences).

3.6.6 Standardization and Classification of Criteria

The technique for the standardization and classification of criteria adopted for this study is based on the work of Feloni, Mousadis and Baltas (2020). According to Feloni *et al.,* (2020), all criteria must have a common scale and this involve standardization of values in the scale 0-1 and classification of criteria (i.e. in this case three constant values are attributed to three clusters of the factor values). Regarding standardization, each criterion R is standardized according to the following equation:

$$X_i = \frac{(R_i - R_{min})}{(R_{max} - R_{min})} X\ SR \text{-------------------------} \quad (1)$$

$$X_i = \frac{(R_{max} - R_i)}{(R_{max} - R_{min})} X\ SR \text{--------------------------} \quad (2)$$

where
X_i = the standardized values of a criterion R,
R_i = Criterion real values
R_{max} and R_{min} = Criterion maximum and minimum values respectively
SR= is the range of standardized values (here it is equal to1).

Equation (1) is used for criterion standardization in case the flood vulnerability increases when the criterion increases (rainfall sealing) and equation (2) is used when the two parameters are conversely dependent (e.g. slope), as mentioned for each criterion above.

According to Feloni *et al.* (2020) the second approach corresponds to the classification of each criterion. Generally, classification can be performed with various methods, for example, Jenks Natural Breaks (Jenks, 1967), K-means (MacQueen, 1967), Fuzzy C-Means (Bezdek, 1981; Dunn, 1973) and Clustering Large Applications (Kaufman &Rousseeuw, 1990). For this study, the Natural Breaks is used for the classification of each criterion value as contained in the simple classification methods that are included in the ArcGIS spatial analysts' toolbox.

3.6.7 Spatial Multi Criteria Analysis

In the first part, the vulnerable area was produced by numerically overlaying a map layer describing the study area. This overlay is carried out as a Boolean overlay. All criteria were combined by logical operators such as intersection (AND) and union (OR). In the second part, Pairwise Comparison Method was used in determining the weights for the criteria. This method involves the comparison of the criteria and allows the comparison of two criteria at a time. This method can convert subjective assessments of relative importance into a linear set of weights. It was developed by Saaty (1980) in the context of a decision making process known as the Analytical Hierarchy Process (AHP). The criterion pairwise comparison matrix takes the pairwise comparisons as an input and produces the relative weights as output, and the AHP provides a mathematical method of translating this matrix into a vector of relative weights for the criteria. All the classified factor maps were added by weighted sum overlay procedure as contained in ArcGIS 10.3 to produce flood vulnerability maps of the study area. The vulnerability levels in the study area based on the final results were categorized into high vulnerability, moderate vulnerability and low vulnerability

Calculating Consistency Ratio (CR)

CR= CI/RI ----------------------------- (3)

Where CI= λ_{max}-n/n-1

RI=Random consistency index

N=Number of criteria.

λ_{max} is priority vector multiplied by each column total.

The rule of thumb is that the consistency ratio should be less than 0.1for the SMCE results to be valid, otherwise, the whole process is repeated.

4. RESULTS AND DISCUSSION

4.1 Mapping Flood Vulnerability in Makurdi

Pairwise comparison method (PCM)/Analytical hierarchical procedure (AHP) developed by Saaty (1980) was used in producing the relative weights based on the Saaty's scale of influence 1 to 9 as shown in 2.The row average provides an approximation of the eigenvector of the square reciprocal matrix. Table 2 shows the eigenvector of weights which is an estimate of the relative weights of the criteria being compared. This was achieved with IDRISI Selva 17.0 software version.

Table 3 shows the consistency ratio for the pairwise comparison procedure. Because individual judgment will never agree perfectly, the degree of consistency achieved in the ratings is measured by a Consistency Ratio (CR) indicating the probability that the matrix ratings were randomly generated.

The rule of thumb is that a CR less than or equal to 0.1 indicates an acceptable reciprocal matrix, a ratio over 0.1 indicates that the matrix should be revised. Revising the matrix entails, finding inconsistent judgments regarding to the importance of criteria, revising these judgments by comparing again the pairs of criteria judged inconsistently. The following Saaty weights were generated:

Soil: 0.0628

Morphometric: 0.3402 (slope; 0.1298 other Physical characteristics: 0.2104)

Landuse: 0.1480

Rainfall: 0.4490

The Table 3 is 0.06. The value of CR=0.06 falls much below the threshold value of 0.1 and it indicates a high level of consistency. Hence we can accept the Saaty weights generated.

The Saaty weights were used to generate the flood vulnerability map shown as figure 2. In this stage, the pair wise comparison results were integrated into ArcGIS 10.3 environment to simulate the flood vulnerable areas. The combination of all the thematic layers (the factors) using the Weighted sum overlay method in accordance to the computed weights was carried out in ArcGIS 10.3 environment. The Weighted sum overlay relies on the concept of overlaying several rasters, multiplying each by their given weights and summing them together to produce a flood vulnerability map (Matori, 2014). The results of the final analysis indicate the potential flood vulnerable areas in the study area. The study area was categorized into three flood vulnerable areas as shown in figure 2 and Table 4. The categorization includes the following: low flood vulnerable area, moderate flood vulnerable area and high flood vulnerable area. Areas that fall under high flood vulnerability in Makurdi occupy 275.238 km2 (25.75%). These areas are at high risk of flooding basically because of the nature of the slope, high rainfall amount, low soil permeability and physical characteristics of the study area. The slope map of the study area as a factor map used for multi-criteria evaluation was classified into three (3) classes namely high, moderate and low vulnerability. This classification was done in ArcGIS 10.3 environment using natural breaks.

The gradient at the high vulnerable areas is low and accumulation of water is more within these areas and this implies that build-up, farmland, vegetation, soils amongst others found within these areas are prone to high level of flood given the nature of the slope within the area. From the results of linear, relief and area mophometric characteristics which was referred to as physical characteristics of Makurdi basin, areas under high flood vulnerability have highest values for relief ratio, circularity ratio, elongation ratio, form factor, drainage density, length of overland flow and lowest values for infiltration number and bifurcation ratio. The hydrological implication of this is that these areas will experience peak flood flow within shorter duration, thereby exposing these areas to higher incidences of flooding. Also, the predominant soils found in these areas of high flood vulnerability are fluvisols and nitisols. These soils are poorly drained and accumulate water. This makes the area to be more exposed to flood and hence highly vulnerability to flood.

Areas with low flood vulnerability in Makurdi occupy a land area of 460.782 km^2 (43.11%). These areas have low flood vulnerability because they are basically located at a higher elevation. At higher elevation, water will really not infiltrate the ground and accumulate but it will rather flow downwards to low elevated areas and accumulate (Gelleh *et al.,* 2016). People living within these high elevated areas are not really at high risk of flooding. Also, areas under low flood vulnerability have lowest values for relief ratio, circularity ratio, elongation ratio, form factor, drainage density, infiltration number and highest values for overland flow and bifurcation ratio. The hydrological implication of this is that these areas will be experiencing peak flood flow at longer duration, thereby exposing these areas to lower incidences of flooding. The predominant soils found in these areas are basically acrisol and alisols which are better drained soils compared to soils in high vulnerable areas of Makurdi. These soils are permeable and do not accumulate water like fluvisol and nitisol that are the predominant soils found in highly vulnerable areas of Makurdi. Areas with moderate flood vulnerability in Makurdi occupy 332.717 km^2 (31.13%) which indicates that the area is more prone to flooding than low vulnerable areas. People living within these areas are also at the risk of flooding but not as those living within the highly vulnerable areas.

This finding is in agreement with the findings of Gelleh, Ibidun and Okeke (2016) that conducted a study on flood vulnerability assessment of Lagos using multi-criteria analysis. Their study classified Lagos into three (3) flood vulnerable areas namely low, moderate and high. The highly vulnerable areas cover an area of 41.7988km^2 and a percentage of 32.06%. These towns are at high risk of flooding basically because of the nature of the slope and the landuse pattern within the area. A similar finding was reported by Yahaya *et al.,* (2010) in Hadejia Jamaa're river basin who applied spatial multi-criteria evaluation to assess flood vulnerable areas and produced a flood vulnerability map showing low flood vulnerability, moderate flood vulnerability and high flood vulnerability areas. Table 4 shows biophysical flood vulnerability statistics of Makurdi.

The social and economic losses as a result of flooding are on the increase because of the recurring flood episodes in the study area; this calls for an effective group decision making under uncertainty to mitigate flooding. Flood vulnerability maps as produced in this research remain a vital tool to meet up with data / information supply for town planning, policy and decision making that would mitigate flooding in Makurdi. Studies of this nature at this point in time has become necessary to provide the necessary caution, warning and information to stakeholders and civil authorities such as planners, decision makers and emergency agency workers in taking positive and in-time steps during the pre-disaster situations. It will similarly help them during post-disaster activities to assess damages and losses caused as a result of flooding.

5. CONCLUSION

Spatial multi-criteria evaluation technique was adopted for the assessment of flood vulnerability in Makurdi. The outcome of the multi-criteria analysis showed that Areas with low, moderate and high flood vulnerability occupy a land area of 460.782 km^2 (43.11%), 332.717 km^2 (31.13%), 275.238 km2 (25.75%) respectively. Built-up areas have high potential for pluvial flooding and flash floods due to excess storm water induced by impervious urban surfaces. This has implication for storm water management. The application of multi-criteria technique to map the flood vulnerability of the area proved to be a vital tool for flood management, control and respond decisions.

Consequently, The overall ranking of flood vulnerability is good for prioritization of flood risk mitigation, control and management such that the highest flood vulnerable basins will be given urgent attention by Benue State government through Benue State Emergency Management Agency; The multi criteria evaluation techniques were able to establish that climatic factor is the highest parameter that influence flood vulnerability in the study area. Since NIMET is already providing seasonal rainfall prediction, they should improve on its accuracy and also target major local flood vulnerability areas for precision and prioritization; 25.75 % of Makurdi fall under areas categorized as having high flood vulnerability. This portion of the study area should receive more attention or preference from the Federal Ministry of Environment and Federal Ministry of Works and Housing with regards to the provision of structural flood control measures (building drainage channels, dykes and dams). Therefore, remediation actions can be applied for the high vulnerability areas while mitigation actions can be focused more on the moderate vulnerability areas were among the recommendations.

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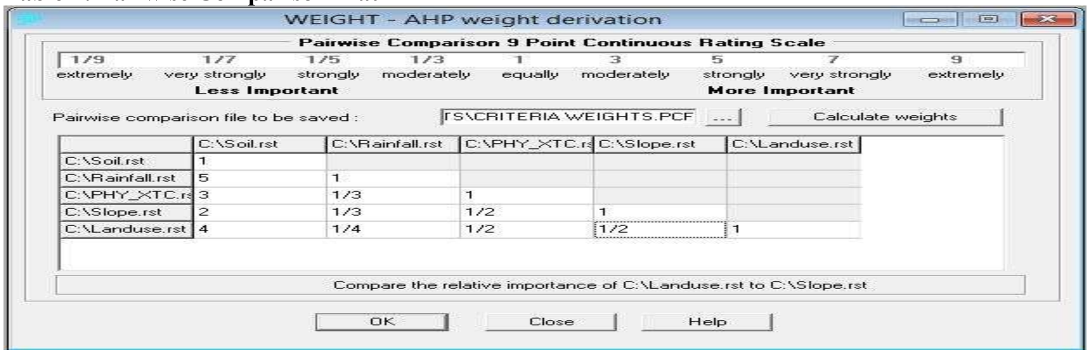
Table 1: Basin Morphometric Parameter

CATEGORY	PARAMETER	DERIVATION PROCEDURE
Area	Basin area	Area = map scale x counted squares (Gregory and walling 1973)
	Circulatory ratio	RC: $4\pi A/P^2$ where RC = circulatory ratio, basin area and π= constant P= basin perimeter (Miller, 1953)
Area	Drainage density	DD = ∑L/A; where DD = Drainage density, ∑L = sum of all stream lengths and A = Basin area (Horton, 1932)
Area	Number of streams	∑NU: Where Nu is the stream number and ∑= sum (strauler, 1952)
Area	Elongation ratio	EL = $2\pi\sqrt{A/L}$ where EL = elongation ratio, A = Basin area, L= Basin length and π constant (Schumn, 1956)
Area	From factor	F = A/L^2 where F = form factor, A = Area of the basin and L length of the basin (Boyce and clark, 1964)
Area	Leminiscate ratio	K = $L^2/4A$ where L = Length of the basin and A = Area of the basin (Schumm, 1956)
Linear	Basin length	This is the straight line from the mouth of the basin to the farthest point on the basin perimeter (schumm, 1956)
Linear	Total stream length	This is the total length of all tributaries and the principal drainage (Schumm, 1963)
Linear	Infiltration number	
Linear	Average stream length	Total stream length divided by total number of streams (Schumm,1963)
Linear	Main stream length	This is the length of the principal drainage line (Schumm, 1963)
Linear	Length of overland flow	Lg=1/2D Km Where, D=Drainage density (Km/Km2) (Horton,1945)
Relief	Basin Slope	Bs = VI/HE Bs = Basin slope, VI = vertical interval and HE = Horizontal equivalent (Schumm, 1963)
	Relief ratio	Rh = H/L where Rh = relief ratio, H = horizontal distance along the longest dimension parallel to the principal drainage line and L = Length of the basin along the principal drainage line (Schumm, 1956)

Source: Ajibade et al., (2010)

Table 2: Pairwise Comparison Matrix



WEIGHT - AHP weight derivation

Pairwise Comparison 9 Point Continuous Rating Scale

1/9	1/7	1/5	1/3	1	3	5	7	9
extremely	very strongly	strongly	moderately	equally	moderately	strongly	very strongly	extremely

Less Important — More Important

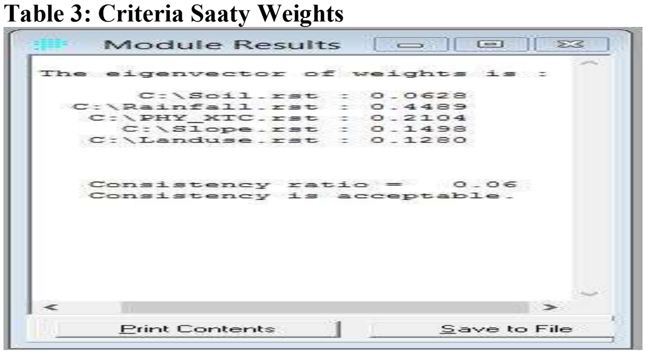
Pairwise comparison file to be saved : TS\CRITERIA WEIGHTS.PCF ... Calculate weights

	C:\Soil.rst	C:\Rainfall.rst	C:\PHY_XTC.rs	C:\Slope.rst	C:\Landuse.rst
C:\Soil.rst	1				
C:\Rainfall.rst	5	1			
C:\PHY_XTC.rs	3	1/3	1		
C:\Slope.rst	2	1/3	1/2	1	
C:\Landuse.rst	4	1/4	1/2	1/2	1

Compare the relative importance of C:\Landuse.rst to C:\Slope.rst

OK Close Help

Table 3: Criteria Saaty Weights



Module Results

The eigenvector of weights is :

C:\Soil.rst : 0.0628
C:\Rainfall.rst : 0.4489
C:\PHY_XTC.rst : 0.2104
C:\Slope.rst : 0.1498
C:\Landuse.rst : 0.1280

Consistency ratio = 0.06
Consistency is acceptable.

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Table 4: Flood Vulnerability Statistics

Vulnerability Level	Count	Area (km^2)	Percentage (%)
Low	511,980	460.782	43.11
Moderate	369, 686	332.717	31.13
High	305, 820	275.238	25.75

Source: Oyatayo, 2017

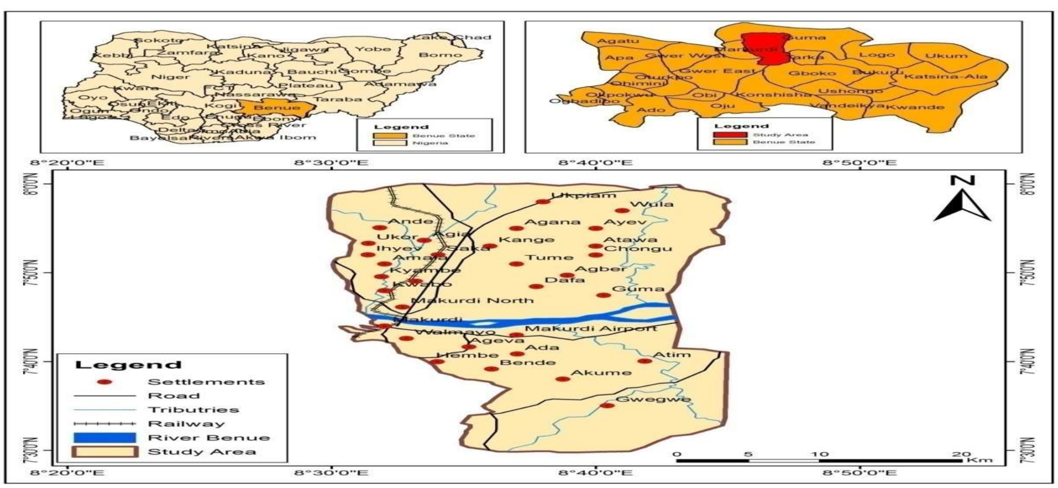

Figure 1: Location of the Study Area
Source: Adapted from the Administrative Map of Benue State

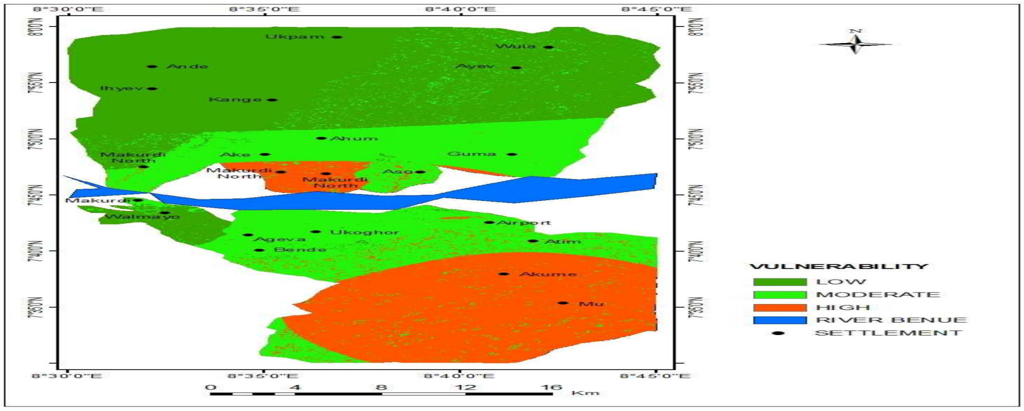

Figure 2: Flood Vulnerability Map of Makurdi Town